DESIGN & EMOTION: THE KANSEI ENGINEERING METHODOLOGY

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Abstract: Today's trends in product development indicated that inclusion of consumer's need to the technical aspect of product design will determine their success in the market. Explicit needs are clear and easy to describe. However, the implicit needs such as emotional experience are difficult to quantify. This paper introduces methods and techniques than can be used to capture consumers' needs in general and specifically describes the framework of Kansei Engineering to handle the implicit needs of consumers. The framework offers quick and easy understanding to the implementation of Kansei Engineering in discovering implicit consumers' needs and analyzes its relations to product design. The author contends that the framework is a useful guide to beginners in the industry and academia to the implementation of the technology in diversed fields including HCI, Interaction Design and the various tangible product design.

Keywords:, Design Methodology, Kansei Engineering, Human Centred Design Informatics, User Experience (UX), User satisfaction

1. Introduction

Evolutions in product design have lead to many inventions, resulting equally good quality products flooding the market. Duly, consumers have vast choices of product and become more and more sophisticated. Forced by the demanding market, producers strive to design product that stands out and attracts consumers. Theoretically, consumer's satisfaction and technical aspects (e.g., functionality, ergonomic and comfort) are equally important in determining the success of product design (Akao, 1990; Green & Srinivasan, 1990; Nagamachi, 1992; Norman, 2004). Hence, producers strive to understand the factors that contribute to consumer's satisfaction in their product. Several methods have been developed to support the valuation of consumer's satisfaction in the effort to understand the consumer's needs and desire. To name a few, there are Quality Function Deployment (QFD) (Akao, 1990), Conjoint Analysis (Green & Srinivasan, 1990), Voice of Customer (VoC) (Griffin & Hauser, 1993), Kansei Engineering (KE) (Nagamachi, 1992).

QFD is an engineering tool developed by Japanese quality technology experts, Akao, growing out of Deming's work from the 1950s on statistical quality control (Akao, 1990; Childs, 2003). Since it was introduced as possible method to identify relations between consumers' (functional) needs and engineering characteristics, it has spread around the world, in various forms. It has become a well established product development method all around the world.

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VoC describes the process of capturing a consumer's requirements as a market research technique that produces a detailed set of consumer wants and needs. These needs are then organized into a hierarchical structure, and prioritized in terms of relative importance and satisfaction with current alternatives. VoC is generally conducted at the start of any new product, process, or service design initiative in order to better understand the consumer's needs and desire. It is mainly used as the key input for QFD and the setting of detail design specifications.

Conjoint Analysis is a statistical technique used in market research to determine how people value different features that make up an individual product or service. It is a method for weighting different product concepts against each other in order to identify which product attributes are preferred by a certain consumer group and the price they are willing to pay for it. For example, the combination of the different attributes like price, size, colour, brand etc. has a joint influence on the consumer decision whether to purchase the product or not (Green & Srinivasan, 1990; Gustafsson, 1996). In the technique assumption is made in a way that if brand is seen as one of product attribute, then a consumer would spend more money on it such as Mercedes than Fiat with the same specifications (Schütte et al., 2005). Conjoint Analysis is based on the consumers' ability to rank concepts with different content in order to make a clear decision on how desirable the concept is.

KE is a technology that unites Kansei into engineering realms in order to realize product that match consumer's needs and desire. It is a scientific discipline where the development of product that pleases and satisfies consumers is carried out technologically (Nagamachi, 1999). This is done by analyzing consumer's Kansei and translates how the product design elicits this Kansei. It collects the consumer's Kansei experience and establishes mathematical prediction models of how the Kansei is connected to product physical characteristics. KE targets to improve human well-being by looking into physiological and psychological aspects that contributes to satisfaction.

Although all of the methods described above are having the same goal, that is to develop product that satisfy consumer's needs and desire, KE has one significant difference. VoC, QFD and Conjoint Analysis focus on the explicit consumer's needs and develop design requirements that match these needs. On the other hand, KE is a method specifically used to analyze consumer's implicit needs and associate them with product design characteristic, so that a guide to design a new concept of product could be established.

