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In-depth Analysis of Affective Engineering Process : a case study on vehicle instrument panel

감성 공학 방법론에 대한 심화 분석 연구 : 차량용 IP에 대한 사례 연구를 중심으로

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협동과정 인지과학 전공

박 성 환

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박성환의 공학박사 학위논문을 인준함

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Abstract

In-depth Analysis of Affective Engineering Process : a case study on vehicle instrument panel

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This dissertation aims to propose quantitative methods for elaborating the existing affective engineering methodology and to demonstrate the proposed methods by conducting a case analysis. Since the mid-1980s, the affective engineering research has been recognized as a methodology of developing user-oriented products. There are a few remarkable differences between the affective engineering research and other engineering researches.

First, the percentage of qualitative studies is relatively higher in affective engineering. A study plan tends to be determined based on a researcher's subjective decision about scope, methods, detailed plans and evaluation criteria through the whole process. Second, the subject of the affective engineering research is humans and thus evaluation results are more difficult to generalize and elaborate. These two differences are both characteristics and limitations of the affective engineering research. Focusing on this fact, five quantitative analysis methods are proposed which could complement the

existing affective engineering research.

Study 1 performed a sematic network analysis of Internet review data and proposed a method of deriving affective structures and main affects, which were necessary for affective evaluation. A case of car instrumental panels was also examined. Online reviews about car interior designs were collected and preprocessed. A semantic network analysis of the preprocessed data was conducted to identify centrality values of each word and connectivity. Based on the analysis result, luxuriousness and naturalness were determined as the target affects related to car instrument panels, and 20 sub-affective words were selected which seemed to constitute the target affects.

Study 2 proposed a quantitative method of examining the validity of each affective word selected for affective evaluation, and verified the proposed method by applying it to cases. An affective evaluation was performed for car instrument panels. In the affective evaluation, degrees of feeling corresponding to each affective word were measured by the semantic differential method, when subjects saw and felt six samples. Besides, a survey was also performed to investigate subjects' understanding about each affective word and their subjective perception of the distinctness of the samples. The evaluation results were analyzed by 5 statistical methods in order to see the validity of each affective word. The analysis results showed that the affective words formed a regular distribution when the numbers of statistical methods satisfied by them were arranged in descending order from 5 to 0. Accordingly, the proposed method revealed that each affective word had a different degree of validity.

Study 3 was a case study aiming to see which of the three conventional semantic differential methods was effective in affective evaluation. An affective evaluation was performed for car instrument panels. The affective evaluation was repeated by applying the three semantic differential methods, that is, Absolute evaluation 1, Absolute evaluation 2 and Relative evaluation. Three quantitative analysis methods were used to the performance of each evaluation method. It turned out that the relative evaluation produced better results than the remaining absolute evaluation types. However, the relative evaluation requires a long time for evaluation. Accordingly, an appropriate semantic differential method needed to be determined by considering various factors influencing experiments such as the number of evaluation samples, the number of participants in an experiment and the duration of an experiment.

Study 4 proposed a method of processing data, which were obtained from affective evaluation, and presenting a significant statistical model. The proposed method was verified by a case study. The difference in the explanatory power of the model was identified by comparing the product reviews of the ordinary participants in the experiment and those of experts. A method of enhancing the explanatory power of the model, which was derived from the ordinary participants, was proposed. The key of the method was dividing participants into different groups by the evaluation criterion for a specific affective word. Two evaluation cases were distinguished. In the one case, the target affect was valued highly when the embossing was large. In the other case, the target affect was valued highly when the embossing was small. Models for each case were constructed, and the explanatory power of each model was examined. The explanatory power obtained by applying the proposed method was better than that obtained from the conventional analysis. Then, the problems of the proposed method and counterarguments were discussed. In addition, the model based on the evaluation results of the ordinary users was compared with another model based on the evaluation of experts in order to consider the difference between the models and the causes for such a difference.

Study 5 derived a positioning map by using the affective evaluation results of

Study 4. Based on the result of Study 4, it turned out that 13 affective words influenced affective models. A principal component analysis of those 13 words was performed to determine 4 components. The multidimensional scaling method was applied to the component scores of the four components in each sample, and thus a positioning map was derived for relative positions in each sample. Two dimensions constituting the positing map were compared with the scores of luxuriousness and naturalness, which were obtained in Study 4, in order to examine the validity. Relative positions of 12 samples on the positioning map were compared. In addition, a method of applying the comparison of samples to marketing and product development was also considered.

This dissertation proposed five quantitative analysis methods to elaborate the existing affective engineering methodology. The proposed methods were demonstrated by conducting a case study for car instrument panels. As the development of user-oriented products has become the philosophy of product design, reliable and highly valid affective evaluation results need to be obtained and applied for product development in order to attract consumers in the market. The findings of this dissertation will contribute to developing a new methodology of yielding more valid and significant results in affective engineering.

Keywords: Affective engineering, Affective evaluation, Quantitative analysis, Semantic network analysis, Positioning map
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Chapter 1. Introduction

1.1. Research Background

Affective engineering is an academic field or an engineering area, where users' affect is quantitatively identified and reflected in product designs (Nagamachi, 1995). Affective engineering is referred to as various names like affective engineering process, affective evaluation and affective design. The emergence of affective engineering is related to the paradigm shift to the user-oriented product development (Green & Jordan, 2003). Until the mid-1980s, characteristics or opinions of consumers (or users) had not been seriously considered for produce development. Product developers began to pay serious attention to users' opinions, taste and other behavioral characteristics for the following two reasons: First, the stagnation of technical development related to products. Second, the advancement of individualism.

First, the stagnation of technical development results in the standardization of products, which in turn tends to facilitate the user-oriented product development. In market economy, consumers' interest and choice is one of the most essential factors to be considered by any individual or groups producing products or services (Philip, 1994). As the supply exceeds the demand, producing items that attract consumers and are chosen by them is the key to the survival of those who producing them. For example, many household appliances, which are indispensable to our daily life, did not have satisfactory functions and qualities, when they were first introduced in the market. Nevertheless, many people bought them by paying high prices in order to satisfy the desire to possess products that others could not afford (van Kleef, van Trijp, & Luning, 2006). The existence of such products itself encouraged people to purchase them. However, as more and more producers supplied similar goods and the prices were lowered down, more people could use them and their existence could not lure consumers to spend money (Krugman, 1980). In other words, products needed to be differentiated in order to attract consumer’s interest and to be chosen instead of competitive products.

One representative strategy to be differentiated from competitive products is developing a new technique and products that have better performance and advanced functions, which are not achieved by competitive products (Philip, 1994). This strategy is suitable for producers who are leading the markets in virtue of superior technology and financial strength. In fact, this strategy was effective in encouraging and satisfying rich consumers and early adopters, who were looking for differentiated goods, into spending money and thus helping producers (developers) leading the market maintain their status. In other words, such producers could maintain their market power by supplying high-end products of each product group. However, as each product area was fully developed and the technical development stagnated, the technical gap among producers became narrower and thus products came to have similar performance and functions. Accordingly, this strategy became ineffective. As the gap between high-end and low-end products disappeared in the market, the satisfaction of the consumer group, who prefer high-end products, also decreased. In other words, the technical development stagnated and a new technique did not sufficiently overcome the old ones, consumers’ satisfaction through technical development was gradually diminished (Goetsch & Davis, 2003).

Second, the advancement of individualism encouraged each consumer (user) to pay more attention to himself/herself in every phase of life including the use of products. As the industrialization brought about material wealth and the replacement of manual works by machines became a widespread phenomenon, more free time has become available to each person. Besides, the traditional family collapsed, and social trends based on individualism facilitated the respect for personal characteristics and taste (Beck, 2002). Such individualization changed consumers' use patterns while products were mass-produced and the prices were lowered. The unit consumer of most products was originally such groups as household. All the members of a household shared a single TV set, a telephone, etc. However, the individualization of society and the popularization of products also individualized use patterns (Levitt, 1965). Every member of a household has his/her own mobile phone and TV sets are not only installed in the living room but also in each room. Personalization of products can be described as the growth of personal products and the segmentation of market. On account of this change, the mass production system changed to the small quantity batch production system and again to the customized production system (Kotha, 1996).

The trend of personalized use of products also caused a change in product designs. Until the mid- and late 20th century, product designs had emphasized usability, efficiency and functionality. Accessory design factors were removed to make designs suitable for mass production. Besides, the materials, shapes and functions of products were standardized in order to facilitate mass production and achieve the acceptable quality and usability of products (Bürdek, 2005). However, this design strategy was not appropriate for the trend of personalized use of products. In this trend, consumers became more interested in products satisfying their taste than standardized ones. Accordingly, the main focus of product markets were consumers or users, and users' behavioral characteristics, opinions and taste began to be seriously considered for product designs (Bürdek, 2005).

The new paradigm of user-oriented product design naturally led to the research and development of products reflecting human characteristics. Studies on humans should consider not only bodily/physical characteristics but also mental/psychological characteristics because people experience various mental states while using a product. Thus, many research and development projects of products began to actively deal with human affect, one of the concepts that define human mental/psychological characteristics (Gobe, 2001). In a narrow sense, affect is closely related to survival and is a mental state that occurs prior to rational thought and is accompanied by instinct and bodily changes (Jones, 2014). In a broader sense, affect means an overall mental impression or feeling occurring to a man who is experiencing an object or a phenomenon (Kalat & Shiota, 2007). In either sense, a person's affect is influential on his/her attempt to solve a certain problem. The increase in the studies on affect indicates that the user-oriented customization began to be seriously considered for developing products. In other words, the physical performance and prices of products were not the main focus of strategies for attracting consumers and being chosen by them. Each user's subjective preference began to be considered.

Affective engineering is one of the academic disciplines, which considers affect for product development. Affective engineering is an engineering approach that recognizes consumers' impression or feeling about a product as a design factor and reflects it in the product design (Nagamachi, 2016). In this approach, users' complex affect caused by the physical stimulus of a product is scientifically measured and analyzed. Thus, characteristics of products, which could bring comfort to a user's affective side, are identified and quantitatively adjusted to fabricate affect-friendly products (Nagamachi & Lokman, 2016). Such a research trend of affective engineering proposes a method of achieving inner well-being and affective satisfaction in the era where material well-being is already achieved by mass production. As mentioned above, affect is a mental impression about a certain object in a broad sense. From the business perspective, users' or consumers' preference and choice of a certain product seems to be greatly affected by their specific affect for the product.

Since the mid-1980s, the affective engineering approach has been recognized as a methodology for user-oriented designs and actively applied to product designs. After Nagamachi (1995) proposed various methods in affective engineering, many researchers have contributed to standardizing the conventional process (Schütte, 2005). The majority of the current studies in affective engineering follow the standard process. Accordingly, the affective engineering process (also referred to as affective evaluation) with a standardized structure is widely recognized as a research methodology in the academic world of affective engineering. Although being accepted as a representative research methodology, the current affective engineering process also has the following limitations. First, some stages of the affective evaluation do not include a sufficiently quantitative analysis. The affective engineering process is a methodology that is much influenced by an expert's subjective judgment. Many issues like research topic, affective words, design parameters and measurement methods are determined mainly based on opinions of affective engineering experts. These experts possess sufficient knowledge to carry out the affective evaluation. Accordingly, their decisions regarding affective evaluation are usually reliable. Besides, in most cases, not a single researcher but a team of researchers conduct an affective evaluation and thus decisions made by the coordination of researchers are mostly right.

Nevertheless, more quantitative analysis is necessary in the affective evaluation. If further details of a decision made by experts need to be arranged or the most appropriate measurement method for the current evaluation should be determined among many candidate methods, experts' subject opinions are not sufficient and the order of priority needs to be determined through comparison. For this reason, a quantitative analysis can assist experts' decision-making.

Second, it is not easy to accurately collect participants' affect in an experiment. Two reasons can be mentioned for this difficulty. On the one hand, participants' affect is identified based on their conscious responses to a questionnaire in most experiments. As mentioned above, affect is an impression or feeling emerging unconsciously. Accordingly, any conscious grasp and response are likely to distort such an unconscious mental state. EEG or fMRI can be used as an alternative to directly measure physiological signals of a human body. However, this method has not been widely applied because of some problems including cost, time and the noise of physiological signals. On the other hand, while participants' affect is identified in affective evaluation, their poor understanding of the goal of the evaluation and the lack of evaluation criterion make accurate identification difficult. Most ordinary participants in an experiment do not have a consistent criterion. For example, they tend to rate the product element 'a' high in some cases but low in other cases. In other words, the perception of the product element 'a' becomes totally different depending on in what context 'a' is placed. This tendency is especially conspicuous among ordinary users rather than experts. This phenomenon degrades the quality of affective evaluation.

Finally, the current affective evaluation has a limited goal. The main goal of affective evaluation is identifying the relationship between users' affect and product design elements and to design a product reflecting users' affect. This goal is most basic and essential with respect to product design. However, data given for this goal can be utilized far beyond. Users' affect is collected in the affective evaluation. Here, not users' simple satisfaction is collected but specific affects are obtained through various studies. This is one of the most concrete investigations among user surveys. Accordingly, if data thus collected are used only to provide a guideline for design parameters, it is a sort of waste.

1.2. Research Objective

The objectives of this study are to propose a few quantitative analysis methods, which can be applied to the existing affective engineering methodology in consideration of the above-mentioned (1.1) roles and limitations of the current affective engineering, and to examine the results produced by the proposed methods in real cases.

First, this study performs a network analysis for the voice of customers in order to see what impressions customers have about a product and what values they regard as important. If the relationship between statistical values obtained by the network analysis and visualized vocabulary is clarified, values, which customers regard as important concerning the product, product elements to be considered in affective evaluation, and the relationship between them will be quantitatively identified.

Second, a method of identifying the importance of selected affective words is proposed by utilizing various statistical techniques concerning the selection of affective words. In an affective evaluation, affective words are selected by literature review and expert discussion. If there is no criterion, even experts may have difficulty in determining the number of affective words, which will be used for the evaluation, and the priority order of affective words. Accordingly, if a useful criterion for such determinations is presented by using statistical techniques, it will assist experts.

Third, measurement methods of affect, which are used in the affective evaluation, are compared. A semantic differential method is usually applied for measuring the degrees of a specific affect, which are felt by participants using a product, in an affective evaluation. A semantic differential method can be used in three ways. The existing affective engineering research adopts one of the three ways to measure affect. However, no study has comparatively analyzed which one is most appropriate for affective evaluation among the three ways. This study compares the three ways under controlled experimental conditions to see which one is most appropriate for affective evaluation. The effectiveness of each way is examined based on the scale of affective evaluation, which is determined by the numbers of participants, evaluation samples, affective words and design parameters.

Fourth, this study also proposes a method of improving the explanatory power of an affective model and a prediction model, which are derived from data obtained from affective measurement. Most of the ordinary users do not have expert knowledge or deep experience. They are likely to provide inconsistent responses in an affective evaluation, which often leads to poor evaluation results. This study attempts to improve this limitation by dividing an evaluation case, in which ordinary users participate, into a multiple number of subgroups and analyzing each of them. In addition, the evaluations of an expert group are compared with those of ordinary users to see the characteristics of each evaluation group.

Finally, a different method of using results of affective evaluations is also proposed. The affective evaluation focused on identifying the relationship between users' affect and design elements of a product and providing a guideline for product design, which considers users' affect. However, when the results of affective evaluation are used only for the above objectives, the affective evaluation becomes too costly. Data of affective evaluation are difficult to collect since they are the measurements of human affect. Accordingly, apart from the above-mentioned objectives, data of affective evaluation need to be utilized for other analyses. This study proposes a method of utilizing such data to compare a marketing strategy and a product.

1.3. Organization of the Dissertation

This dissertation comprises eight chapters including this one.

Chapter 2 provides a simple review of the existing studies on affect and affective engineering. The review includes the definition of affect, types of affect-related concepts, neural basis of affect, nerve organs related to affect, the definition of affective engineering, types of affective engineering process, research methods used in the process, and methodologies of evaluation and analysis.

Chapter 3 conducts a network analysis of online review data about car instrument panels. The analysis results are applied to an affective evaluation of a leather instrument panel for car. It turns out that such a network analysis is useful to select target affects and affective words, which can be used in a case study.

Chapter 4 proposes an evaluation method for the importance of affective words and performs a case study for a leather instrument panel for car. Five statistical analysis criteria are available to evaluate the importance of affective words. The importance of each word is examined based on how many statistical criteria among five ones are satisfied by it. In view of the case study result, the applicability of this method to real affective evaluation is considered.

Chapter 5 performs an experiment for the leather instrument panel for car to compare three semantic differential methods, which are conventionally used for affective evaluation. The three semantic differential methods include two absolute evaluation methods and one relative evaluation method. Three statistical analyses are used to clarify which one of the three semantic differential methods produces the best result. Besides, the effectiveness of the semantic differential methods is comparatively examined under affective evaluation conditions.

Chapter 6 proposes a method of improving the explanatory power of an affective model and a prediction model, which are derived from data of ordinary users. A case study is also performed for the leather instrument panel for car. Affective and prediction models are also derived from experts and compared with those of the ordinary users. The effectiveness of the proposed method is identified by comparing the explanatory power of a model between with and without applying the method. The problems of the proposed method, counterarguments and the difference between the models of experts and those of the ordinary users are discussed.

Chapter 7 presents a positioning map by utilizing a principal component analysis method and a multi-dimensional scale method. Affects having a significant impact on a product are derived from the affective evaluation. In other words, it is evaluated how much each of those affects is felt by participants for each product sample. In this way, the degrees of affects can be compared among samples. In case too many affects are evaluated, such a comparison could be complicated. Accordingly, the dimension reduction method is used to propose a positioning map where affects can be relatively compared among samples. The effectiveness and limitations of the positioning map based on the dimension reduction method are also considered.

Chapter 8 summarizes the objectives, main contents and findings of this dissertation. The implications of those findings are also discussed. Finally, the limitations and further works are explained.

Chapter 2. Literature Review

2.1. Overview

This chapter aims to summarize the concepts, definitions, and important content of previous researches related to the subject covered here, which will help the reader better understand this study. Because the main theme of this study is improvement of the existing affective engineering process methodology, we will first discuss the definition of affect, concepts related to affect, and the physiological basis of affect, which are the most essential concepts pertaining to affect. Second, the history of affective engineering to date will be reviewed by discussing the methodologies that have been proposed and the most generalized methodology. In addition, the types of detailed methodologies required for conducting the affective engineering process will be reviewed by dividing them into survey methodologies and evaluation methodologies.