This paper is written to describe the methodology of KE, targeting to provide quick and easy understanding to its implementation in various domains. Several successful implementation of the technology are introduced to give insights to its usefulness in real world. The introduces framework is target to be useful guide to beginners in the industry as well as academia to the implementation of this technology, not only in industrial design, but also in diverse field involving consumer experience including HCI, Interaction Design and other appropriate discipline.

2. The Definition of Kansei

Kansei is a Japanese term used to express one's impression towards artefact, situation and surrounding. Deeply rooted in the Japanese culture, direct translation of Kansei to other language is rather difficult. Having various interpretations by different literature, Kansei is generally referred to sensitivity, sensibility, feeling and emotion (Nagamachi, 1992; Ishihara et al., 1993; Harada, 1998; Yoshikawa, 2000). Psychologically, Kansei means the mental state where knowledge, emotion, and sentiment are harmonized, and people with rich Kansei is people who is rich in emotion and sentiment, adaptive, warm

and responsive (Nagamachi, 2003). He asserted that the more people try to describe Kansei in different way the harder they can attain the true meaning. Thus, today the word 'Kansei' is being used as it is. According to him as being the founder of KE, the closest interpretation of Kansei is "psychological feeling" people have with a product, situations or surroundings.

Harada (1998) described Kansei as a mental function, and more precisely as being a higher function of the brain, and therefore it is implicit. The process of Kansei begins with gathering the sensory related functions such as feelings, emotions and intuition, by means of the five senses (i.e. vision, hearing, smell, taste and skin sensation). Figure 1 shows the process of Kansei and the five senses within the structure of the brain.

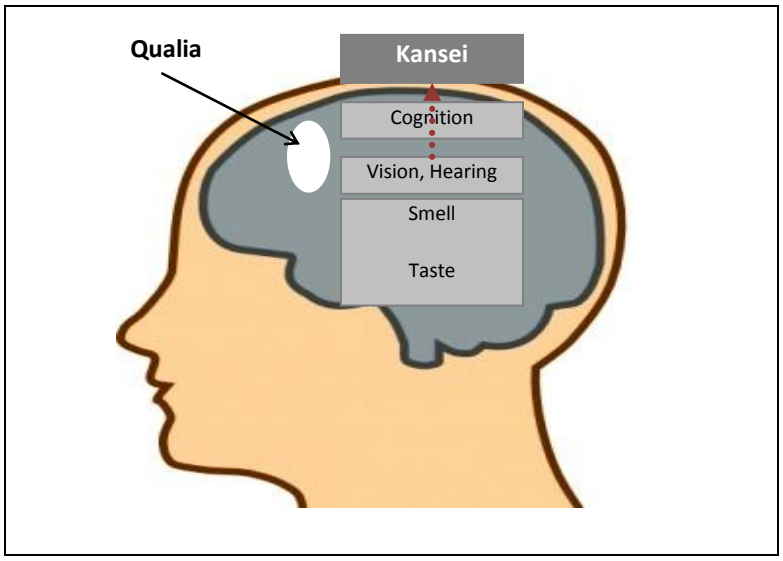


Figure 1: The Process of Kansei (Lokman & Nagamachi, 2009).

When these senses are triggered, psychological cognition concerned with perception, judgment and memory will surface. In the scenario of going into an unfamiliar restaurant, your vision, smell, taste and cognition would judge whether the restaurant is *"very friendly"* and or provide *"good service"*. These are "Kansei". The Kansei emerges through cognition with several contributing sensations in place.