2.2. Affect

2.2.1. Definition of Affect

It is difficult to define the concept of affect clearly. Most people know implicitly what affect means, but defining affect explicitly is difficult (Kalat & Shiota, 2007). The first definition of affect in science was given by James in his paper (1884). According to him, affect is defined as "the phenomenon that is expressed by the experience (events, environments, human relationships, etc.) of the individual stacked and reacted internally" (James, 1884). Since then, much research on affect has been carried out continually, as a result of which the definition of affect has been supplemented and expanded. Zajonc (1980) viewed affect as an instinctual phenomenon that appears first, before a cognitive response to a particular stimulus occurs. Myers defined affect as a psychological and physiological experience that occurs in the mind by environmental or physical influences. Myers (2004) defined affect as a psychological and physiological experience that occurs in the mind by environmental or physical influences.

Antonio Damasio (1998) defined affect as a complex expression of regulatory organs to achieve balance in vivo. According to him, affect helps achieve the objective of survival in life without the need for thought. Damasio (1999) claimed that affect should therefore be defined as actions that can be fully observed for at least scientific purposes. However, if affect refers to observable behavior only, it is also a problem because it will refer to the behavior itself rather than the term "affect". Affect is often referred to as a feeling that explans behavior (Kalat & Shiota, 2007). Nagamachi (2016), who first proposed affective engineering, defined affect as subjective thoughts on stimuli perceived through sensations. Fredrickson (2001) defined affect as a feeling which can be consciously accessible. Thus, there is no consensus on how to define affect among researchers, and terms related to affect are also diverse.

2.2.2. Concepts related to Affect

The reason why researchers differ in regard to the definition of affect without being able to arrive at a consensus is because the meaning of affect overlaps with the meanings of concepts similar to affect. Therefore, it is necessary to clearly define other concepts related to affect and to clarify the relations among the concepts. For example, affect, emotion, mood, and feeling are representative concepts that are mixed up and unclear (Ekkekakis, 2013).

Because the concept of affect encompasses a very broad range of content, Russell and Barrett (2009) defined the new concept of "core affect" (Ekkekakis, 2013). They defined core affect as "a neurophysiological state consciously accessible as a simple primitive non-reflective feeling most evident in mood and emotion but always available to consciousness" (Russell & Barrett, 2009). Russell (2003) emphasized that core affect is a conscious experience and is psychological rather than cognitive or ruminative. Representative examples include pleasure, displeasure, tension, calmness, energy, tiredness, and so on. All conscious experiences of humans are related to core affect, and can lead to changes in it (Russell, 1980, 2005).

2.2.2.1. Core Affect

Barrett, Mesquita, Ochsner, and Gross (2007) found that affect can be explained at the level of pleasure. In addition to the level of pleasure, the degree of arousal was also seen as an important factor in explaining the affective experience.

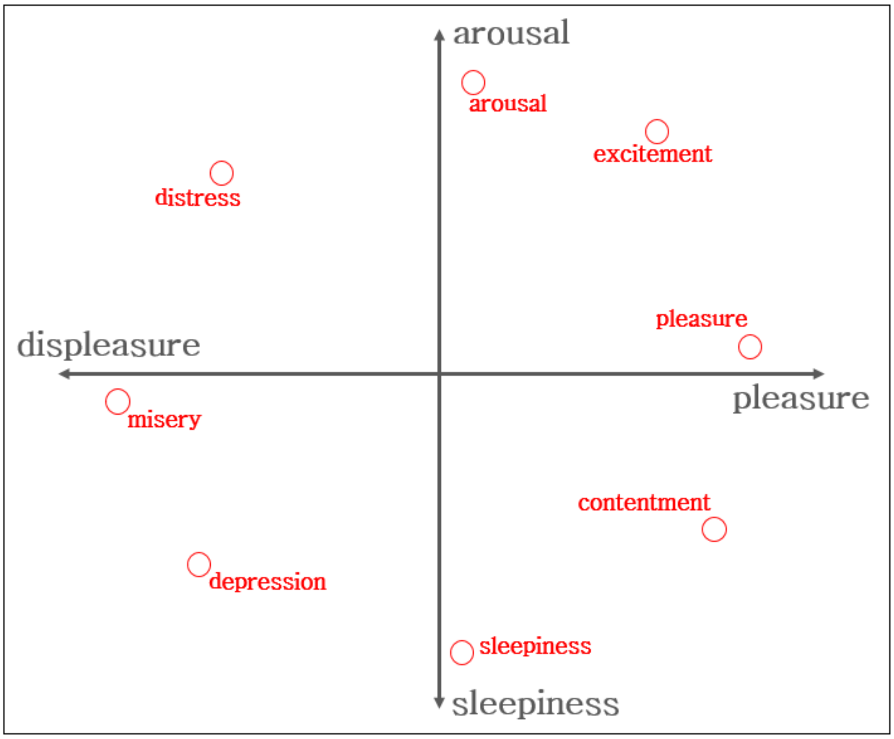


Figure 2.1. Circumplex model of affect (adapted from Russell, 1980)

This is based on the concept of core affect that Russell (1980) proposed, according to which the affective experience can be represented as a two-dimensional model, and the Y axis is defined as the axis related to the level of arousal and the X axis as the axis related to the level of pleasure (Russell, 1980). Positive values on each axis represent activation, and negative values represent suppression. The various affective experiences of humans are expressed by a combination of the degree of pleasure level and the degree of arousal level. This is called the circumplex model, and it is useful to explain the affective experience. For example, the affect of "excitement" refers to the case where both the pleasure level and the arousal level are high, and the affect of "discouragement" refers to the case where both the displeasure level and the sleepiness level are high (Figure 2.1).

2.2.2.2. Emotion

Emotion is defined as the degree of pleasure and displeasure felt by humans and as the conscious experience of strong mental activities that are associated with the degree (Panksepp, 2004). Ekman (1999) defined emotion as being reactive, and occurring within a short period of time, and related to specific events that have scope. Parrott (2001) defined emotion as a state that is expressed mentally, physically, and emotionally, swayed by external stimuli. Russell and Barrett (1999) defined emotion as "a complex set of interrelated sub-events concerned with a specific objects" and stated that specific objects can be anything, such as humans, events, objects, past work, present work, future work, or something virtual.

Scherer (2005) thought that emotion is related to the collaborative response of the five main systems (Ekkekakis, 2013): 1) the information-processing cognitive component, 2) the neurophysiological component, 3) the executive component, which prepares and directs responsive actions, 4) the expressive component, which communicates the emotion via vocal and facial expressions, and 5) the experimental component, which monitors the internal state of the organism and its interaction with the environmental and generates subjective feelings. He defined emotion as "an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism" (Scherer, 2005). By synthesizing the results of various researchers, it can be broadly defined that emotion is a state of the human mind expressed through mental, physical, and behavioral mediators and their coordination rather than a state that appears directly in the human mind by external stimuli (Jung, 2008).

2.2.2.3. Mood

Nowlis and Nowlis (1956) showed that the concepts of emotion and mood can be defined differently in terms of quantitative aspects. Quantitative aspects here refers to duration and intensity (Ekkekakis, 2013). They stated that the duration of emotion is generally shorter than the duration of mood and that the intensity of an emotional reaction is stronger and more explosive than the intensity of mood (Nowlis & Nowlis, 1956). In this regard, Ekman (1992) found that the duration of emotion generally varies from seconds to minutes, and from hours to days in rare case only. On the other hand, he found that the duration of mood generally ranges from hours to days.

In addition to duration and intensity, other properties describing mood were proposed. According to one of them, because the cause of mood is uncertain, mood is “diffuse and global” (Morris, 1992). Because mood is not a response of a specific event or an object, it was thought to have a state of diffuseness. Similarly, Russell also thought that what causes mood is unclear and vague in most cases (Russell, 2003). If mood is related to an object, it is emanated from an evaluation of that object. It is the same principle that governs how emotion is emanated. In this regard, Lazarus (1991) said that both mood and emotion may be reactions to an evaluation of the relationship with external objects, but there is a difference between mood and emotion. He said that whereas mood is related to the large, universal, and ontological issues of life, emotion is an immediate response.

Similarly, there are differences among core affect, emotion, and mood. These differences are summarized in Table 2.1 and Table 2.2. In addition to core affect, emotion, and mood, more concepts are confused with affect.

Table 2.1. Tentative distinctions between core affect, emotion and mood (part 1)

	Core affect	Emotion	Mood
Present when?	Always	Rarely	Much of the time
Duration?	Constant	Short (seconds to minutes)	Long (hours or days – or longer in clinical cases, such as depression)
Intensity?	Variable (ebb and flows)	High	Lower than emotion (but could be high in clinical cases, such as depression)
Multiple components?	No, elementary (the most elementary consciously accessible affective feelings)	Yes (core affect, cognitive appraisal, bodily changes, vocal and facial expressions, action tendencies)	Yes but some components (e.g., peripheral physiology, facial expression, action tendencies) are not as pronounced or distinct as in emotions
About something?	Not necessarily	Yes	Possibly, although not necessarily about something specific (could be "about everything, about the world in general")
Antecedent appraisal?	Not necessary in "free-floating" core affect (but may co-occur with an appraisal in emotion or mood)	Necessary	Necessary
Object of appraisal?	N/A	Specific stimulus, clearly identifiable	Varies but could be larger, "existential" Issues or concerns or not easily identifiable
Temporal relation to stimulus?	Direct	Immediate or close	May be distant

Table 2.2. Tentative distinctions between core affect, emotion and mood (part 2)

	Core affect	Emotion	Mood
Evolutionary origins?	Ancient, primitive	More recent than core affect	More recent than core affect
Cultural influence?	Limited	Presumed strong	Presumed strong
Function?	Approach useful and avoid harmful stimuli, prioritize multiple sensory stimuli, form valenced memories and preferences	Direct attention, coordinate response across multiple channels, communicate	Prepare or caution about what the future might bring, influence cognition, lower threshold for elicitation of congruent emotions
Examples?	Pleasure, displeasure, tension, relaxation, energy, tiredness	Anger, fear, anxiety, jealousy, pride, shame, guilt, love, sadness, grief, disgust	Dysphoria, euphoria, irritation, joyfulness, cheerfulness, grumpiness

Attitude is also one of them. Eagly and Chaiken (1993) defined attitude as “a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor.” This property is consistent with the property of emotion, mood, and so on. Long duration, which is a characteristic of attitude, is also similar to mood (Frijda, 1986). In this respect, attitude can be seen as a concept based on mood and other affective experiences (Desmet, 2008). Attitude is influenced by the instinctive aspects of humans and by what we learn from the environment such as our community, culture, country, and home (Desmet, 2008). Thus, even for one object, each individual will have different attitudes depending on the biological and environmental conditions they are governed by.

2.2.3. Neural Bases of Affect

Neural bases related to affect can be divided into three parts: (1) First, the autonomic nervous system (ANS), which induces physical changes in response to affect. (2) Second, the limbic system, which is related to the instinctive needs of humans such as appetite, sexual desire, and flight from danger. (3) Lastly, the cerebral cortex, especially the frontal lobe, which is related to higher functionalities of humans such as decision making and communication with others.

2.2.3.1. The Autonomic Nervous System (ANS)

The ANS is the part of the peripheral nervous system (PNS) system that regulates the internal organs and physical activity independent of human will. Because the ANS operates relatively independently of cerebral cortex control, it is called the autonomic nervous system. The ANS is divided into the sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS). These two systems have opposite effects on the same organ. For example, when we face physical threats, the SNS is activated, causing enlargement of the pupil of the eye, an increase in the heart rate, and suppression of salivation. On the contrary, when our bodies experience a comfortable or joyful situation, the activation of the parasympathetic nervous system leads to physical changes, such as the contraction of the pupil of the eye, a decrease in the heart rate, and activation of salivation. The characteristics of the ANS for each organ are summarized in Table 2.3.

Table 2.3. Parasympathetic and sympathetic system of ANS

	Parasympathetic nerves “Rest and digest”	**Sympathetic nerves “Fight or Flight”**
Pupils	Constrict pupils	Dilate pupils
Heart	Slow heartbeat	Increase heartbeat
Salivary gland	Stimulate saliva	Inhibit salivation
Lung	Constrict airways	Relax airways
Stomach	Stimulate activity of stomach	Inhibit activity of stomach
Liver	Inhibit release of glucose; Stimulate gallbladder	Stimulate release of glucose; Inhibit gallbladder
Intestine	Stimulate activity of intestines	Inhibit activity of intestines
Adrenal gland	N/A	Secrete epinephrine and norepinephrine
Urinary bladder	Contract bladder	Relax bladder
Reproductive organ	Promote erection of genitals	Promote ejaculation and vaginal contraction

2.2.3.2. Limbic System

The limbic system is the area of the brain where affects of humans such as happiness, sadness, fear, and disgust are regulated, and memory is formed.

Various sub-structures in the limbic system regulate affects and form memories. The amygdala, hippocampus, thalamus, and hypothalamus are typical sub-structures (Figure 2.2).

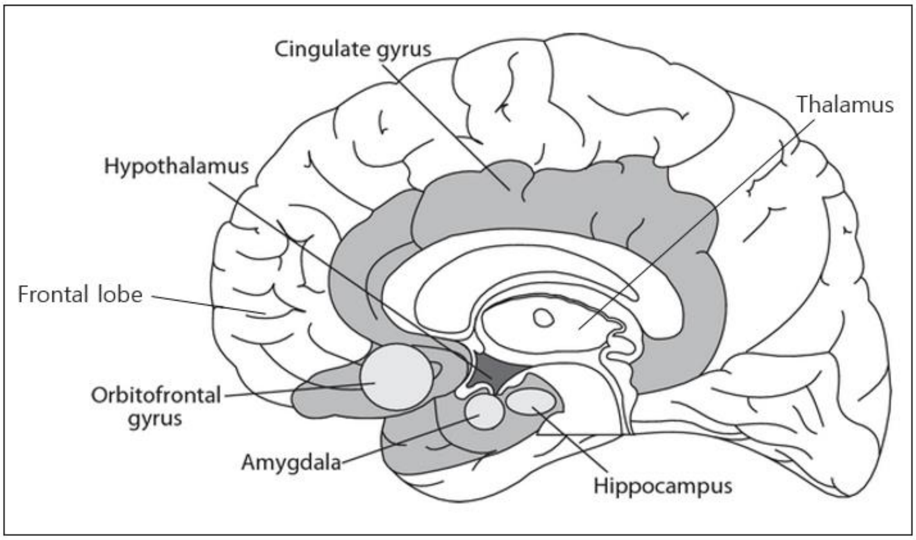


Figure 2.2. Structures related with affect in brain

The amygdala deals with affective aspects of behavior and memory (Goleman, 2006). It is connected with various brain areas including the sensory area, motor area, and autonomic neural substrates. The amygdala gets visual, auditory, tactile, etc., information from the sensory area and analyzes it to express affects related to them. Thus, the amygdala is sensitive to early sensory processing and influences detailed perception (Sylwester, 1994). When a person feels fear, the amygdala recognizes it as an emergency situation, and takes control of most of the brain, including the region related to rationality, and directs the behaviors of the person. This is similar to a country devoting all its resources first and foremost to the war mission, when a war breaks out.

However, when the affective reaction judges the situation to be dangerous, some of the visual information is not passed through the cerebral cortex and is directly transferred to the amygdala. It cannot process information as accurately as the cerebral cortex, but it is faster than the cerebral cortex (Goleman, 2006). Therefore, while information processing by affect may not be accurate and logical, countering external crises by affective processing is faster than by rational processing.

The amygdala is also a repository of affective impressions and memories (Goleman, 2006). When we react without specific reasons, it is because the memories and reactions related to that behavior have already entered the amygdala. For example, when we hear that somebody who was close to us is dead, our amygdala is activated, and this activated amygdala imprints the impression of that time into our memory (Boeck & Martín, 1997). In this way, the amygdala is intuitively and quickly involved in human behavior and judgment.

The hippocampus translates events experienced into long-term memory and stores them in the cortex. Whereas the amygdala remembers the subjective affect or feeling of a particular event, the hippocampus remembers the objective conditions (location, time, etc.) and the detailed content of the event (Sylwester, 1994). For example, the hippocampus lets us know whether a person whom we see is known to us or not. However, affective recollection of the person in front of us is possible through the amygdala. In other words, the hippocampus plays a role in providing memories of objective conditions and content that are necessary for imparting affective meanings to a particular object.

The thalamus serves as an early relay center for spreading sensory information input through sensory organs to relevant areas of the brain. Through this role, the thalamus informs the whole brain about events occurring outside the body. Through a direct connection to the amygdala, the thalamus can deliver information regarding external threats to the amygdala at a high speed (but not accurately). This allows humans to generate affective reactions related to a specific event even before the event is fully understood (Sylwester, 1994). The hypothalamus is a structure located under the thalamus. By monitoring the regulation hormones or homeostasis in the body, the hypothalamus informs the brain of what is happening inside the body. By controlling various hormones, the hypothalamus allows humans to cope with situations appropriately under various external conditions. For example, in a dangerous situation, the hypothalamus promotes the "fight flight stress response" by releasing adrenocorticotropic hormone through the pituitary gland (Sylwester, 1994).

2.2.3.3. Frontal Lobe

Unlike other animals, humans have a highly developed cerebral cortex in the brain. This gives them the capability for more complex thinking than other animals. The cerebral cortex accepts, classifies, and interprets sensory information, and makes rational decisions based on it, allowing actions resulting from this processing. In the cerebral cortex, the forehead and upper part of the forehead are called the frontal lobe. The frontal lobe is the area of the brain involved in critical thinking, problem solving, future planning, and future prediction (Goleman, 2006).

The frontal lobe has an important role in adjusting affective states and judgments in response to events. Critical thinking and the problem-solving ability of the frontal lobe make free-willed behaviors possible, and suppress irrational behaviors that spring from affective biases. In general cases, the frontal lobe suppresses affective responses from the beginning. As mentioned above, sensory information arriving at the thalamus spreads to various parts of the brain including the frontal lobe, and at this time, the frontal lobe works with other brain regions to produce appropriate responses. When affective responses are needed in this process, the frontal lobe expresses affective responses by cooperating with limbic system structures like the amygdala. Because the response of the frontal lobe is produced through cooperation with many other brain areas, it is inevitably slower than the response by the amygdala (Boeck & Martín, 1997).

If the frontal lobe does not function properly, affective responses are also abnormally expressed. When the degree of affective response such as happiness, sadness, anger, and fear is excessive or improper, the frontal lobe plays a role of suppressing it. For example, when the affect of fear is expressed excessively by the amygdala, the frontal lobe is activated to regulate the excessive expression. Interactions between the limbic system and the frontal lobe are not just for affective regulation but also for general mental activity (Goleman, 2006). Mirror neurons existing in the frontal lobe area help us feel the emotions of others indirectly. They are also important structures of the brain that are related to affective experiences.

2.2.3.4. Dopamine Pathway

In the previous sections, the specific organs of the brain related to human affect were discussed, while in this part, the neurotransmitter associated with affect will be discussed. Dopamine is an important neurotransmitter that regulates human affect (Bear, Connors, & Paradiso, 2007). Dopamine is a neurotransmitter in the central nervous system and is also a precursor of adrenaline and norepinephrine. It is secreted by the dopaminergic neurons in the substantia nigra of the middle brain and ventral tegmental area (VTA), and is involved in nerve signaling, pleasure, motivation, affect regulation, and exercise control (Bear et al., 2007). In particular, it is related to pleasure, and it plays a central role in reinforcing and rewarding behaviors by pleasure. The set of neurons that release or synthesize dopamine in the brain is called the dopamine pathway.

The dopamine pathway consists largely of the following five pathways: the mesolimbic pathway, mesocortical pathway, nigrostriatal pathway, tuberoinfundibular pathway, and hypothalamospinal projection. Of them, the pathway that provides rewards for pleasure is the mesolimbic pathway. The mesolimbic pathway is the pathway of dopaminergic neurons from the VTA into the ventral striatum composed of the nucleus accumbens (NAcc) and the olfactory tubercle. The mesolimbic pathway regulates cognitive processes such as incentive salience, reinforcement learning, fear, and motivation. If dopamine is depleted in this pathway, humans or animals will not take action to obtain a reward. Conversely, as the production of dopamine in this pathway increases, the frequency of behavior to obtain a reward also increases. The release of dopamine in this pathway plays an important role in regulating pleasure.

2.3. Affective Engineering

2.3.1. Definition of Affective Engineering

Affective engineering is a representative product development methodology that incorporates the user's impressions, feelings, and demands on products in product development (Schütte, 2002). Affective engineering (kansei engineering) as a methodology was proposed first in the 1970s (Nagamachi, 2002). From the term "kansei," which is the Japanese word for "affect," Nagamachi called the proposed methodology kansei engineering. Since then, various researchers have borrowed Nagamachi's affective engineering methodology and adapted it to their own research. Thus, the methodology of affective engineering has become an important element in the field of product development. In the sense that users' affective needs are reflected in the detailed product design, affective engineering can be defined as "translating technology of a consumer's feeling of the product to the design elements" (Nagamachi, 1995). According to Nagamachi (2001), affective engineering focuses on the following three questions:

- how to accurately understand affects of consumers

- how to reflect and translate affective understanding into product design

- how to create a system and organization for affect-oriented design

To answer these questions, various types of affective engineering methodologies have been proposed. Today, by combining these different types of methodologies, a set of processes has been established to identify users' affect and to incorporate it in product development. This is called the affective engineering process, and various survey and analysis methodologies are used at the individual process stages of the affective engineering process.

2.3.2. Definition of Affect in Affective Engineering

As seen above, in general, affect can be defined as the change in the mental state that occurs inside humans due to an external stimulus. Changes in mental state may last for a short period of time, or they may last for a long period of time, but they are all referred to as affects (Kalat & Shiota, 2007; Myers, 2004). This general definition of affect is commonly used in affective engineering, but it also covers a wider range. The feeling or thought about the design parameters is also defined as affect in affective engineering (Schwarz, Kovacevic & Kos, 2015). When users interact with the product, all the feelings that are expressed inside the user are defined as affects.

The feelings expressed when interacting with the product can be abstract, like "good/bad," or can be related to sensation, like "rough/smooth." In addition to this, in affective engineering, feelings about product characteristics like design parameters can be judged as affect. For example, the surface properties of a product, such as how "flat/rugged" the material is, can be defined as affect. This product characteristic itself does not have emotional value. Thus, a feeling regarding the detailed product characteristics can be incorporated into the affective structure associated with the product by ascertaining the relationship with the abstract high-dimensional affect (for example, good/bad).

2.3.3. Affective Engineering Methodologies proposed in the Early Days

Early affective engineering methodologies are divided into three types (Nagamachi, 1995). Affective engineering type 1 means "category classification from zero to nth-category." Type 2 means a systematic affective engineering methodology that utilizes a computer system. Type 3 means a methodology that applies mathematical modeling to derive appropriate product design parameters (Nagamachi, 1995).

2.3.3.1. Affective Engineering Type 1

Affective engineering type 1 is a method that gradually increases the number of levels by subdividing the concepts of a product to be analyzed into more detailed concepts (Nagamachi & Lokman, 2016). An example of type 1 is the gradual segmentation of the design properties of a product. By linking the segmented product properties to the actual technical specification, specific specifications for the product to be created are established. Type 1 consists of five steps (Figure 2.3).

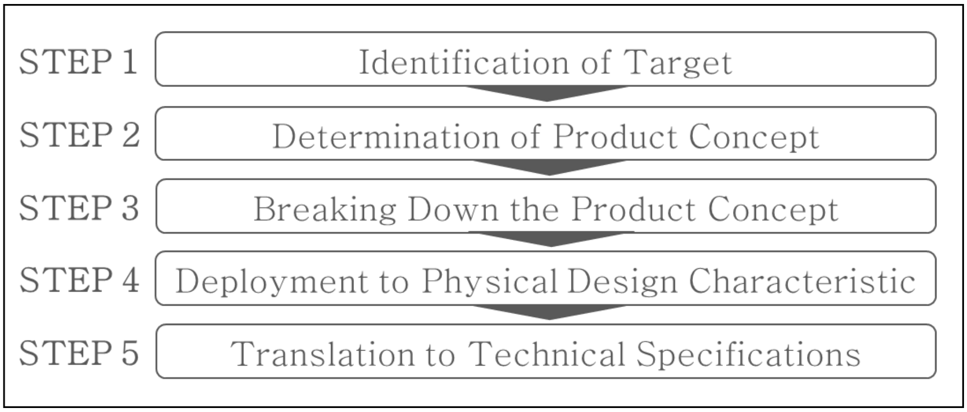


Figure 2.3. Steps of affective engineering type 1

Step 1 is a process for the selection of a group of people who are expected to use the product. By selecting the target group and understanding the affective states of the people of the target group, we can determine how to respond. For example, it should be determined whether the group that uses a particular product is a group of children, adults, males, or females. This can be determined through professional consultation or marketing surveys (Nagamachi & Lokman, 2016).

Step 2 is a process for deciding the product concepts. This step determines which product concept should be added to an existing product for user satisfaction. By surveying the lifestyles of target users or analyzing user-related data with the help of experienced researchers, the product concept can be determined. In affective engineering (kansei engineering), the product concept is called the zero-order affect (kansei) concept (Nagamachi & Lokman, 2016).

Step 3 is a process for subdividing the product concept determined in step 2. Because the product concept determined in step 2 has no specific details such as size, color, and function, the levels of concepts are subdivided in step 3 until appropriate design characteristics are derived (Nagamachi & Lokman, 2016). The concept derived by subdividing the product concept once more is called the 1st order concept, and the concept derived by subdividing the 1st order concept once more is called the 2nd order concept. In this way, the segmentation process is continued until the concept is not subdivided into sub-concepts in step 3.

Step 4 is a process for deriving the design characteristics (Nagamachi & Lokman, 2016). Various sub-concepts are derived by segmentation processes in step 3, and the physical design characteristics matched to each derived sub-concept are determined in step 4. Physical design characteristics include not only external features such as the shape, weight, and color of the product, but also the functional characteristics that the product should have and the identities that the product should seek. The concept segmentation process and design characteristic matching process of step 3/step 4 are visualized in Figure 2.4.

Step 5 is a process that converts the previously selected physical design characteristics into actual technical specifications (Nagamachi & Lokman, 2016). Although the work-up to step 4 is a series of processes for deriving the design characteristics of a product that can satisfy the user's affect, the derived design characteristics cannot be directly applied to the production of the product. Step 5 is the process of establishing the actual technical specifications for the production of the product, and it includes developing new technologies and confirming whether they conform to the desired concepts or not.

Whereas affective engineering type 1 is a series of processes that subdivide the product concept, derive the physical design characteristics based on the concept, and translate it into appropriate technical specifications, affective engineering type 2 differs from type 1 in terms of converting user's affective needs into physical characteristics by using techniques supported by computer technology.

Affective engineering type 2 is a methodology that translates the image of feeling of a product that users have into real product design elements and is recognized as a system (Nagamachi & Lokman, 2016).

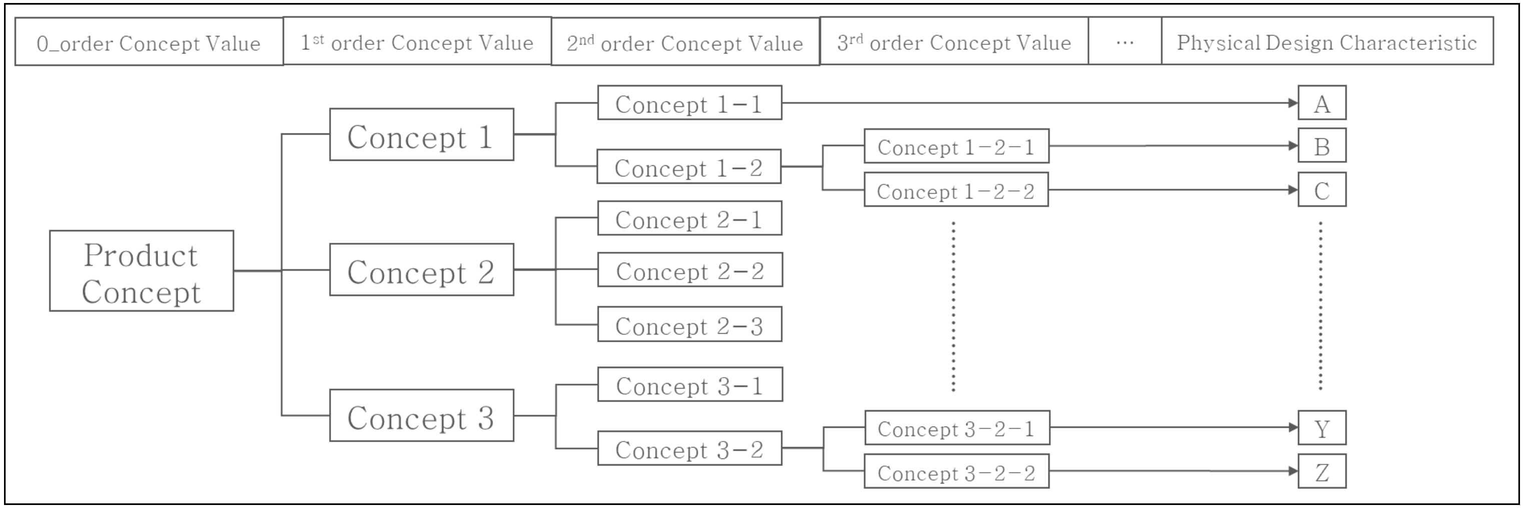


Figure 2.4. The conceptual diagram of affective engineering type 1 (adapted from Nagamachi & Lokman, 2016)

2.3.3.2. Affective Engineering Type 2 & Type 3

Type 2 comprises four types of database and computing technology (Schütte, 2002): a database that includes affect-related vocabularies of users, a database that includes the images of a product to be evaluated, a database of design and color, and a database that includes information on how the databases are connected to one another. This is called an affective engineering system, and it is the core of type 2. The conceptual diagram of the affective engineering system (type 2) is given in Figure 2.5.

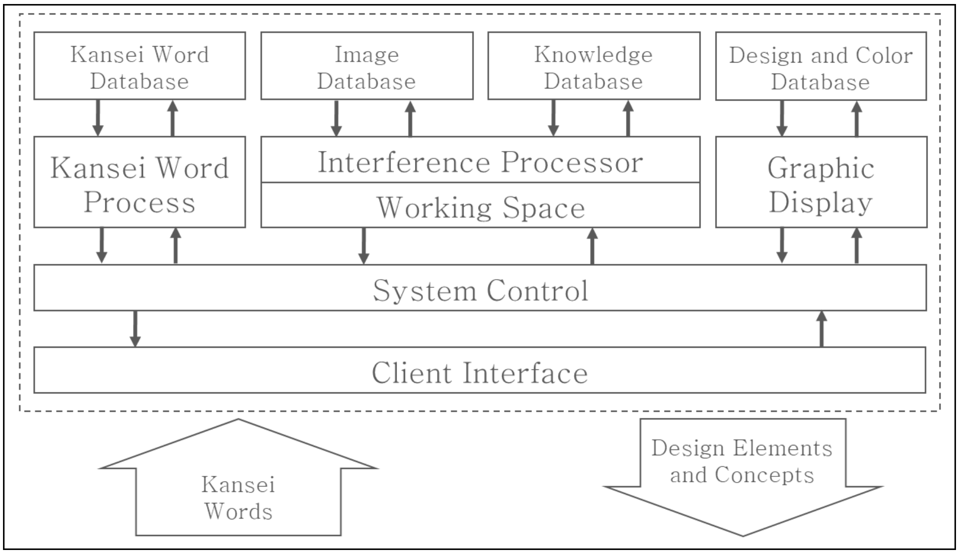


Figure 2.5. The conceptual diagram of affective engineering System (type2)

In the affective engineering system, when users input the vocabularies related to a specific affect that users desire in the product, the affective engineering system obtains those vocabularies through the affective vocabulary database, which determines whether the input vocabularies can be recognized or not. If the affective vocabulary database is able to recognize the input vocabularies, they are transferred to the knowledge database. The knowledge database uses an inference processor to link the input vocabulary with the image of a particular product. The inference processor then decides the design details. To obtain the final design factors or concepts, ruled-based computer technologies such as expert systems, neural networks, genetic algorithms, and fuzzy logic are needed (Nagamachi & Lokman, 2016).

The difference between type 3 and type 1/type 2 is the application of mathematical modeling. Because type 3 uses mathematical modeling, it is possible to obtain the coefficient value of the relationship between the affect of the user as the input value and the physical design characteristic as the output value (Nagamachi & Lokman, 2016). Statistical techniques such as quantification type 1–3 are used for the mathematical modeling.

2.3.4. Integrated Affective Engineering Process by Combining Various Types

Early affective engineering was proposed with various types of methodologies as described previously (Schütte, 2002). However, the affective engineering process used in the actual field utilizes appropriate combinations of various types of methodologies (Nagamachi, 2008) when performing an affective evaluation on a particular product, because a single-type evaluation may be too limited to achieve the purpose of the evaluation. For example, although affective engineering type 1 can identify which product concept is associated with a certain product attribute by subdividing product concepts, it cannot identify the relationship between product concepts and affects. A description of the integrated affective engineering process is summarized in Figure 2.6. In general, the affective engineering process consists of four stages: "choice of domain," "span the semantic space," "span the properties of product," and "synthesis."

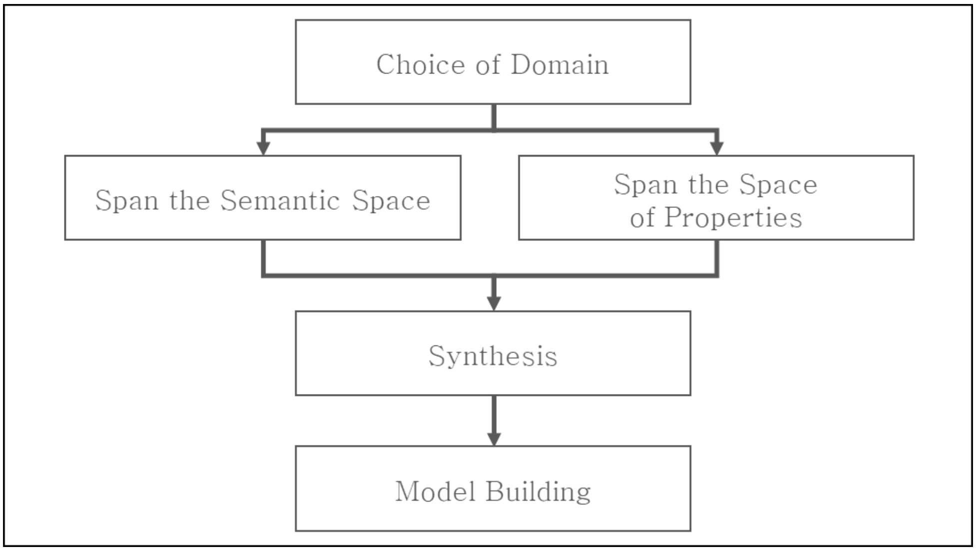


Figure 2.6. Conceptual diagram of integrated affective engineering process

“Choice of domain” is the stage performed to decide the product type and detailed characteristics of the product to be evaluated, and select the user group and market niche in which to sell the product (Schütte*, Eklund, Axelsson, & Nagamachi, 2004). In this stage, survey methodologies such as the focus group interview (FGI) and the expert interview are used (Schütte & Eklund, 2005). On the basis of the information derived in this way, the product sample and affective word are selected. “Span the semantic space” is the stage of selecting the affective words that are used to evaluate the selected product and its subtopics selected at the “choice of domain” stage. The concept and terminology of the semantic space were proposed by Osgood and colleagues (1964). They judged that all objects can be expressed in a vector space defined by semantic expression (vocabulary), and on the basis of this, they viewed a set of vocabularies expressing a product as a semantic space (Schütte* et al., 2004).

The “span the space of properties” stage derives the attributes related to the selected domain and finds the attributes that influence the affect of the user (Schütte* et al., 2004). In this stage, among the product attributes such as weight, shape, texture, and sound, the attribute expected to influence the user’s affect is selected, and product samples that will be used for evaluation are chosen. The “synthesis” stage connects the result of the “semantic space” with the result of the “span the space of properties” stage (Schütte & Eklund, 2005; Schütte* et al., 2004). An attribute of a product can be related to various affective words, and an affective word can also be related to various product attributes. Identifying these relationships and drawing conclusions is a key part of the affective engineering process. By identifying the relationship between the degree of affect that participants felt when they evaluated the selected products and the design parameters of the product attributes, conclusions on how the degree of affect differs with the design parameters are drawn.