As being implicit, Kansei process cannot be measured directly. What can be observed are actually not Kansei but the causes and the consequences of the Kansei process (Nagasawa 2004). Therefore, Kansei can be measured only indirectly and partially, by measuring sense activities, internal factors, and psycho-physiological and behavioural responses (Harada 1998; Nagamachi, 2003; Ishihara et al., 2005; Lévy et al., 2007). In the scope of Kansei studies, sense activities are measured by evaluating the impact of a specific sense stimulus on brain activity. Physiological measures are done by evaluating responses to specific external stimulations. Responses can be physiological or behavioural (measured by electromyography (EMG), heart rate, electroencephalography (EEG), event-related potential (ERP), or Functional magnetic resonance imaging (fMRI)) or expressive (body or facial expression). Psychological measures can be done by personality tests (Eysenck, 1964), semantic differential scales method (Osgood et al., 1957), or other questionnaires (Nagamachi, 2003; Ishihara et al., 2005; Lévy et al., 2007). In KE, there is a method where people will be asked to express their Kansei in words upon seeing products, or

for products that they want to buy in the future. These kinds of words are called "Kansei Words" (KW) (Nagamachi, 2003; Ishihara et al., 2005). Kansei researchers have to think which entrance is appropriate to reach the human Kansei and how to measure the expression(s). The Kansei entrance is not always just one gateway, but it may be a combination of several gateways. Figure 2 shows options of appropriate gateway in reaching Kansei.

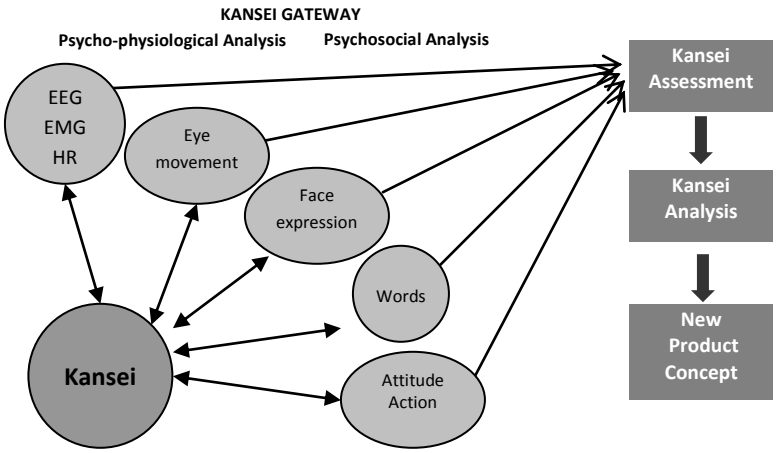


Figure 2: Kansei Gateways (Lokman & Nagamachi, 2009).

The term "Kansei" used in KE refers to an organized state of mind which has emotions and images held in the mind towards physical objects such as products or environment. For example, "luxury", "elegant", "flashy", "young" and alike as in the "that dress looks luxury and elegant", or "that car looks flashy and for youth" are all Kansei words describing feelings to certain product. Although in most cases Kansei is used the form of adjective, nouns as well as short sentences can also be employed (Nagamachi, 2003).

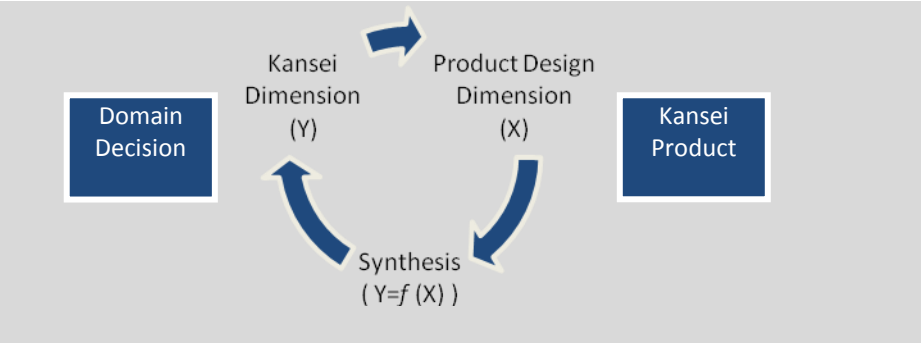
Among the Kansei terms used in KE, there are Kansei that reflect the era and change occasionally such as trend-related Kansei, and ones that practically do not change such as fundamental Kansei (colours, etc.). Furthermore, differences of culture and social behaviour between individual and countries may cause difference in the Kansei itself (Matsubara et al., 1999; Nagamachi, 2003; Ishihara et al., 2005) and there are Kansei that are almost similar, but different in terms of the expressed Kansei words. Therefore, issues such as culture and timeliness are some of the delicate matter need to be considered when applying KE internationally.