2.3.5. Investigation Methodologies

To identify subjects of the affective engineering process and to obtain user opinions and vocabularies related to the product, investigations should be conducted. The investigation methods used in the affective engineering process include interview methods and literature studies. Interviewing is a qualitative method to draw information by asking questions and obtaining answers to them (Kvale, 1996). The interviewer is usually a person who has been trained professionally. On the other hand, the interviewee may or may not be an expert in a particular field. The format of interviewing can be structured, unstructured, or both. In the case of structured interviews, based on the prepared questionnaires, answers are received to a limited set of questions. Unstructured interviews are conducted in a free environment without prepared questionnaires.

2.3.5.1. Interview

Typically, interview methods used in affective engineering are the FGI and the in-depth interview. The FGI is a method of collecting data through a conversation between the interviewer and interviewee, and a small number of interviewees is selected from users who are expected to consume a particular product or be interested in that product (Kim, 2017). The FGI is distinguished from in-depth interviews in that several interviewees are grouped together and freely share their opinions, and is distinguished from the general survey in that it does not use structured questionnaires. The advantage of the FGI is that it provides in-depth and broad information on the ideas and opinions the target user group has of the product. However, because the number of interviewees is limited to under 10 people, it is difficult to generalize the interviewee group to an entire population. In addition, because it is not a structured interview, it is difficult to analyze accurately (Kent, 1993).

An in-depth interview is a semi-structured interview method in which the interviewer has an overall framework for the questions but does not specify the detailed questions or the order of questions in advance. While in-depth interviews need to be prepared in advance with regard to questions, the questions should be appropriately restructured to be able to question flexibly without being fixed in the question frame (Rubin & Rubin, 2011).

2.3.5.2. Literature Studies

Literature studies are methods of extracting information on research topics from existing research papers, reports, newspaper articles, books, and so on. In affective engineering, literature studies are usually used for extracting affective words. Because data are retrieved from existing research, it is advantageous in that the data can be verified and used immediately for research. It also saves time and money in that you can obtain the data without further investigation. However, there is the disadvantage that the reliability of current research can be influenced by the reliability of previous research, and it is difficult to obtain new data that was not existing (Kim, 2017).

2.3.6. Evaluation Methodologies

To conduct the affective engineering process, evaluation result data of the users on the product are needed. There are evaluation methods for this. The evaluation methods used in the affective engineering process can distinguished as non-verbal and verbal evaluation methods.

2.3.6.1. Non-verbal Evaluation Method

The non-verbal evaluation method evaluates the activities of the human body. For example, changes in facial expressions, voice, gesture, etc., are analyzed, and physiological changes such as EEG and EMG are analyzed and measured. The non-verbal evaluation method is an objective evaluation method, but there is the limitation that only observable affects (joy, disgust, anger, etc.) that can be observed externally can be measured.

The six basic affects (joy, sadness, anger, disgust, surprise, and fear) presented by Ekman can be recognized by others through facial expressions, because facial expressions of these six affects are constant regardless of the country of cultural influence. Therefore, facial expressions have been studied as indicators of the human affective state. When the six basic affects are expressed by facial expressions, each affect has a unique facial expression pattern (Ekman, 1994). For example, when angry, the face shows a fixed gaze, a frowning eyebrow, and a hardened lip (Jung, 2008). Each affect has a unique facial expression pattern, and the affect of another person is recognized by this facial expression pattern. Facial Action Coding System (Ekman & Friesen, 1978) and Discriminative Facial Movement Coding System (Izard, 1979) are used to recognize facial expression patterns.

Voice is also a non-verbal expression that is used to identify affective states. Affects can be inferred through the height of the voice, the change in the height, the size, the tone, the speed of the speech, and the accuracy of pronunciation. As with facial expression recognition, it is assumed that there is a different pattern for each voice, and the affect is inferred on the basis of the different pattern of vocal cues (Desmet, 2003). Physiological responses such as heart rate, changes in muscle tension, brain waves, changes in pupil, etc., are related to the ANS, and level changes in them are closely related to the affective state (Jung, 2008). There are various devices that can measure changes in physiological signals. Through these devices, it is possible to record changes in the physiological signals that a person experiences in a specific situation, and it is possible to infer physiological changes under the specific affective state.

2.3.6.2. Verbal Evaluation Method

The verbal evaluation method can evaluate subjective and complex affective states better than the non-verbal evaluation method (Jung, 2008). The verbal evaluation method includes a self-reporting questionnaire in which participants voluntarily describe their thoughts and a vocabulary evaluation method in which participants judge their feelings using the affective words presented by the experimenter. The vocabulary evaluation method has two advantages. One is that because the number of affects that can be expressed increases with the number of words, various affects can be collected and measured. The other is that by mixing words, mixed affects can be measured. The words used in the vocabulary evaluation method are mainly adjectives that indicate affective states. The semantic differential method and the Likert scaling method are the most commonly used vocabulary evaluation methods.

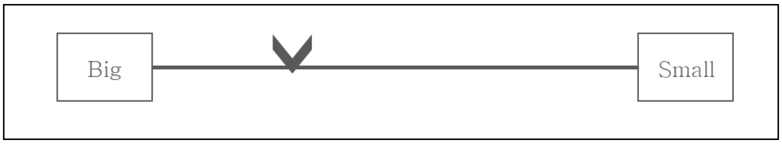


Figure 2.7. An example of Semantic Differential Method

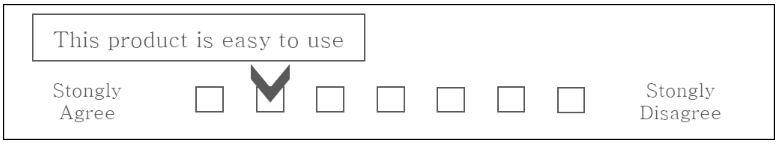


Figure 2.8. An example of Likert Scale Method

The semantic differential method is an evaluation method proposed by Osgood (1952). It is an evaluation method consisting of a line-wise pairing up of words with conflicting meaning such as 'Big – Small' or 'Good – Bad', and participants check the level they think matches their opinion about the particular topic or concept on the line (Figure 2.7). The Likert scaling method is an evaluation method proposed by Likert. In this method, the attitude toward the topic or concept to be measured is divided into 5–7 steps from very positive to very negative, and participants express their opinions by selecting one of the 5–7 steps (Figure 2.8).

2.4. Conclusion

In this chapter, the definition and neural basis of affect have been reviewed, and the overall affective engineering process, which is used to apply affective aspects to products or services, has also been introduced. As is clear from the background explanation, human affect is an innate, basic, and instinctive psychological reaction. In this regard, developing and improving the affective aspects of products is meaningful in that the user's basic and latent desire is satisfied. Currently, affective evaluation derives evaluation data by asking participants of an experiment to consciously share their opinions about a specific affect. In addition, various statistical techniques are used to quantitatively analyze participants' opinions and produce statistical results.

The affective evaluation method, which has been considered in this chapter, provides a good statistical model and predictions. Nevertheless, there are still limitations concerning participants' erroneous ratings, inadequate evaluation methods, and the expandability of evaluation results. If those limitations are overcome, better performance and prediction models will be produced by affective evaluations. Accordingly, the current affective evaluation methodology needs to be improved and further analyzed to obtain a method that produces more accurate and deeper evaluation results.

Chapter 3. Affective Structure Extraction using Network Analysis for Web Data

3.1. Introduction

Doerfel (1998) defines semantic network analysis as "a study in which word associations in text are analyzed, and those word associations represent the meaning inherent to the data." Semantic network analysis involves the application of the concepts of social network analysis to a text (Carley, Columbus, & Azoulay, 2012; Tanenbaum & Brand, 2008). Social network analysis expresses interpersonal relationships in terms of nodes and links. Each individual included in analysis is represented by a "node" and all relationships that the individual has with others within the social network are connected with "links." Social network analysis can thus be defined as "a study of all the relationships that individuals have with others, expressed with the concepts of node and link." In semantic network analysis, each word is expressed as a node and the words in a sentence are considered to be interlinked, i.e., connected with links. "Individual" and "relationships among individuals" in social network analysis is replaced with "word" and "relationships among words" in semantic network analysis (Hoser, Hotho, Jäschke, Schmitz, & Stumme, 2006). In a semantic network analysis, only words with semantic content such as noun, adjective, and verb are assigned to nodes. In this study, semantic network analysis will be called as network analysis.

Network analysis implements network visualization by mapping a network consisting of words related to a specific topic and the relationships among these words. Centrality is then derived to measure the influence and importance of each word in the network. There are four centrality measures: degree centrality is measure of the number of the links directly connecting each node; closeness centrality is a measure of the distance to each node calculated as the inverse of the sum of the shortest distances between one node and other nodes; betweenness centrality is a measure of the number of the shortest paths that pass a given node; eigenvector centrality is a measure that reflects the centrality of an adjacent node (Wasserman & Faust, 1994; Borgatti, Everett, & Freeman, 2002; Freeman, 1978; Borgatti, Mehra, Brass, & Labianca, 2009). Additionally, word frequency can be obtained to check how often a given word has been mentioned with a data set. Researchers can draw specific conclusions related to their research subject by interpreting the meanings of the data derived through network analysis.

Network analysis can be applied to any topic insofar as there are a sufficient number of texts dealing with that topic. In this study, network analysis was performed using online review data on car instrument panels (IP). The analysis was carried out in the following order: collection of text data on the Internet; data structuring and preprocessing of the collected words, merging similar words into one representative word to reduce the number of the nodes; network analysis of the preprocessed words and network mapping; calculation of the values of the four centrality measures; and word frequency analysis. The analysis results were then subjected to expert review and discussion for the affective evaluation related to IP.

3.2. Data Structuring

To collect the targeted text data, a web crawler was used to obtain the imported car test drive reports from the website Motor Graph. The scope of data collection was limited to imported car test drive reports because imported cars generally receive higher cognitive and affective consumer review compared with domestic cars, and the affect intended to be analyzed is affect with higher emotional value. We collected only the test drive reports drafted by expert test drive reviewers, assuming that they would deliver high-quality data in terms of diversity of words and expressions at lexical and semantic levels. Of the 210 reports thus collected, 49 reports contained IP-related descriptions.

First, all sentences containing IP-related opinion or evaluation were extracted from these 49 reports. Although the total number of sentences exceeded 49, all IP-related sentences in each of the 49 reports were gathered together and reformulated as a single sentence so that network analysis could be performed on 49 one-sentence texts. Prior to analysis, these 49 texts were subjected to preprocessing for data structuring. First, each text was divided into meaningful units in accordance with the propositional theory (Anderson & Bower, 1974). The number of meaningful units mentioned at least once in any of the 49 texts was 117. Each of these 117 meaningful unit were defined as a word for convenience sake.

These 117 words were compared and similar words were clustered together. Similar words are recognized as different nodes on the network. If they are recognized as different meaning units and assigned to separate nodes, analysis is likely to yield distorted results and, consequently, low quality. In an attempt to prevent this type of error, we clustered all similar words, i.e., synonyms including derivatives and also antonyms if used for affective evaluation, together and replaced the cluster with a representative word. In this process, the number of the words was reduced from 117 to 23. These 23 words were labelled keywords. The words replaced with their respective keywords are listed in Table 3.1/Table 3.2.

Table 3.1. Keywords and their related words (part 1)

Keyword	Related words
Luxurious	Luxurious / deluxe / luxuriously / premium / high class / splendid / splendor / lavish / expensive / high end / scruffy / shabby / affordable / low-priced / cheap
Luster	High-luster / posh / shiny / lustrous / sparkling / chrome
Dashboard	Dashboard
Warm	Warmth
Finish	Finish / completion / completeness / perfectness / flawless / attention to details / process / processed / refined / roughly finished / meticulously / thoroughgoing / elaborately
Pattern	Pattern / style / regular / needlework
Smooth	Smooth / smoothness
Color	Color / tone / two-tone / reddish / red / orange / brown /bronze
Delicate	Elaborate / delicate / thorough / intricate
Refined	Refined / sophistication / elegantly / stylish
Center fascia	Center fascia / Center console
Material	Material / raw material / leather / leather material / carbon package / wood panel / wood trim / artificial leather / nappa leather / Alcantara / plastic / carbon fiber / wood grain / wooden
Visual	Visual / visible / for eyes / flashy / invisible / layout / curve / design / mark / wrinkly / embellished / stitch / sewing
Aesthetics	Beautiful / pretty / elegant
Neat	Neat / trim / simple

Table 3.2. Keywords and their related words (part 2)

Keyword	Related words
Harmonious	Harmonious / natural / spontaneous
Quality	Quality / high-quality / excellent / ordinary
Touch	Touch / grazing / stroking / at fingertips / hand contact / with hands on / brushing hand / touching the boy / tight
Classic	Classic
Comfortable	Comfortable / comfy / secure / relaxing / relaxed
Cozy	Cozy / restful
Surface	Surface
Elastic	Elastic

To characterize the 23 keywords according to their attributes, we set four categories: design elements, sense elements, evaluation parts, and affective elements. "Design elements" was defined as "physical evaluation elements that are taken into consideration at the design stage." Seven keywords were assigned to this category: material, finish, quality, color, luster, pattern, and surface. "Sense elements" was defined as "elements related to sense organs mobilized when experiencing a product." Two keywords were assigned to this category: visual and touch. "Evaluation parts" was defined as "parts corresponding to specific components of a product." Two keywords were assigned to this category: center fascia and dashboard. "Affective elements" was defined as "elements related to feelings and impressions that arise when experiencing a product." By definition, affective elements encompass words with both positive and negative emotional values. Twelve keywords were assigned to this category: luxurious, smooth, delicate, refined, comfortable, aesthetics, harmonious, neat, cozy, elastic, warm and classic. The definition of 4 categories and the selection of keywords belonging to each category was based on expert opinions. The keywords classified by category are listed in Table 3.3.

Table 3.3. List of the keywords by category

Category	Keyword
Design elements	Material / finish / quality / color / luster / pattern / surface
Sense elements	Visual / touch
Evaluation parts	Center fascia / dashboard
Affective elements	Luxurious / smooth / delicate / refined / comfortable / aesthetics / harmonious / neat / cozy / elastic / warm / classic

A keyword (including any word replaced by it) appearing more than once in a text was defined as a single appearance of the corresponding keyword irrespective of frequency. For example, if a text contains the words real leather, fabric, and synthetic leather, the text is marked as containing material-related words, without specifying the number of these words. A co-occurrence matrix was then generated using the keywords thus derived from each text. A co-occurrence matrix is a two-dimensional array of co-occurring keyword pairs representing the number of the texts containing a given keyword pair.

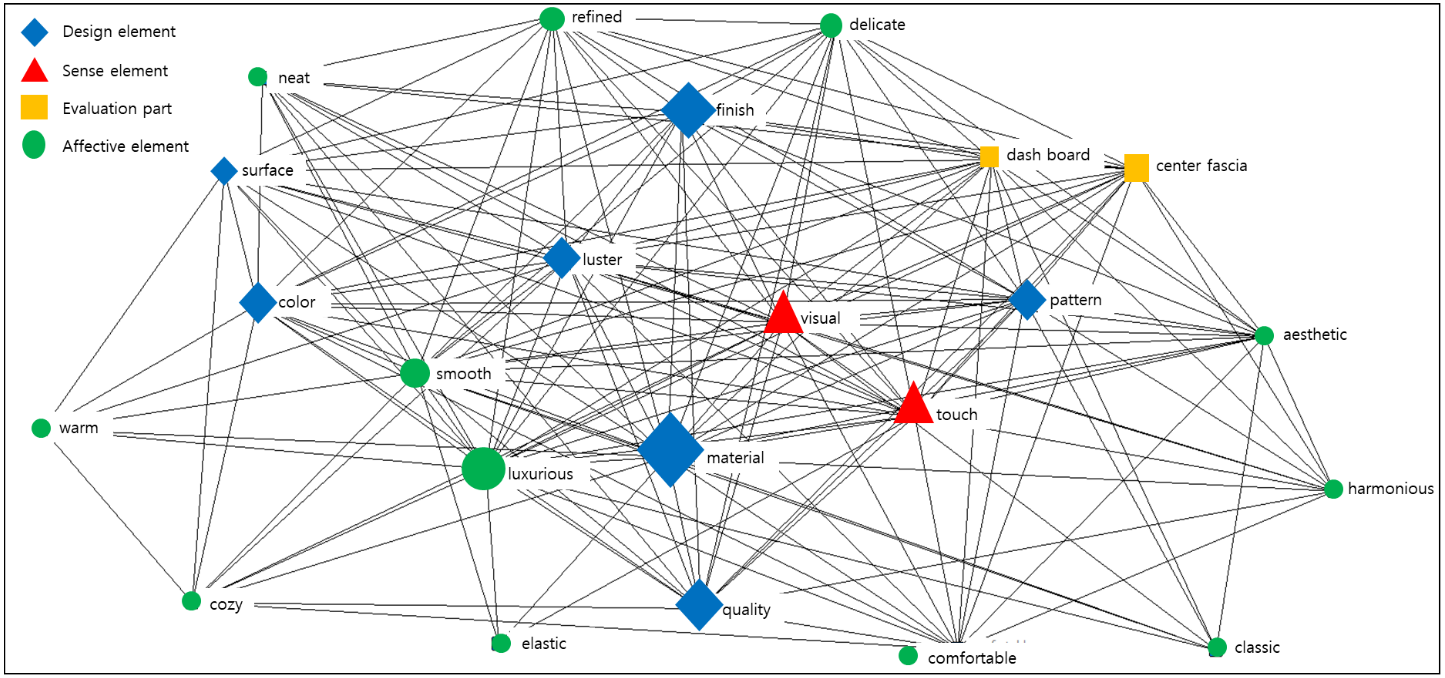


Figure 3.1. Network of keywords related with vehicle instrument panel

3.3. Results

Using the co-occurrence matrix for the 24 keywords that were generated by data structuring, we constructed a network analysis and calculated the values of the four centrality measures considered (degree centrality, closeness centrality, eigenvector centrality, and betweenness centrality), using UCINET 6.0 and Netdraw 2.0. Additionally, A frequency analysis was performed to check the frequency of occurrence of each keyword.

3.3.1. Network Formation and Frequency Analysis

The structured text dataset was used to construct a network visualizing the interrelatedness among the keywords (Figure 3.1). Keywords material, visual, luxurious, smooth, and finish are located at the center of the network.

Then the frequency of each keyword was analyzed to check the frequency of its occurrence in the texts (Figure 3.2). Of the 24 keywords, “material” occurred most frequently by being mentioned 39 times, i.e., in 39 out of 49 texts, followed by “visual” (28 times), “luxurious” (27 times), and “finish” (26 times). Including “touch” (14 times) and “quality” (11 times), six keywords were found to have been mentioned over ten times. Broken down by category, three keywords are design elements (material, finish, and quality), two keywords sense elements (visual and touch), and one affective element (luxurious).

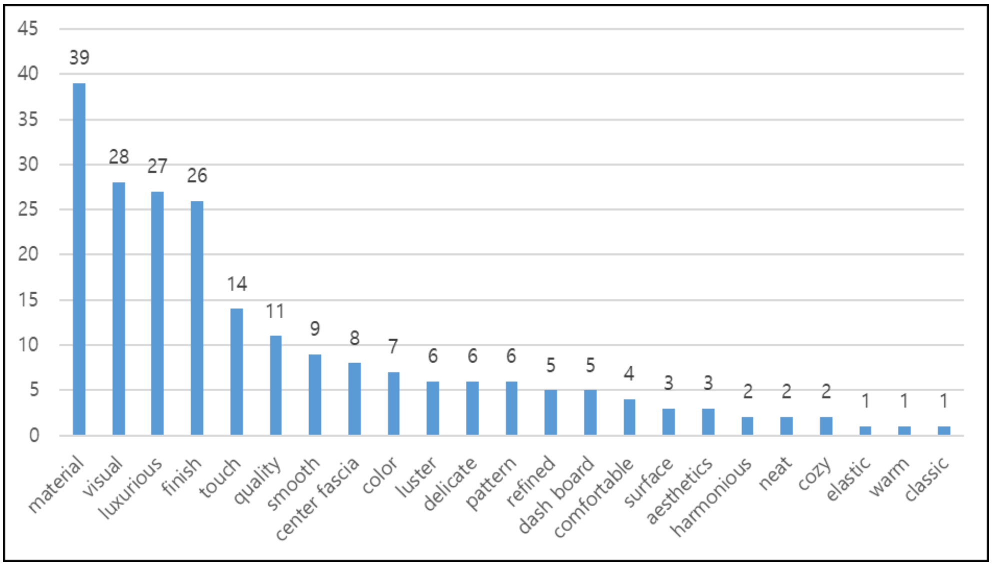


Figure 3.2. Frequency of keywords in the network

3.3.2. Centrality Value Analysis

For each keyword, the above-mentioned four centrality values were calculated (Table 3.4/Table 3.5). According to the definition of degree centrality, the keywords with the highest number of the direct connections with other keywords was "material" (normalized value = 6.091), which implies that most of the keywords are directly connected to "material" (Kim, 2016), followed by visual, luxurious, finish, and touch. Comparing the closeness centrality indicating the positional advantage as well, the keyword with the highest value was "material," which implies that "material" can be easily connected to other keywords in the network (Kim, 2016), followed by visual, luxurious, smooth, and luster.

Table 3.4. Normalized value of 4 centalities (part 1)

Keyword rank	Degree centrality	Keyword rank	Closeness centrality
material	6.091	material	1.000
visual	5.455	luxurious	0.957
luxurious	4.682	visual	0.917
finish	4.364	smooth	0.917
touch	2.773	luster	0.880
smooth	2.227	touch	0.880
quality	2.000	pattern	0.846
center fascia	1.909	color	0.815
pattern	1.773	dashboard	0.815
color	1.636	finish	0.786
dashboard	1.591	center fascia	0.786
luster	1.500	quality	0.759
delicate	1.364	delicate	0.733
refined	1.318	refined	0.733
comfortable	1.000	surface	0.733
surface	1.000	aesthetics	0.733
neat	0.955	comfortable	0.710
aesthetics	0.955	neat	0.667
harmonious	0.591	harmonious	0.647
cozy	0.545	cozy	0.647
warm	0.318	warm	0.595
classic	0.318	classic	0.595
elastic	0.182	elastic	0.550

Table 3.5. Normalized value of 4 centalities (part 2)

Keyword rank	Eigenvector centrality	Keyword rank	Betweenness centrality
material	0.482	material	0.064
visual	0.426	luxurious	0.054
finish	0.402	smooth	0.048
luxurious	0.401	touch	0.031
touch	0.232	visual	0.029
quality	0.183	luster	0.028
smooth	0.175	pattern	0.017
center fascia	0.167	color	0.017
pattern	0.133	dashboard	0.015
color	0.129	quality	0.011
delicate	0.124	center fascia	0.009
dashboard	0.119	surface	0.009
refined	0.116	aesthetics	0.008
luster	0.112	finish	0.006
neat	0.096	comfortable	0.006
surface	0.076	delicate	0.003
comfortable	0.069	refined	0.003
aesthetics	0.069	cozy	0.003
cozy	0.037	harmonious	0.001
harmonious	0.036	neat	0.001
classic	0.025	elastic	0.000
warm	0.019	warm	0.000
elastic	0.018	classic	0.000

The same trend was observed also in the betweenness centrality value indicating the mediator role of each keyword in the network, with “material” identified as the keyword with the highest value, which implies that “material” plays a crucial role in controlling the information flow in the network (Kim, 2016), followed by luxurious, smooth, visual, and touch. Likewise, “Material” showed the highest eigenvector centrality value, which is calculated taking into account the centrality measures of other linked keywords. This indicates that “material” is the most important keyword when the overall centralities of keywords are considered. Other keywords with high eigenvector centrality measures were—in decreasing order of value—visual, luxurious, finish, and touch.

3.4. Discussion

We established the IP-related affective structure based on the results obtained in 3.2 and 3.3 as follows: We first derived the characteristics of each keyword using the values of the four centrality measures and the four categories of keywords and then structured the relationships among the keywords based on the characteristics thus derived. The upper first quartile of the list (Table 3.4/Table 3.5) is defined as an important keyword. Based on the criterion, the top 5 keywords of each centrality were judged to be important keywords. The analysis of the four centrality values revealed material, visual, and luxurious as the three keywords belonging to the top 5 keywords in all four centralities.

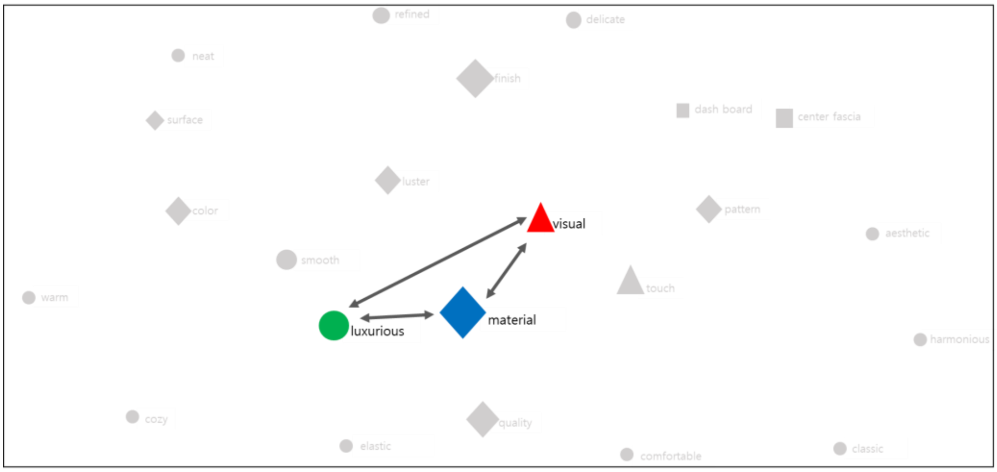


Figure 3.3. 3 core keywords in the network

We selected these three keywords as the "core keywords" in the network, with "material" being the keyword with the highest value in all four centralities.

This allowed the assumptions that material of the IP is the factor most frequently considered by the IP reviewers when writing a test drive report and that luxuriousness visually experienced is the main criterion for evaluation of the material (Figure 3.3). The keyword frequency analysis under the criterion of top 5 in at least one of the four centralities reveals finish, touch, smooth, and luster in addition to material, visual, and luxurious as the keywords meeting the criterion. We selected these seven keywords as the "major keywords" in the network.

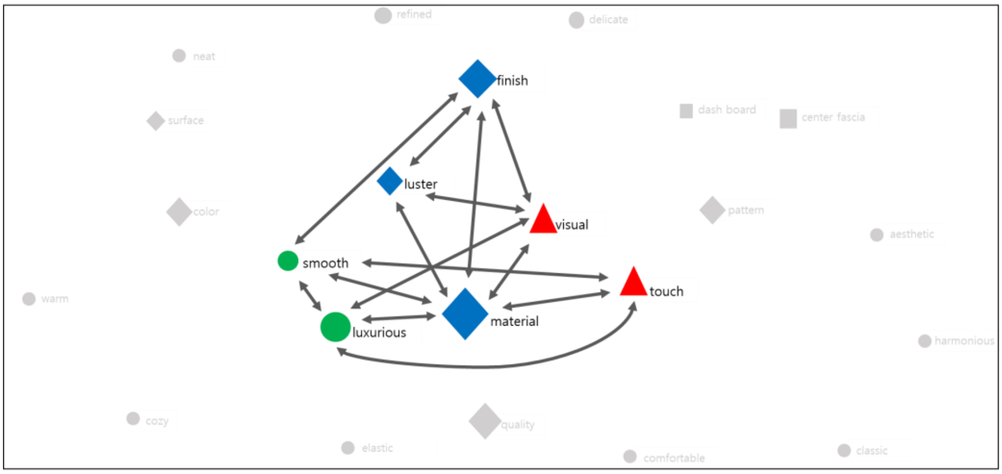


Figure 3.4. 7 major key words in the network

Breaking down the major keywords by category, three keywords are design elements (material, finish, and quality), two keywords sense elements (visual and touch), and two affective elements (luxurious and smooth). The three design keywords can be interpreted as follows: "material" is the keyword referring to the material covering the IP, which attracts the most attention when users review the IP; "luster" is a visual design element considered when reviewing the IP material under the visual aspect, "finish" is a design element related to IP completeness. Taking these three major design elements together, it can be inferred that IP material and production finish are important evaluation criteria and luster is a determinant design factor. From the two major affective keywords "luxurious" and "smooth," it can be inferred that reviewers examine, above all, whether the IP is felt luxurious or not and that the smoothness of the material is a determinant factor for luxuriousness (Figure 3.4).

In the following, the characteristics of the remaining 17 keywords and their positions in the network are discussed. From the evaluation part-related keywords "center fascia" and "dashboard," it can be inferred that users generally evaluate the IP with focus on these two parts. Looking more closely at the non-major design keywords quality, color, pattern, and surface (those remaining after excluding the three major design keywords material, luster, and finish), "color," "pattern," and "surface" are design keywords related to the IP material. Along with "luster," they can be regarded as important factors to be taken into consideration at the design stage. "Quality," which was frequently mentioned in the reviewers' reports (11 times in the 47 texts analyzed), is the keyword that represents the product quality closely associated with user satisfaction in terms of IP material and completeness. In conjunction with the keyword "luxurious," the keyword "quality" allows the interpretation that luxuriousness acts as a yardstick for evaluating the product quality (Figure 3.5).

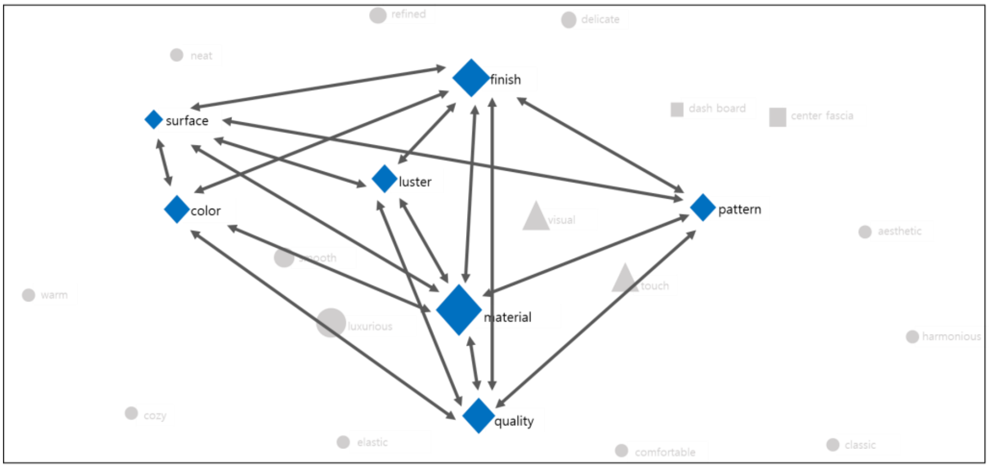


Figure 3.5. Relations among design elements

The 11 affective keywords remaining after excluding the major affective keywords "luxurious" and "smooth" have low occurrence frequencies, building the lower frequency keyword group in the frequency analysis. That is, these keywords are not generally mentioned, but appear only in specific texts. This suggests that they are used for expressing the thoughts of specific user groups rather than representing generally employed affective elements. Therefore, these affective elements cannot be regarded as generally applicable IP-related affective elements; they can remain a candidate group, though. It depends on further in-depth discussion via literature review and expert interviews whether each of these 11 affective elements can be added as an affect constituting the IP-related affective structure (Figure3.5).

The network analysis yielded the finding that the affective elements generally mentioned in review texts are "luxurious" and "smooth." These two affective elements are assumed to be associated with the affects applicable to IP affective evaluation. Accordingly, luxuriousness and smoothness can be regarded as the major candidate group targeted for affective evaluation. Luxuriousness is a complex and abstract affect, whereas smoothness is a relatively simple and clear affect that can be experienced by touching. From this, smoothness is one of the affects that play their respective roles in constituting luxuriousness.

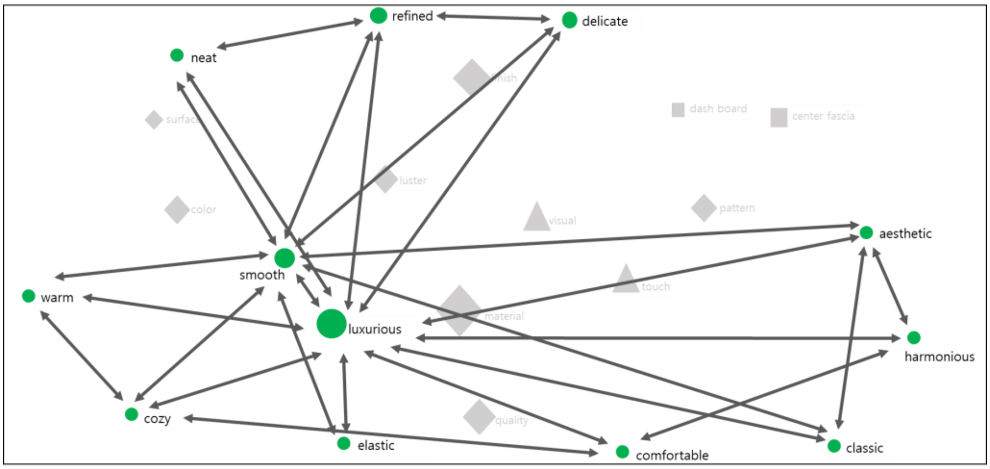


Figure 3.6. Relations among affective elements

Additionally, the design elements color, pattern, surface, and luster may be associated with of affective sub-elements of the luxuriousness of the IP material, given that evaluation takes place through physical interactions. As mentioned above, the 11 low frequency affective elements can become one of the latent affective elements constituting luxuriousness. This cannot be determined only by the results of a network analysis, but through additional discussion and research. To conclude, luxuriousness can be selected as the target affect to be verified through the affective evaluation. Along with design elements, smoothness can be selected as a sub-affect constituting the target affect. Additionally, the 11 non-major (low-frequency) affective elements may be treated as a candidate group of affective sub-elements latently constituting the target affect (Figure 3.6).

Table 3.1 shows that many of the words in the word cluster represented by the keyword “material” are related to leather and wood. This suggests that users (drivers) are interested in the IP product material. When this is coupled with the target affect “luxuriousness,” concrete considerations about luxurious materials preferred by drivers may be made. In the leather industry, consumers tend to perceive products made out of real leather as costly premium products and those made out of synthetic leather as low-cost consumer product (Park, 2017). This suggest that the quality perception widespread across the leather industry is applicable to the leather material used for the IP. That is, if users have a tactile sensation of real leather, the IP will arouse a more intensive affect of luxuriousness in them. For this reason, “natural tactility” needs to be selected as a target affect equivalent to “luxuriousness.”

Chapter 4. Evaluating the Validity of Affective Words

4.1. Introduction

One of the basic and important steps of the affective evaluation process is using a product and rating affects expressed by affective words. Accordingly, the result of an affective evaluation depends greatly on the selection of suitable affective words. Affective words are conventionally selected in the following way. First, a pool of affective words is made. Affective words, which are selected by similar studies and used in various relevant documents, are surveyed to organize such a pool. Once a pool of affective words is completed, words with the same meanings are deleted, and other words with similar meanings are pinned down to representative words. From the words thus filtered, seemingly suitable ones are picked up again. Finally, synonymy and antonymy of the words thus selected are surveyed to organize pairs of words and then finally determine a group of affective words, which is to be used in the study (Kim, Ko, Rhiu, & Yun, 2019; Schütte* et al., 2004). As mentioned in Chapter 3, affective words related to a leather instrument panel for car were also selected by the above process. This method of selecting affective words displays an excessive involvement of a researcher's subjectivity. Moreover, the effective application of selected affective words to evaluation is also estimated based on a researcher's subjective judgment.

The goal of this experiment is to see whether the selected affective words are appropriate for the affective evaluation through a quantitative analysis. A statistical method was applied to the process of selecting affective words, which tended to be much affected by a researcher's subjectivity. In this way, the improvement of objectivity was intended to judge the adequacy of the affective words for the affective evaluation. To do this, criteria for defining appropriate affective words were set up, and a statistical technique was used to see whether each affective word satisfied the definition. Two criteria for defining which affective words are suitable for affective evaluation were selected. The first one was the understanding of affective words. This was defined as "the degree to which a participant of an experiment understands an affective word". The second one was the distinctness of samples. As the degrees to which an affect is felt for each sample become more diverse, the affective evaluation can produce more reliable results. Accordingly, an affect needs to be felt to sufficiently different degrees for each sample in order to obtain a better evaluation result. The distinctness of samples was defined as "the difference of ratings given by participants to a certain affective word for each sample in an experiment".