3. The KE Methodologies

Product emotion has been recognized as the primary aspect of consumer's satisfaction (Norman, 2004) and market success (Nagamachi, 2004). For many years, Japan has always been ahead of other country in developing new and innovative product. Their successes heavily rely on their sensitiveness to the demand of the consumer's implicit needs, i.e. the Kansei, via the implementation of technology today known as

KE. The principles for the implementation of KE involves several steps using possibly any tools and methods from different discipline such as marketing, psychology and statistics. KE studies typically consist of both qualitative and quantitative research steps. Much has been written about the process (Nagamachi, 1992; Camurri et al., 1999; Yamada et al., 1999; Takama et al., 2001; Bouchard et al., 2003; Guerin, 2004; Ishihara et al., 2005; Schütte et al., 2005; Lokman et al., 2009; Barone et al., 2009), and there are many possible ways to gather the information such as focus group (Matsubara et al., 1999; Kim et al., 2003), self-report system (Schütte & Eklund, 2001; Ishihara et al., 2007a; Lokman et al., 2009) and ethnographic techniques (Shaari, 2010). In any ways, the focus is always to the emotional aspect of consumer's experience with current products or product concept based on producer's objectives.

Figure 3 demonstrate the framework of KE that the author developed to summarize the principles in implementing KE hitherto practiced. The methods used in each phases of KE implementation is subsequently reviewed.



Type I : Category Classification	Type II : KES	Type III : KE Modeling	Type IV : Hybrid KE
Type V : Virtual KE	Type VI : Collaborative	Type VII : Concurrent KE	Type VI : Rough Set KE

Figure 3: The Principle of KE.

The procedure involves phases of Domain Decision, Kansei Dimension, Product Design Dimension and Synthesis, in the goal of developing Kansei Product. There are hitherto eight types of KE (Nagamachi, 2003; Ishihara et al., 2005), as illustrated in the principle, which are subject to expansion at any point of time even during the publication of this article. The types are briefly described as the following:

a) KE Type I: Category Classification

Category classification is a break down technique from a targeted concept of a new product to the associated subjective Kansei to the objective design parameters. The procedure involves qualitative research method with the use of KJ Method or alternatively called affinity diagram. Famous example of this category implementation is in the development of the most successful sports car the world has ever seen in the history by Mazda named Miata (Nagamachi, 1999).

b) KE Type II: KE System

This is Computer Aided KE System (KES). The KES comprises databases and inference engine to support a computerized system that handles process of interpreting consumer's feeling and emotion to perceptual design element. Example of this type of KE implantation can be seen in

house design support system (Nagamachi & Nishino, 1999), flower arrangement (Ishihara et al., 2007a), and fashion image system (Nagamachi & Lokman, 2009).

c) KE Type III: KE Modeling

This type of KE utilizes mathematical modelling as logic in a computerized system. This is mainly used to handle fuzzy logic to form machine intelligence. Word sound diagnostic system (Nagamachi, 1993) is an example of the implementation of this KE type.

d) KE Type IV: Hybrid KE

This is a type of KE System (KES) by Forward KES and Backward KES to form Hybrid KES. This type of KE enables iterative process from design element to Kansei evaluation. Hybrid KE implementation can be seen in the study of high heel design (Chen et al., 2008) and in the work of Matsubara & Nagamachi (1997b).