4.2. Method

This experiment used six car instrument panel samples, which had the same shape but were wrapped in different leather materials. Total 24 participants took part in the experiment. There were 17 male and 7 female participants, whose mean age was 27.1 years. All 24 participants were regular consumer who were not expertise in vehicle interior. A counterbalanced measures design was applied to the presenting order of samples in order to prevent an order effect. The questionnaire was organized to evaluate 20 affective words by the semantic differential method. Details of the experiment method such as the experimental setup and the information about samples and affective words are explained at full length in separate lists below.

4.2.1. Selection of Samples and Affective Words

In this study, six samples of different types of leather instrument panel (IP) for car were used in the experiment. The six types of IP samples had the same shape but were wrapped in different leather materials. The six leather materials were selected because they seemed to be easily distinguished both visually and tactually. Design variables of each sample were used as supplementary data for selecting the samples. One sample had natural leather and the other five samples used artificial leather. Figure 4.1 shows the shape of the instrument panel. Figure 4.2 and Table 4.1/Table 4.2 present the photos of leather surfaces and the values of design variables, respectively, for each sample.

Figure 4.1. The shape of vehicle instrument panel

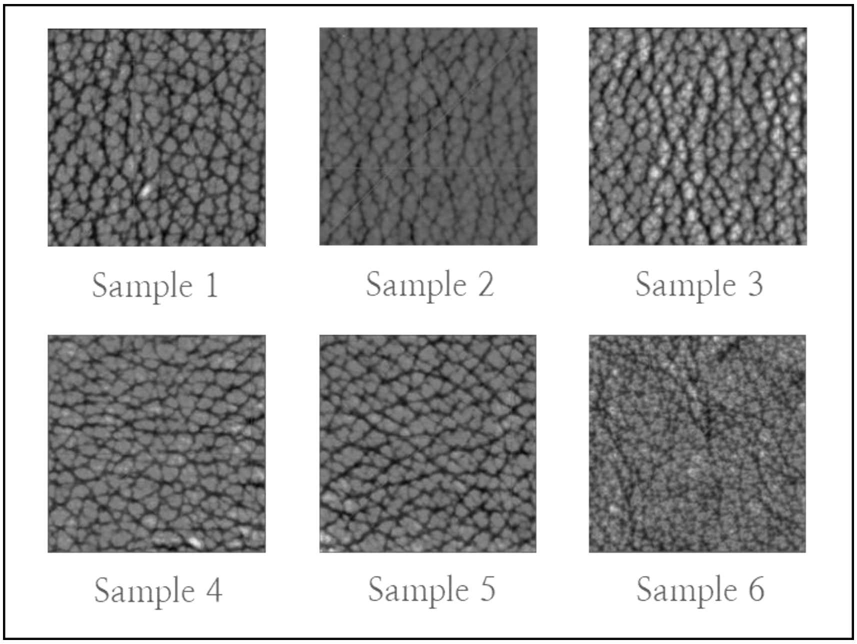


Figure 4.2. The appearance of leather surface by sample

Table 4.1. The values of design parameters by sample (part 1)

Sample No.	Gray scale	Gloss	Ra (μm)	Thermal conductivity (W/mK)	WVTR (g/m^2day)
1	3.187	1.1	18.086	0.123	629
2	3.14	1.2	15.495	0.119	617
3	3.18	1.1	21.073	0.122	553
4	3.14	1.1	16.966	0.123	640
5	4.867	1.2	16.155	0.131	716
6	4.817	0.6	15.178	0.122	1150

Table 4.2. The values of design parameters by sample (part 2)

Sample No.	Static friction coefficient	Squeak	Softness (mm)	Young´s Modulus (kgf/cm^2)	Artificial/ Natural
1	0.355	0.075	3.7	470.573	Artificial
2	0.374	0.068	3.9	314.744	Artificial
3	0.326	0.055	4.1	161.414	Artificial
4	0.382	0.052	4.1	125.126	Artificial
5	0.493	0.043	3.9	298.331	Artificial
6	0.457	0.388	4.57	203.507	Natural

A total of 20 pairs of affective words were selected for the experiment through the above-mentioned process (Table 4.3). As each pair consisted of opposite words, the participants of the experiment could understand each affect more easily. Each pair of words was regarded as a single affective word. The affective words thus selected were expressions of feelings obtained by seeing or touching leather surfaces. 20 affective words are as follows: Bright colored – Dark colored, Looking warm – Looking cool, Polished – Not polished, Warm – Cool, Sticky – Not sticky, Moist – Dry, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Large deformation in embossed edge – Small deformation in embossed edge, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material, Natural seams – Unnatural seams. The definitions of each affective word are presented in Table 4.3.

Table 4.3. List of affective words and related parts

Evaluated part	Evaluation words
Overall surface	Bright colored – Dark colored
	Looking warm – Looking cool
	Polished – Not polished
	Warm – Cool
	Sticky – Not sticky
	Moist – Dry
	Slick – Not slick
	Rough – Smooth
	Rugged – Even
	Elastic – Inelastic
	Soft – Solid
	Stuffed – Hollow
	Wide spacing of embossed area – Narrow spacing of embossed area
	Large embossing – Small embossing
	Regular embossing pattern – Irregular embossing pattern
	Deep embossing – Shallow embossing
Edge	Large deformation in embossed edge – Small deformation in embossed edge
Bent	Bent with many wrinkles – Bent with only a few wrinkles
Stitch line	Stitch line matching well with material – Stitch line matching poor with material
Seam	Natural seams – unnatural seams

4.2.2. Evaluation Environment

Samples were evaluated on a stand with a front height 640 mm, rear height 865 mm, side width 510 mm, and angle 25°. The stand was concealed by a dark colored cover so that the effects of light emitted and the color of the stand were avoided. The seat for the participants was placed 890 mm from the right side of the stand so that it was in the same position as when they sat in the driver's seat in a car. The height of the seat was 430 mm, and the height of the sample putting on the stand was 960 mm. Thus the relative height of the seat and sample was 530 mm.

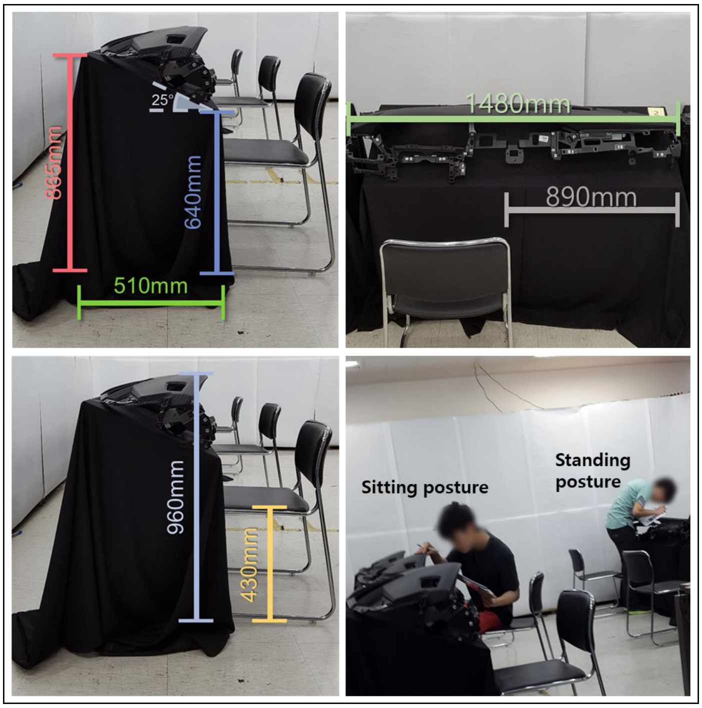


Figure 4.3. Information on the evaluation environment

When the participants were evaluating the samples, participants were instructed to evaluate the samples in two poses: sitting position and standing position. The evaluation in the sitting position assumes that the participant is seated in the driver's seat. In this posture, the participant could move the chair back and forth when evaluating. When evaluating the samples in standing position, participants could only evaluate them from the front side not rear side. Nine LED lamps were used to provide maximum brightness for the place where the evaluation is proceeded. The LED lamps are five times brighter than the same number of regular fluorescent lamps. By using the LED lamps, the evaluation place could achieve a brightness of 1000 lux. The samples were located 640mm above the ground. The location was suitable for both sitting position and standing position. Information on the evaluation environment described so far is summarized in Figure 4.3.

4.2.3. Questionnaire

The questionnaire was organized to evaluate 20 affective words by the semantic differential method. Each participant was asked to fill in age and gender. Apart from the questions for evaluating affective words, there were two additional questions about the understanding of each affective word and the distinctness of samples. These two questions aimed to identify each participant’s understanding of each affective word and the difference in the degrees to which each affect was felt for each sample. Appendix A provides the questionnaire form based on the semantic differential method and the questions asking the understanding of affective words and the distinctness of samples.

4.2.4. Analysis Method

A few statistical analysis methods were applied to examine the validity of affective words. First, the one-sample test was conducted to see statistical significance between reference scores and scores obtained by evaluation. As 24 participants took part in the experiment, the quantity of responses was not sufficient and the scores of the responses did not show any regularity. For this reason, the Wilcoxon signed-rank test, which is a non-parametric statistical method, was adopted. Coefficients of variation (CV) were calculated to identify the degrees of homogeneity or variability among evaluation scores. Participants' understanding of affective words and the distinctness of samples were judged based on those CV values. ANOVA was used to see whether the mean values among samples were significantly different. Since the number of responses was not sufficient and the analysis result did not show any regularity, the Kruskal-Wallis test was used, which is a non-parametric independent k-sample testing method.

4.3. Results

Based on the experiment results, various analyses were conducted to see whether the affective words were valid enough to be used in practice. Various statistical methods were utilized to analyze how well the participants understood each affective word (Understanding of affective words) and how differently each affect was felt for each sample (Distinctness of samples).

4.3.1. Analysis Results of the Understanding of Affective Words

4.3.1.1. Analysis of Questionnaire Scores for the Understanding of Subjective Affective Words

For the analysis, the survey results were utilized which indicated each participant's understanding of the meaning of each affective word. In case a survey result was significantly above 4, the participant was considered to have a sufficient understanding of the affective word. Otherwise, that is, in case the result was significantly below 4, the participant was considered to have a poor understanding of the affective word. When a result did not have statistical significance, the participant's understanding of the affective word could not be clearly identified but was not regarded as deep enough. The non-parametric one sample test (Wilcoxon signed-rank test) was used for the analysis.

The analysis result showed that participants of the experiment had a sufficiently significant understanding of the following 11 words: Bright colored – Dark colored, Looking warm – Looking cool, Polished – Not polished, Sticky – Not sticky, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, Soft – Solid, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material ($p<.05$). Table 4.4 presents the analysis result for the understanding of each affective word.

Table 4.4. Analysis result for the understanding of each affective word

Evaluation words	Mean value	Observed median	Significance level
Bright colored	5.222**	6	.000
Looking warm	4.556**	5	.005
Polished	5.056**	5	.000
Warm	3.806	3.5	.371
Sticky	4.847**	5	.000
Moist	4.264	4	.215
Slick	5.139**	5	.000
Rough	5.181**	5	.000
Rugged	4.736**	5	.000
Elastic	4.917**	5	.000
Soft	5.444**	6	.000
Stuffed	4.014	4	.940
Wide spacing of embossed area	3.847	4	.500
Large embossing	4.417	5	.072
Regular embossing pattern	3.778	4	.261
Deep embossing	4.028	4	.983
Large deformation in embossed edge	4.083	4	.682
Bent with many wrinkles	4.500*	4.5	.012
Stitch line matching well with material	4.472*	5	.037
Natural seams	4	4	.846

* $p<.05$, ** $p<.01$

4.3.1.2. Analysis of Coefficient of Variation for Affective Word Scores for Each Sample

The second method of analyzing the understanding of affective words was calculating the coefficient of variation (CV) for each sample. CV is calculated by dividing the standard deviation of a particular group by the arithmetic mean of that group (Everitt, 1995). CV is also referred to as relative standard deviation (RSD). In case there are two or more groups with different means, RSD is a standardized dispersion reflecting the relative homogeneity of each group. CV values range between 0 and 1. If a CV value approaches 0, the values of a group have less variability. On the other hand, if a CV value comes closer to 1, the variability is interpreted to be larger (Rosner, 2015). Generally, in case CV is below 0.2, the variability is so small that the values of a group can be considered as stable. In case CV ranges between 0.2 and 0.3, the values can be analyzed to be largely stable. Finally, in case of CV exceeding 0.3, the values of a group are so variable as to be unstable (Rosner, 2015).

In this analysis, it was assumed that as the CV value decreases, participants' evaluations would be more consistent. In other words, if a certain affective word is deeply understood, participants are expected to rate a certain sample similarly. CV values of each affective word were identified under this assumption. Since CV values were derived for each of six samples in each affective word, six CV values could be obtained for each affective word. Following a reference (Rosner, 2015), when a CV value was below 0.3, the participants were regarded to have a relatively deep understanding of the affective word. When a CV was 0.3 or above, the participants were regarded to have a relatively poor understanding of the affective word.

The numbers of CV values, which were below 0.3 and 0.3 or above respectively, were counted to quantify the understanding of each word. The number of samples with CV below 0.3 was 1 or below in 13 out of 20 affective words. This result indicated that, if 0.3 was adopted as the reference, no significant result could be produced in this experiment. Accordingly, as this experiment depended on participants' subjectivity and thus were more variable than natural science experiments, the reference value was eased to 0.35 for analysis.

The analysis result, which was obtained by applying the reference CV value of 0.35 for the understanding of affective words, is as follows. For 'Bright colored – Dark colored', 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above. For 'Looking warm – Looking cool', 1 sample showed a CV value of below 0.35 and 5 samples had CV values of 0.35 or above. For 'Polished – Not polished', all 6 samples had CV values of 0.35 or above. For 'Warm - Cool', 3 samples showed CV values of below 0.35 and the remaining 3 samples had CV values of 0.35 or above. For 'Sticky – Not sticky', all 6 samples had CV values of 0.35 or above. For 'Moist - Dry', 3 samples showed CV values of below 0.35 and the remaining 3 samples had CV values of 0.35 or above. For 'Slick – Not slick', 2 samples showed CV values of below 0.35 and 4 samples had CV values of 0.35 or above. For 'Rough – Smooth', 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above.

For 'Rugged – Even', 3 samples showed CV values of below 0.35 and the remaining 3 samples had CV values of 0.35 or above. For 'Elastic – Inelastic', 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above. For 'Soft – Solid', 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above. For 'Stuffed – Hollow', 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above. For 'Wrinkled – Not wrinkled', all 6 samples had CV values of 0.35

or above.

For ‘Wide spacing of embossed area – Narrow spacing of embossed area’, 2 samples showed CV values of below 0.35 and 4 samples had CV values of 0.35 or above. For ‘Large embossing – Small embossing’, 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above. For ‘Regular embossing pattern – Irregular embossing pattern’, all 6 samples had CV values of 0.35 or above. For ‘Deep embossing – Shallow embossing’, 2 samples showed CV values of below 0.35 and 4 samples had CV values of 0.35 or above. For ‘Large deformation in embossed edge – Small deformation in embossed edge’, all 6 samples had CV values of 0.35 or above. For ‘Bent with many wrinkles – Bent with only a few wrinkles’, 1 sample showed CV values of below 0.35 and 5 samples had CV values of 0.35 or above.

For ‘Stitch line matching well with material – Stitch line matching poor with material’, 5 samples showed CV values of below 0.35 and 1 sample had CV values of 0.35 or above. Finally, for ‘Natural seams – unnatural seams’, 4 samples showed CV values of below 0.35 and 2 samples had CV values of 0.35 or above (Table 4.4). In the case of 10 affective words, less than 3 samples showed CV values of less than 0.35. Among those words, 5 words had no sample with a CV value of less than 0.35. 2 words had one sample and the remaining 3 words had 2 samples with CV values of less than 0.35. Table 4.5/Table 4.6 present the coefficients of variation for each affective word and each sample and the number of samples satisfying the CV reference value for each affective word.