e) KE Type V: Virtual KE

Virtual KE incorporates KE techniques into Virtual Reality, and enable consumer to examine Kansei product in a virtual world. Example of this type of KE implementation can be seen in the design of kitchen cabinet by Matsushita Electric Works (Enomoto et al., 1993).

f) KE Type VI: Collaborative KE

In this type of KE, designers and or consumers in different places utilize a mutual Kansei database and collaborate through a network to develop a new product design. Example of this type is the Internet Collaborative Design System (Ishihara et al., 2005).

g) KE Type VII: Concurrent KE

In Concurrent KE, representatives from different department in a company join together and perform Kansei evaluation and analysis. It can also be done by assembling experts in related discipline to perform Concurrent KE to develop a targeted concept of product design. The approach enables the holistic perspective of product design such as from the aspect of engineering to product quality to marketing. Example of the implementation can be seen in the research of shampoo container design (Nagamachi, 2000).

h) KE Type VIII: Rough Sets KE

Rough Sets KE is claimed to be the best type to deal with ambiguous and uncertain Kansei data (Nagamachi et al., 2006). Using this type, Kansei that is in general has nonlinear characteristics can be treated independently and decision rules can be determined by group meaning in If-Then style (Nishino, 2005). Example of the type can be seen in the study of beer can design (Okamoto, 2007).

The decision of the type of KE to employ depends on organization, designers or Kansei Engineer's objectives or strategies in the assessment of Kansei. The following describe briefly the implementation of each phases illustrated in Figure 3.

4. Domain Decision

This is the phase of identifying specific domain to be investigated using KE methodology. In KE studies, focusing to a specific domain is essential since Kansei experience is unique with different product

(Nagamachi, 2003). The decision of domain can be done such as by using market analysis technique or by segmentation of target consumers. Also, decision has to be made whether to conduct KE based on existing product or to start designing a new concept of product from scratch. Different approach can be employed, and none can be categorized as better compared to the other. As a rule of thumb, domain can be decided based on the existence of flexibility to improve existing situation.

5. Kansei Dimension

The phase consists of three stages:

a) Identification of Kansei.
First of all, expressions of the dimension of Kansei in the form of adjective or noun, called Kansei Words (KW), must be prepared. Usually the number of initially prepared KW will be very large, and reduction of this number can be performed by qualitative or quantitative methods.

b) Measurement of Kansei.
Kansei measurement is the process of capturing consumer's Kansei. Since Kansei is subjective, ambiguous and unstructured, it is impossible to measure it directly. Therefore, we need to devise indirect measurement methods by using alternative expression approach (Ishihara et al., 2005). Kansei measurement is classified to physiological measures and psychological measures.

Physiological measure targets to capture consumer behaviours, response and body expressions. This can be done by means of analysis of brain waves by electroencephalogram (EEG), muscular loads measurement by electromyography (EMG), eye movement and other physiological ergonomic indicators which are used to measure Kansei while a consumer is using or looking at the product. Example of study performed using this kind of measure can be found in the impact of heat to heart rate (Nishikawa et al., 1997), refrigerator design (Nagamachi, 2007), and response to robot movement (Ishihara et al., 2007b).

Psychological measure deals with human mental state such as consumer behaviour, expression, action, and impression. This can be measured using self reporting system such as Different Emotional Scale (DES), Semantic Differential (SD) scale or free labelling system. This type of measure is very popular in KE implementation due to its simplicity. To give some example of the successful implementation are in the study of female suite (Ishihara et al., 1996), lift truck (Schütte et al., 2005), flower arrangement (Ishihara et al., 2007a), web design (Lokman et al., 2009) and cell phone (Hashizume et al., 2010).

c) Analysis of Kansei.
Evaluation of Kansei gives opportunity for one study to investigate the similar meanings, structure and the concept in consumer Kansei. The following denotes some of the analysis commonly performed to analyze the consumers' Kansei:

i. <u>Investigating Similarities Between Variables</u>

Kansei responses differ in different domain, thus identification of similarities enables discovery of more objective Kansei that reflects the domain. In KE, Correlation Coefficient Analysis is widely used as a measure of the strength of the association between variables. It is commonly used to measure correlation between Kansei in a domain enabling the investigation of similarity between Kansei so that highly correlated Kansei could be

summarized. The result will could be used to measure more objective Kansei. Alternatively, qualitative research method could also be used to produce similar result.

ii. Deriving Principal Components

Even though a study is performed using more objective Kansei, it is believed that it will still result in some redundancy of variables due to the subjective perception. Here, redundancy means that some of the variables are correlated with one another, possibly because they are measuring the same construct. Because of this redundancy, it is believed that it should be possible to reduce the observed variables into a smaller number of principal components that will account for most of the variance in the observed variables.
Principal Component Analysis (PCA) is a data reduction technique used to identify a small set of variables that account for a large proportion of the total variance in the original variables. Components can be calculated from the correlation matrix (the default) or the covariance matrix. Output consists of the eigenvalues (i.e., the variances of the principal components), the proportion and cumulative proportion of the total variance explained by each principal component, and the coefficients for each principal component.

In KE, PCA is commonly used to find semantic space of Kansei and specimens, and Kansei strategy could be determined by PC Vector plot. Kansei strategy is important as it could be used by businesses to strategize new concept of product, with clues on competitor's product design. The Plot of PC loadings could be used to visualize how much the evaluation on Kansei affects variables, and the plot of PC Score shows which Kansei has strong relations to what specimen.

iii. Determining the Concept of Kansei

Factor analysis (FA) is a statistical data reduction technique used to explain variability among observed random variables in terms of fewer unobserved random variables called factors. FA assumes that all the rating data on different attributes can be reduced down to a few important dimensions. This reduction is possible because the rating given to any one attribute is partially the result of the influence of other attributes.

FA is commonly used to find psychological structure of Kansei that constitute the essential concept of Kansei of the domain under investigation. The result could be used to strategize new concept of Kansei product that represent consumer's Kansei determinants in a domain.

5.1 Product Design Dimension

This phase is the process of determining important design elements such as colour, size, and shape of the product specimen. The process could be performed by using empirical method or qualitative technique.

By empirical method, the procedure begins with collection of specimens having visible differences in design from existing product in the market within a specific domain. Then, empirical observation is performed to investigate design elements in all specimens from the consumer's viewpoint, such as red in colour or round in shape. Decision to limit the number of design elements depends on the level of details that need to be included in one study. Controlling the number of elements enables more objective measurement. On the other hand, including all observable elements could result to more accurate measurement. Finally, valid specimens for the Kansei Measurement procedure could be

determined from all the initial specimens by following a set of rules in KE. The resulting valid specimen will correspondingly determine the intended product design dimension.

In qualitative method, the design dimension could be determined by employing group of experts. The expert would have to rely on their experience and skill to achieve design dimension for a predefined concept of new product. This could be done by using KJ Method, which enables the categorization of a Kansei concept into associated Kansei dimension until it is possible to determine design requirements.

5.2 Synthesis

In this phase, analysis is performed to discover how the design of a product influence consumer's Kansei. In the analysis process, both qualitative and quantitative method could be used. The process is targeted to reveal association of Kansei dimension to product design dimension, and thus the design requirements to produce a product that embeds targeted Kansei could be formulated. To perform the synthesis phase by qualitative method, KJ method could be used.