Table 4.5. Analysis result for the coefficient of variation of affective word scores for each sample (part 1)

Sample No.		Bright colored	Looking warm	Polished	Warm	Sticky	Moist	Slick	Rough	Rugged	Elastic
1	Mean	4.750	3.750	4.000	3.333	3.958	4.083	3.583	4.333	4.375	4.500
	Std.	1.3910	1.5673	1.5604	1.2740	1.7315	1.6129	1.3160	1.0495	1.4390	1.3513
	CV	0.2928	0.4180	0.3901	0.3822	0.4374	0.3950	0.3673	0.2422	0.3289	0.3003
2	Mean	2.833	4.083	4.000	4.000	3.375	4.083	4.167	3.458	3.750	4.792
	Std.	1.1293	1.3486	1.5036	1.1795	1.3453	1.3486	1.5788	1.1788	1.3910	1.5874
	CV	0.3986	0.3303	0.3759	0.2949	0.3986	0.3303	0.3789	0.3408	0.3709	0.3313
3	Mean	3.292	3.667	2.917	4.208	3.542	2.875	4.542	3.292	2.417	3.333
	Std.	2.0743	1.3406	1.7425	1.5030	1.3181	1.4836	2.0637	2.0951	1.6918	1.7856
	CV	0.6302	0.3656	0.5974	0.3572	0.3722	0.5160	0.4544	0.6365	0.7001	0.5357
4	Mean	4.750	3.542	4.083	4.125	3.958	4.417	4.125	3.708	3.875	4.875
	Std.	1.2597	1.3181	1.5857	1.3290	1.3981	1.2129	1.3613	1.3981	1.4836	1.5126
	CV	0.2652	0.3722	0.3883	0.3222	0.3532	0.2746	0.3300	0.3770	0.3829	0.3103
5	Mean	5.000	3.292	3.750	3.792	3.458	3.667	3.708	4.167	4.042	5.125
	Std.	1.2511	1.5174	1.6746	1.2151	1.2504	1.2039	1.2329	1.2740	1.1971	1.2959
	CV	0.2502	0.4610	0.4466	0.3205	0.3616	0.3283	0.3325	0.3058	0.2962	0.2529
6	Mean	4.917	3.542	4.000	4.250	3.542	3.875	3.958	3.875	4.083	4.250
	Std.	1.2825	1.6413	1.5880	1.5393	1.2504	1.4238	1.5458	1.1539	1.1389	1.5948
	CV	0.2609	0.4634	0.3970	0.3622	0.3530	0.3674	0.3905	0.2978	0.2789	0.3753
The number of CV < 0.35		4	1	0	3	0	3	2	4	3	4
The number of CV ≥ 0.35		2	5	6	3	6	3	4	2	3	2

* *p*<.05, ** *p*<.01

Table 4.6. Analysis result for the coefficient of variation of affective word scores for each sample (part 2)

Sample No.		Soft	Stuffed	Wide spacing of embossed area	Large embossing	Regular embossing pattern	Deep embossing	Large deformation in embossed edge	Bent with many wrinkles	Stitch line matching well with	Natural seams
1	Mean	4.458	4.333	4.000	4.250	3.208	4.125	3.333	2.875	5.333	4.875
	Std.	1.6934	1.6330	1.5604	1.2597	1.7932	1.3290	1.9035	1.3613	1.2394	1.4238
	CV	0.3798	0.3768	0.3901	0.2964	0.5589	0.3222	0.5710	0.4735	0.2324	0.2921
2	Mean	4.750	4.625	4.000	4.083	3.542	3.792	3.208	3.083	4.750	4.375
	Std.	1.6485	1.4084	1.0632	1.1765	1.7440	1.1788	1.5317	1.6396	1.3270	1.5551
	CV	0.3470	0.3045	0.2658	0.2881	0.4924	0.3109	0.4774	0.5318	0.2794	0.3555
3	Mean	5.292	3.625	1.750	1.208	5.208	1.542	2.500	3.208	3.417	3.542
	Std.	1.4885	1.5829	1.4818	.6580	2.2838	1.0624	1.8178	1.6934	1.9318	1.5874
	CV	0.2813	0.4367	0.8467	0.5446	0.4385	0.6891	0.7271	0.5278	0.5654	0.4482
4	Mean	4.417	4.875	3.833	3.958	3.375	3.458	3.583	4.250	4.917	5.000
	Std.	1.3805	1.0347	1.2394	1.3667	1.8133	1.4136	1.6129	1.6219	1.4421	1.4142
	CV	0.3126	0.2123	0.3233	0.3453	0.5373	0.4087	0.4501	0.3816	0.2933	0.2828
5	Mean	2.750	5.000	3.625	3.500	2.958	3.208	3.792	4.167	4.958	4.250
	Std.	1.2938	1.2158	1.3453	1.3188	1.4885	1.4440	1.8411	1.8572	1.3981	1.3910
	CV	0.4705	0.2432	0.3711	0.3768	0.5031	0.4501	0.4856	0.4457	0.2820	0.3273
6	Mean	4.917	4.375	3.250	3.750	3.500	3.375	3.292	4.500	5.542	5.208
	Std.	1.2482	1.4390	1.2597	1.0321	1.3831	1.3453	1.5737	1.4446	1.1025	1.4440
	CV	0.2539	0.3289	0.3876	0.2752	0.3952	0.3986	0.4781	0.3210	0.1990	0.2772
The number of CV < 0.35		4	4	2	4	0	2	0	1	5	4
The number of CV ≥ 0.35		2	2	4	2	6	4	6	5	1	2

* p<.05, ** p<.01

4.3.2. Analysis Result of the Distinctness of Samples

4.3.2.1. Analysis of Survey Scores Concerning Subjective Distinctness of Samples

A survey was performed in which the participants of the experiment were asked to show how well they could distinguish each sample. The survey result was analyzed as follows. In case a score was significantly above 4, the distinctness of samples for an affective word was regarded as sufficiently high. On the other hand, in case a score was significantly was below 4, the distinctness was regarded as low. When a result did not have statistical significance, the distinctness of the affective word could not be clearly identified but was not regarded as high enough. The non-parametric one sample test (Wilcoxon signed-rank test) was used for the analysis.

The analysis result showed that the participants could significantly distinguish samples for the following 9 words: Warm – Cool, Moist – Dry, Slick – Not Slick, Rough – Smooth, Elastic – Inelastic, Soft – Solid, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern ($p<.05$). Among these words, the result was significantly above the reference value of 4 in the following 5 words: Moist – Dry, Slick – Not Slick, Rough – Smooth, Elastic – Inelastic and Soft – Solid. In the remaining 4 words, the result was significantly below 4. Table 4.7 presents the analysis result for the distinctness of samples for each affective word.

Table 4.7. Analysis result for the subjective distinctness among samples

Evaluation words	Mean value	Observed median	Significance level
Bright colored	3.944	4	.783
Looking warm	3.653	3	.089
Polished	3.958	4	.829
Warm	3.222**	3	.000
Sticky	4.083	4	.656
Moist	4.389*	4	.024
Slick	4.542**	5	.002
Rough	4.750**	5	.000
Rugged	4.264	4	.128
Elastic	4.472**	5	.009
Soft	5.000**	5	.000
Stuffed	3.778	4	.175
Wide spacing of embossed area	3.014**	3	.000
Large embossing	3.458*	3	.010
Regular embossing pattern	3.153**	3	.000
Deep embossing	3.667	4	.083
Large deformation in embossed edge	3.625	3	.079
Bent with many wrinkles	3.889	4	.576
Stitch line matching well with material	3.875	4	.610
Natural seams	3.764	4	.288

* $p<.05$,   ** $p<.01$

4.3.2.2. Comparative Analysis of the Coefficients of Variation of the Mean Values of Affective Word Scores for Each Sample

As mentioned above, the coefficient of variation (CV) is calculated by dividing the standard deviation of a particular group by the arithmetic mean of that group. If a CV is small, the values of a group have a small variability. On the other hand, if a CV is large, the values of a group have a large variability (Rosner, 2015). In this analysis, the variability of mean values of evaluation scores for each of 6 samples was identified in order to examine the distinctness of samples. If the difference in the mean values of samples for an affective word is large, the participants can be considered to have distinguished the samples for the word proficiently. In other words, the larger the CV value the more distinctive the samples for an affective word. Table 4.8/Table 4.9 present mean values of each sample and CV values of each affective word.

Table 4.8. List of mean values of each sample and CV values of each affective word (part 1)

Sample No.		Bright colored	Looking warm	Polished	Warm	Sticky	Moist	Slick	Rough	Rugged	Elastic
1	Mean	4.750	3.750	4.000	3.333	3.958	4.083	3.583	4.333	4.375	4.500
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.3910	1.5673	1.5604	1.2740	1.7315	1.6129	1.3160	1.0495	1.4390	1.3513
2	Mean	2.833	4.083	4.000	4.000	3.375	4.083	4.167	3.458	3.750	4.792
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.1293	1.3486	1.5036	1.1795	1.3453	1.3486	1.5788	1.1788	1.3910	1.5874
3	Mean	3.292	3.667	2.917	4.208	3.542	2.875	4.542	3.292	2.417	3.333
	N	24	24	24	24	24	24	24	24	24	24
	Std.	2.0743	1.3406	1.7425	1.5030	1.3181	1.4836	2.0637	2.0951	1.6918	1.7856
4	Mean	4.750	3.542	4.083	4.125	3.958	4.417	4.125	3.708	3.875	4.875
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.2597	1.3181	1.5857	1.3290	1.3981	1.2129	1.3613	1.3981	1.4836	1.5126
5	Mean	5.000	3.292	3.750	3.792	3.458	3.667	3.708	4.167	4.042	5.125
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.2511	1.5174	1.6746	1.2151	1.2504	1.2039	1.2329	1.2740	1.1971	1.2959
6	Mean	4.917	3.542	4.000	4.250	3.542	3.875	3.958	3.875	4.083	4.250
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.2825	1.6413	1.5880	1.5393	1.2504	1.4238	1.5458	1.1539	1.1389	1.5948
CV of means		0.2212	0.0726	0.1169	0.0873	0.0701	0.1387	0.0860	0.1056	0.1836	0.1425

Table 4.9. List of mean values of each sample and CV values of each affective word (part 2)

Sample No.		Soft	Stuffed	Wide spacing of embossed area	Large embossing	Regular embossing pattern	Deep embossing	Large deformation in embossed edge	Bent with many wrinkles	Stitch line matching well with	Natural seams
1	Mean	4.458	4.333	4.000	4.250	3.208	4.125	3.333	2.875	5.333	4.875
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.6934	1.6330	1.5604	1.2597	1.7932	1.3290	1.9035	1.3613	1.2394	1.4238
2	Mean	4.750	4.625	4.000	4.083	3.542	3.792	3.208	3.083	4.750	4.375
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.6485	1.4084	1.0632	1.1765	1.7440	1.1788	1.5317	1.6396	1.3270	1.5551
3	Mean	5.292	3.625	1.750	1.208	5.208	1.542	2.500	3.208	3.417	3.542
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.4885	1.5829	1.4818	.6580	2.2838	1.0624	1.8178	1.6934	1.9318	1.5874
4	Mean	4.417	4.875	3.833	3.958	3.375	3.458	3.583	4.250	4.917	5.000
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.3805	1.0347	1.2394	1.3667	1.8133	1.4136	1.6129	1.6219	1.4421	1.4142
5	Mean	2.750	5.000	3.625	3.500	2.958	3.208	3.792	4.167	4.958	4.250
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.2938	1.2158	1.3453	1.3188	1.4885	1.4440	1.8411	1.8572	1.3981	1.3910
6	Mean	4.917	4.375	3.250	3.750	3.500	3.375	3.292	4.500	5.542	5.208
	N	24	24	24	24	24	24	24	24	24	24
	Std.	1.2482	1.4390	1.2597	1.0321	1.3831	1.3453	1.5737	1.4446	1.1025	1.4440
CV of means		0.1995	0.1100	0.2524	0.3276	0.2206	0.2765	0.1341	0.1906	0.1549	0.1350

CV values for the mean values of samples were calculated for 20 affective words. It turned out that CV values were below 0.3 in 19 out of 20 words. In other words, if CV values are analyzed for each word by applying the conventionally recognized criterion (Rosner, 2015), samples were not significantly distinguished by participants in 19 out of 20 words. This indicated that the analysis was meaningless. Accordingly, the affective words were ranked in descending order in terms of CV value as follows: 'Large embossing – Small embossing' took the first place, followed by 'Deep embossing – Shallow embossing' and 'Wide spacing of embossed area - Narrow spacing of embossed area'. On the other hand, 'Sticky – Not sticky' was ranked lowest, followed by 'Looking warm – Looking cool' and 'Slick – Not slick'. Table 4.10 presents the ranking result obtained by CV values.

Table 4.10. Ranking result obtained by CV values of affective words

Rank	Evaluation words	CV values between mean value of sample
1	Bright colored	0.3276
2	Looking warm	0.2765
3	Polished	0.2524
4	Warm	0.2212
5	Sticky	0.2206
6	Moist	0.1995
7	Slick	0.1906
8	Rough	0.1836
9	Rugged	0.1549
10	Elastic	0.1425
11	Soft	0.1387
12	Stuffed	0.1350
13	Wide spacing of embossed area	0.1341
14	Large embossing	0.1169
15	Regular embossing pattern	0.1100
16	Deep embossing	0.1056
17	Large deformation in embossed edge	0.0873
18	Bent with many wrinkles	0.0860
19	Stitch line matching well with material	0.0726
20	Natural seams	0.0701

4.3.2.3. Analysis of the Statistical Significance of the Difference in Affective Word Scores among Samples

The goal of this analysis was to examine whether the evaluation scores of six samples for each affective word showed a significantly statistical difference. When the participants of the experiment evaluated the six samples for each affective word, if the evaluation scores were significantly different among samples, the distinctness of samples was regarded as high for the affective word. Otherwise, the distinctness of samples was regarded as low. The Kruskal-Wallis test, which is a non-parametric independent K-sample testing method, was used for the analysis. The analysis revealed that the samples had a significant difference of scores in 13 out of 20 affective words ($p<.05$).

The significant difference of scores among samples was shown in the following words: Bright colored – Dark colored, Moist – Dry, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material, Natural seams – Unnatural seams. In addition, the significance level for 'Large deformation in embossed edge - Small deformation in embossed edge' ($p=0.073$) did not satisfy the reference but showed a tendency. Table 4.11 presents the analysis results for each affective word.

Table 4.11. The result of the Kruskal-Wallis test of affective word score difference between samples

Affective word	Bright colored	Looking warm	Polished	Warm	Sticky	Moist	Slick	Rough	Rugged	Elastic
Chi square	36.360**	4.418	7.801	8.130	3.726	16.350**	5.682	8.534	23.331**	18.037**
Degree of freedom	5	5	5	5	5	5	5	5	5	5
Significance probability	.000	.491	.168	.149	.589	.006	.338	.129	.000	.003
Affective word	**Soft**	**Stuffed**	**Wide spacing of embossed area**	**Large embossing**	**Regular embossing pattern**	**Deep embossing**	**Large deformation in embossed edge**	**Bent with many wrinkles**	**Stitch line matching well with material**	**Natural seams**
Chi square	35.612**	12.136*	36.695**	56.597**	17.222**	42.283**	10.080	20.088**	19.271**	17.613**
Degree of freedom	5	5	5	5	5	5	5	5	5	5
Significance probability	.000	.033	.000	.000	.004	.000	.073	.001	.002	.003

* p<.05, ** p<.01

4.4. Discussion

This study attempted to quantitatively analyze how validly each affective word, which was selected in a series of processes, could be applied to the affective evaluation. Three statistical methods including the one sample test, the analysis of CV (Coefficient of Variation) and ANOVA (the Kruskal – Wallis test) were used for the analysis. Participants' understanding of the words was quantitatively analyzed by applying the one sample test and the CV analysis. The distinctness of samples was quantitatively analyzed by using the one sample test, the CV analysis and ANOVA method. The validity of the 20 affective words was comprehensively examined by 5 analyses. As for the CV of the understanding of words, the validity of a word was regarded as high if the reference value (< 0.35) was satisfied in at least 3 out of 6 samples. As for the CV of the distinctness of samples, the reference value was set to 0.15, and the validity of a word was defined to be high, if its CV was 0.15 and above. Based on the 5 analyses, Table 4.12 comprehensively shows how many analyses were satisfied by each word.

Table 4.12. Total results of Affective words validity

Evaluation words	Analysis 1	Analysis 2	Analysis 3	Analysis 4	Analysis 5	total
Bright colored	O	O	O	O	O	5
Looking warm	O	O		O	O	4
Polished	O	O		O	O	4
Warm	O	O	O		O	4
Sticky	O	O		O	O	4
Moist		O	O		O	3
Slick		O		O	O	3
Rough	O	O	O			3
Rugged	O			O	O	3
Elastic				O	O	2
Soft				O	O	2
Stuffed	O		O			2
Wide spacing of embossed area		O			O	2
Large embossing				O	O	2
Regular embossing pattern		O			O	2
Deep embossing		O				1
Large deformation in embossed edge	O					1
Bent with many wrinkles	O					1
Stitch line matching well with material	O					1
Natural seams						0

As a result, only ‘Soft – Solid’ satisfied all the five analyses. In other words, ‘Soft – Solid’ was the most appropriate affective word for the affective evaluation of the leather instrument panel. Other 4 words, which include Bright colored – Dark colored, Rugged – Even, Elastic – Inelastic and Stitch line matching well with material – Stitch line matching poor with material, satisfied 4 analyses. Another 4 words, which were Moist – Dry, Large embossing – Small embossing, Rough – Smooth, and Bent with many wrinkles – Bent with only a few wrinkles, satisfied 3 analyses. 6 words, including Wide spacing of embossed area – Narrow spacing of embossed area, Regular embossing pattern – Irregular embossing pattern, Slick – Not slick, Stuffed – Hollow, Deep embossing – Shallow embossing, and Natural seams – Unnatural seams satisfied only 2 analyses. Four words, which include Warm – Cool, Looking warm – Looking cool, Polished – Not polished, and Sticky – Not sticky satisfied only 1 analysis. Finally, Large deformation in embossed edge – Small deformation in embossed edge did not satisfy any analysis.

The comprehensive analysis of the experiment result showed that the sensory characteristics of each affective word had no specific relation or pattern with the number of analyses satisfied by the affective word. ‘Soft – Solid’, which satisfied all of the five analyses, is a tactile affective word, while ‘Large deformation in embossed edge – Small deformation in embossed edge’ satisfying no analysis reflects a lot of visual characteristics. In spite of this difference, the remaining cases showed the co-existence of visual and tactile affective words. Accordingly, no pattern can be inferred. For example, among the words satisfying 4 analyses, ‘Bright colored – Dark colored’ and ‘Stitch line matching well with material – Stitch line matching poor with material’ are related to vision, while ‘Rugged – Even’ and ‘Elastic – Inelastic’ are related to touch.

One remarkable thing at least in this experiment was that the number of words satisfying analyses had a certain pattern. Only one affective word satisfied all or nothing of the 5 analyses. 4 words satisfied either 4 analyses or only 1 analysis. Another group of 4 words satisfied 3 analyses and 6 words satisfied 2 analyses. If the numbers of words are arranged in the descending order of the numbers of analyses they satisfied, the pattern of 1-4-4-6-4-1 is obtained. To put it more positively, the numbers of the words satisfying analyses seem to show a bell-shaped normal distribution to a certain extent. Such a pattern will be useful to increase or decrease the number of affective words for an affective evaluation. Consequently, based on the above experiment result, when the number of affective words is determined based on the scale or complexity of an affective evaluation, the number can be adjusted to that of analyses satisfied.

Chapter 5. Comparing Semantic Differential Methods

5.1. Introduction

The semantic differential method is one of the essential components of an affective evaluation, where participants use a product and rate how much they feel a certain affect. The conventional affective evaluation asks participants to rate every question about affective word for all samples presented one by one. This process can be described in details as follows. First, samples are presented to participants in an arbitrary order. Participants answer every survey question about each sample for each affective word. After one sample is completely evaluated, another sample begins to be evaluated by answering all the questions.

This process is repeated until all the samples are completely evaluated (Bhise, Mallick, & Sarma, 2009; Luible, Varheenmaa, Magnenat-Thalmann, & Meinander, 2007; Skedung et al., 2011). A vast majority of the affective evaluations are conducted in that way. However, there are other types of semantic differential methods. One of them is evaluating every sample at each question. This method can be described as follows. First, samples are presented to participants in an arbitrary order. Then, participants evaluate all the samples for a single affective word in that arbitrary order.