In the case of quantitative method, multiple regression model is used to accurately predict the influence of the design elements, i.e. the element and variations, on the consumer's Kansei. This is achieved with the help of the least square method, which minimizes the squared prediction error (Ishihara, 2007c). The mathematical calculations are performed with the help of standard statistical software tools, and thus the details of the computational method will not be elaborated here. For further details, see Everitt (2005). Most KE studies widely used Quantification Theory type I (QT1) to analyze relationships between Kansei and product design elements. In the calculation, evaluation values on Kansei, y (dependent) variable, and design elements, x (independent) variables, needs to be transformed to dummy variables. Using dummy variables in KE requires special attention, since design elements need to be classified into two levels: the design element, and the variation of each element. For instance, the colour of car corresponds to an element and its variation of colour (e.g. red, black, silver). In QT 1, weights to the categories will be calculated with multiple regression model by solving (number of all categories – 1) simultaneous equations (Hayashi, 1952). QT 1 is deterministic because it is a variation of multiple regression model, and it uses least square method as solving method (Ishihara et al., 2007c).

Alternatively, there are several other methods that can be used to analyse Kansei depending on the objectives. Among others are Fuzzy Logics (Shimizu & Jindo 1995), Neural Networks (Ishihara et al. 1996), Genetic Algorithm (Nishino et al. 1999), Rough-Set Analysis (Nishino, 2005), and Partial Least Square Analysis (Ishihara et al., 2007c).

6. Kansei Product

Kansei product is a product resulted from both qualitative and quantitative approach in KE implementation. A successful Kansei product could be developed by amalgamation of design requirements produced by KE implementation and the experience and skill of product designers. Some noted example of Kansei product are Mazda Miata (Nagamachi, 1999), Wacoal Good-up Bra (Nagamachi, 2003), Boeing 7E7 Interior Design (Guerin, 2004), and Sharp Refrigerator (Nagamachi, 2007).

There are numerous other products of KE such as automobiles, home appliances, kitchen cabinet design, virtual community design, airplane interior design, and the list keep mounting (Nagamachi, 1999; Camurri et al., 1999; Yamada et al., 1999; Takama et al., 2001; Childs et al., 2003; Guerin, 2004; Schütte et al., 2005; Ishihara et al., 2007a; Ishihara et al., 2007b). In the implementation, KE has been used at different point of the product development cycle where sensible flexibility exists in making decisions concerning any design aspects of the product.

Besides its success in the industrial implementation, the interest in adoption of KE in academic research has been mounting. Among others are the research on RV cars (Ueda et al., 1996), landscape (Matsubara & Nagamachi, 1997a), canned coffe (Ishihara et al., 1997), bathroom (Nishikawa et al., 1998), bridge (Ichitsubo et al., 1998), textile fabric (Barker, 1999), dance/music interactive system (Camurri et al., 1999), door handle (Higashitani et al., 1999), sofa design (Yamada et al., 1999), smart store (Higuchi et al., 2003), web branding (Yoon & Lee, 2003), online chat (Wang et al., 2004), lift truck (Schütte et al., 2005), robotics (Ishihara et al., 2007b), postural seat (Barone et al., 2009), robotics (Papadopoulos et al., 2010; Ford et al., 2010), indigenous product (Shaari, 2010) and many more. The focus of such research is to explore the Kansei responses users would feel when interacting with the product, situation or surroundings with the goal of deriving its association with the design elements.

6.1 Conclusions

The framework of KE presented in this paper introduced a synopsis of the methods and tools used in KE in order to evaluate the relationship between the individual's psychological experience of a specific product and its design characteristic. The paper has described in detail the procedure of KE, providing the principal of KE, which can be used as guide in the implementation of KE in the academia as well as industry. The unique emotional responses to specific product domain is also discussed and suggested to be treated carefully in KE studies. Although the paper provides systematic procedure in implementing KE, the actual activity in the implementation may in some cases be difficult, since many tools used in KE are borrowed from other scientific or technological fields (Schütte et al., 2005), and require some skills and expertise. Some of these tools require great resources and consume a great amount of time, affecting the duration of the validity and demanding high costs for the research. Henceforth, the paper suggests inclusion of expertise from different field into the research team to reach optimum capability and success in the implementation.

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