After one affective word is completely evaluated, another word is evaluated in the same order. This process is repeated until the last affective word (Wongsriruksa, Howes, Conreen, & Miodownik, 2012). The difference is this: The former conventional method is evaluating every affective word for each sample and then the same process is repeated for another sample, while the latter method is evaluating every sample for one affect word and then the same process is repeated for another word.

Another semantic differential method evaluates pairs of samples. This method can be described as follows. First, all the possible pairs of samples are presented. Then, all the affective words are evaluated for each sample pair. When the evaluation is completed for one pair, the same process is applied to another pair. This process is repeated until all the pairs are completely evaluated (Kim, Park, & Lee, 2008). If the previous two methods are absolute evaluation methods, this method is a relative evaluation method.

In this study, those three semantic differential methods are referred to as Absolute evaluation type 1, Absolute evaluation type 2 and Relative evaluation type, respectively. Table 5.1 provides characteristics of each method. There have been studies applying one of those semantic differential methods. However, no study has simultaneously applied them for comparison.

Table 5.1. Semantic differential evaluation methods

Evaluation method	Definition	Detailed process	References
Absolute evaluation type 1	Answer all of the absolute evaluation type questions simultaneously for samples presented in order	1) Samples are presented in an arbitrary order 2) Every question is answered for one sample 3) Another sample is presented 4) Process 2) is performed	Luible, C. et al., 2007 Bhise, V. D. et al., 2009 Skedung, L. et al., 2011
Absolute evaluation type 2	Answer the absolute evaluation type questions one by one for samples presented in order	1) All samples are presented 2) Every sample is evaluated for a single word in an arbitrary order 3) Every sample is evaluated for another word in a newly presented order	Wongsriruksa, S. et al., 2012
Relative evaluation	Answer all of the relative evaluation type questions for sample pairs presented in order	1) All the samples are paired in every possible way 2) A sample pair is comparatively evaluated based on every question 3) Process 2) is repeated for another pair 4) Total scores are derived by using an expert choice program	Park, 2006 Kim et al., 2008; 2009

The goal of this experiment is to compare the above three semantic differential methods. These methods were quantitatively compared by repeating the evaluation for the same participant group and the same evaluation samples in three ways under controlled conditions. First, it was checked how many affective words among 20 affective words showed a significant difference in evaluation scores of 6 samples. A semantic differential method was defined to be adequate for the evaluation if a large number of affective words showed a significant difference in the evaluation scores of samples.

Second, for affective words, which had a significant difference in the evaluation scores of samples in two or more methods, a post analysis was performed to see how well the samples were distinguished. This analysis aimed to identify which evaluation method distinguished samples groups more clearly. Finally, the correlation between an affective word and a design variable, which seemed to be related to that word, was comparatively identified by applying each of the semantic differential methods. The more affective words showed a meaningful correlation, the more effective the semantic differential method was for evaluation. Among the meaningful correlations, the one showing a higher correlation was regarded as a more effective method.

5.2. Method

This experiment was conducted in almost the same way as in Experiment 1. Six IP samples, which had the same shape but were wrapped in different leather materials, were used. Total 24 participants took part in the experiment. There were 17 male and 7 female participants, whose mean age was 27.1 years. All 24 participants were general consumer who were not expertise in vehicle interior. All the participants repeated the same affective evaluation three times, that is, by applying 3 different semantic differential methods. A counterbalanced measures design was applied to the presenting order of samples in order to prevent an order effect both for the semantic differential methods and the samples. The same 20 affective words were also used. Table 5.2 lists the words and their definitions.

Table 5.2. List of affective words and related parts

Evaluated part	Evaluation words
Overall surface	Bright colored – Dark colored
	Looking warm – Looking cool
	Polished – Not polished
	Warm – Cool
	Sticky – Not sticky
	Moist – Dry
	Slick – Not slick
	Rough – Smooth
	Rugged – Even
	Elastic – Inelastic
	Soft – Solid
	Stuffed – Hollow
	Wide spacing of embossed area – Narrow spacing of embossed area
	Large embossing – Small embossing
	Regular embossing pattern – Irregular embossing pattern
	Deep embossing – Shallow embossing
Edge	Large deformation in embossed edge – Small deformation in embossed edge
Bent	Bent with many wrinkles – Bent with only a few wrinkles
Stitch line	Stitch line matching well with material – Stitch line matching poor with material
Seam	Natural seams – unnatural seams

5.2.1. Questionnaires

Since this experiment repeated the same evaluation for three different semantic differential methods, appropriate questionnaires were developed for each method. The questionnaire of the absolute evaluation type 1 was so designed that every affective word could be evaluated for one sample. Each page had a blank for a sample number and listed all the affective words. The questionnaire of the absolute evaluation type 2 enabled all the samples to be evaluated for one affective word. To prevent an order effect, the samples were arranged in different orders for each participant.

Each questionnaire provided to participants specified the order of sample numbers. The questionnaire of the relative evaluation type had two blanks where the numbers of two samples compared could be filled in. The questions asked each participant to mark comparison scores for two samples. In other words, the questionnaire specified a reference sample and a sample compared therewith and asked each participant to score a difference between them. The questionnaire forms for the three semantic differential methods and the questions about participants' understanding of words and the distinctness of samples are introduced in Appendix B.

5.2.2. Analysis Methods

Three statistical analysis methods were used for this study. The ANOVA method was applied to see how many affective words showed a significant difference in evaluation scores of samples in each semantic differential method. As 24 participants took part in the experiment, the quantity of responses was not sufficient and the scores of the responses did not show any regularity. For this reason, the Kruskal-Wallis test, which is a non-parametric independent K-sample testing method, was adopted. For affective words, which had a significant difference in the evaluation scores of samples in two or more methods, a post analysis was performed to see how well the samples were distinguished. In other words, the number of sample groups, which were distinguished, was identified. As each group had the same number of samples, the Tukey HSD method was adopted for the post analysis. Finally, in order to examine the relationship between an affective word and a design variable related to that word, a correlation method was used, and the significance and magnitude of the correlation were identified.

5.2.3. Design Parameter of Samples

A total of 9 design parameters were measured in each sample: gray scale, gloss, roughness average (Ra), thermal conductivity, Water Vapor Transmission Rate (WVTR), static friction coefficient, squeak, softness, and Young's modulus. Gray scale (You, Ryu, Oh, Yun, & Kim, 2006) was selected as a design parameter instead of color because every sample has achromatic colors. They were different only in brightness. Gray scale was measured with a color-difference meter OLOEY JZ-300. Gloss is a physical property that light is reflected directly from the surface of an object, and the degree of gloss is determined by the degree of smoothness of the surface and the reflection angle of the projected light source (You et al., 2006).

In this study, gloss was measured using a gloss meter HG60. Roughness average (Ra) is a physical property that how rough the surface of leather is. It was measured by TopoGetter 3D scanner. Thermal conductivity is defined as the degree to which heat is transferred from the front side to the back side of the material. It was measured by using HC-074/Technox in accordance with ASTM-C518/ISO-8301. Water Vapor Transmission Rate (WVTR) is a measure of the amount of passage of water vapor through a leather. The measurement of the WVTR was carried out in accordance with the guidelines of EN13726-1; leather samples with a 35mm diameter were inserted inside the cup with 50g water, and then placed in a constant-temperature and air-humidifier for 24 hours. Then the changed weight and rate of change was calculated. Static friction coefficient is derived from static friction force. It was measured by the Lloyd Instrument (Kim, Lee, Lee, Shin, & Yun, 2018).

Two samples are made from the same leather, one of which is fixed to the bottom of the Lloyd instrument and the other is fixed to the bottom of 4.5 kg of object, and put them together. As the Lloyd instrument pulled the 4.5kg of object, the load was measured when the object started moving. Squeak is a newly defined value that is from normalizing friction force value. It is yielded by dividing the difference between the maximum frictional force value and the minimum frictional force value by the mean frictional force value. Softness is a parameter which indicates the degree of softness of leather. It is defined by how the leather is compressed when pressed with a certain force. Softness was measured by a softness tester ST-300 (Kim et al., 2018). Young's modulus is a coefficient that represents the relationship between deformation and pressure. It is measured by a tensile testing machine KJ-1066A. The values were measured by holding the samples in a tensile testing machine and pulling them at a speed of 200 mm/min until the samples were torn. The list of the 9 design parameter values for the 6 samples is summarized in Table 5.3/Table 5.4.

Table 5.3. The value of design parameters by sample (part 1)

Sample No.	Gray scale	Gloss	Ra (μm)	Thermal conductivity (W/mK)	WVTR (g/m^2day)
1	3.187	1.1	18.086	0.123	629
2	3.14	1.2	15.495	0.119	617
3	3.18	1.1	21.073	0.122	553
4	3.14	1.1	16.966	0.123	640
5	4.867	1.2	16.155	0.131	716
6	4.817	0.6	15.178	0.122	1150

Table 5.4. The value of design parameters by sample (part 2)

Sample No.	Static friction coefficient	Squeak	Softness (mm)	Young´s Modulus (kgf/cm^2)	Artificial/ Natural
1	0.355	0.075	3.7	470.573	Artificial
2	0.374	0.068	3.9	314.744	Artificial
3	0.326	0.055	4.1	161.414	Artificial
4	0.382	0.052	4.1	125.126	Artificial
5	0.493	0.043	3.9	298.331	Artificial
6	0.457	0.388	4.57	203.507	Natural

5.3. Results

The three semantic differential methods were compared by conducting ANOVA (the Kruskal-Wallis test). The numbers of affective words showing a statistically significant difference among samples in each method were compared. A post analysis was performed to confirm the ANOVA result in detail. The correlation between an affective word and design variables was examined to compare the semantic differential methods.

5.3.1. Analysis of the Statistically Significant Difference in Affective Word Scores among Samples in each Semantic Differential Method

The Kruskal-Wallis test showed that, when the absolute evaluation type 1 was applied, 13 affective words had a statistically significant difference in affective word scores among samples. The 13 affective words were as follows: Bright colored – Dark colored, Moist – Dry, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material, Natural seams – Unnatural seams.

When the absolute evaluation type 2 was applied, 12 affective words had a statistically significant difference in affective word scores among samples. The 12 affective words were as follows: Bright colored – Dark colored, Polished – Not polished, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material.

When the relative evaluation type was applied, 18 affective words had a statistically significant difference in affective word scores among samples. The 18 affective words were as follows: Bright colored – Dark colored, Polished – Not polished, Sticky – Not sticky, Moist – Dry, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Large deformation in embossed edge – Small deformation in embossed edge, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material, Natural seams – Unnatural seams.

The relative evaluation type, the absolute evaluation type 1 and the absolute evaluation type 2 revealed 18, 13 and 12 affective words, respectively, which showed a significant difference in evaluation scores among samples. The two absolute evaluation types produced similar results with the difference of only one affective word. Table 5.5/Table 5.6 present the analysis result.

Table 5.5. The result of Kruskal-Wallis test of affective word score difference between samples (part 1)

Evaluation type		Bright colored	Looking warm	Polished	Warm	Sticky	Moist	Slick	Rough	Rugged	Elastic
Absolute evaluation type 1	Chi square	36.360**	4.418	7.801	8.130	3.726	16.350**	5.682	8.534	23.331**	18.037**
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.000	.491	.168	.149	.589	.006	.338	.129	.000	.003
	The number of sub groups	2	1	1	1	1	2	1	1	2	2
Absolute evaluation type 2	Chi square	21.723**	5.783	14.438*	8.539	6.600	5.063	6.748	10.959	21.889**	16.407**
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.001	.328	.013	.129	.252	.408	.240	.052	.001	.006
	The number of sub groups	2	1	2	1	1	1	1	1	2	2
Relative evaluation	Chi square	82.764**	5.748	27.887**	6.658	26.563**	26.109**	35.665**	35.584**	32.623**	43.036**
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.000	.331	.000	.247	.000	.000	.000	.000	.000	.000
	The number of sub groups	3	1	3	1	2	3	3	2	3	3

* p<.05, ** p<.01

Table 5.6. The result of Kruskal-Wallis test of affective word score difference between samples (part 2)

Evaluation type		Soft	Stuffed	Wide spacing of embossed area	Large embossing	Regular embossing pattern	Deep embossing	Large deformation in embossed edge	Bent with many wrinkles	Stitch line Matching well with material	Natural seams
Absolute evaluation type 1	Chi square	35.612**	12.136*	36.695**	56.597**	17.222**	42.283**	10.080	20.088**	19.271**	17.613**
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.000	.033	.000	.000	.004	.000	.073	.001	.002	.003
	The number of sub groups	2	2	2	2	2	2	1	2	3	2
Absolute evaluation type 2	Chi square	41.944**	12.671*	27.159**	49.082**	16.354**	42.281**	9.223	18.400**	12.818*	7.600
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.000	.027	.000	.000	.006	.000	.100	.002	.025	.180
	The number of sub groups	3	2	2	2	2	2	1	2	2	1
Relative evaluation	Chi square	70.702**	50.589**	62.204**	56.993**	38.223**	81.856**	30.889**	30.191**	43.818**	39.476**
	Degree of freedom	5	5	5	5	5	5	5	5	5	5
	Significance probability	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	The number of sub groups	3	3	2	3	2	3	3	3	3	3

* p<.05, ** p<.01

5.3.2. Post Analysis for Details of the Semantic Differential Methods

'Bright colored – Dark colored' showed a statistically significant result in all the three semantic differential methods. In the absolute evaluation type 1, 6 samples were divided into 2 groups. In the absolute evaluation type 2, 6 samples were also divided into 2 groups. In the relative evaluation type, 6 samples were divided into 3 groups. 'Polished – Not polished' showed a statistically significant result in the absolute evaluation type 2 and the relative evaluation type. In the absolute evaluation type 2, 6 samples were divided into 2 groups. In the relative evaluation type, 6 samples were divided into 3 groups. 'Moist – Dry' showed a statistically significant result in the absolute evaluation type 1 and the relative evaluation type. In the absolute evaluation type 1, 6 samples were divided into 2 groups. In the relative evaluation type, 6 samples were divided into 3 groups.

'Rugged – Even' showed a statistically significant result in all the three semantic differential methods. In the absolute evaluation type 1, 6 samples were divided into 2 groups. In the absolute evaluation type 2, 6 samples were also divided into 2 groups. In the relative evaluation type, 6 samples were divided into 3 groups. Other 9 words including 'Elastic – Inelastic', 'Soft - Solid', 'Stuffed – Hollow', 'Wide spacing of embossed area – Narrow spacing of embossed area', 'Large embossing – Small embossing', 'Regular embossing pattern - Irregular embossing pattern', 'Deep embossing – Shallow embossing', 'Bent with many wrinkles – Bent with only a few wrinkles' and 'Stitch line matching well with material – Stitch line matching poor with material' showed a statistically significant result in all the three semantic differential methods. Among those words, 'Rugged – Even', 'Elastic – Inelastic', 'Stuffed – Hollow', 'Large embossing – Small embossing' and

‘Bent with many wrinkles – Bent with only a few wrinkles’ showed that the samples were divided into 2 groups in the absolute evaluation type 1 and type 2 and into 3 group in the relative evaluation type. In the case of ‘Soft – Solid’, the samples were divided into 2 groups in the absolute evaluation type 1 and into 3 groups both in the absolute evaluation type 2 and in the relative evaluation type. In the case of ‘Wide spacing of embossed area – Narrow spacing of embossed area’ and ‘Regular embossing pattern - Irregular embossing pattern’, the samples were divided into 2 groups in all of the three methods. In the case of ‘Stitch line matching well with material – Stitch line matching poor with material’, the samples were divided into 3 groups in the absolute evaluation type 1 and the relative evaluation type, and also into 2 groups in the absolute evaluation type 2. Finally, ‘Natural seams – Unnatural seams’ showed a statistically significant difference in the absolute evaluation type 1 and the relative evaluation type. In the absolute evaluation type 1, the samples were divided into two groups. In the relative evaluation type, the samples were divided into 3 groups. Table 5.5/Table 5.6 provided the number of groups divided after the post analysis for each affective word. Details of sample grouping are presented in Appendix C.

Table 5.7. List of design variables for affective words and their relevance prediction

Affective words	Design variable	Relevance prediction
Bright colored	Gray Scale	Feel bright as the gray scale decreases
Looking warm	Gray Scale	Look cool as the gray scale decreases.
Polished	Gloss	Feel polished as the gloss increases.
Warm	Thermal Conductivity	Feel warm as the thermal conductivity increases.
Sticky	Squeak	Feel sticky as the squeak increases.
Moist	Water Vapor Transmission Rate (WVTR)	Feel dry as WVTR increases.
Slick	Static friction Coefficient	Feel not slick as the static friction coefficient increases.
Rough	Roughness average (Ra)	Feel rough as Ra increases.
Rugged	Roughness average (Ra)	Feel rugged as Ra increases.
Elastic	Softness	Feel elastic as the softness decreases.
Soft	Softness	Feel soft as the softness increases.
Stuffed	Softness	Feel hollow as the softness increases.
Large embossing	Roughness average (Ra)	Embossing feels larger as Ra increases.
Deep embossing	Roughness average (Ra)	Embossing feels deeper as Ra increases.
Large deformation in embossed edge	Young's Modulus	Embossing deformation in edge seems to decrease as the Young's modulus increases.
Bent with many wrinkles	Young's Modulus	Bent has more wrinkles as the Young's Modulus increases.

5.3.3. Analysis of the Correlation between Affective Words and Design Variables

2 criteria were set up to identify the correlation between an affective word and a design variable related to that word. First, it was checked whether there was a significant correlation (p<.05). Second, in case there was such a correlation, the size of the correlation coefficient was identified. The reference correlation coefficient was set to the absolute value of 0.3.

According to Field (2009), correlation is appropriate when the correlation coefficient is above the absolute value of 0.3. Based on the literature review and experts' meeting, design variables, which seemed to be related to affective words, were selected for each affective word. Table 5.7 shows the relevance between them. Wide spacing of embossed area – Narrow spacing of embossed area, Regular embossing pattern – Irregular embossing pattern, Stitch line matching well with material – Stitch line matching poor with material, and Natural seams – Unnatural seams were excluded from the analysis because no relevant design variable was clearly identified for each of these 4 words.

The analysis showed that, in the absolute evaluation type 1, 8 affective words had a significant correlation with design variables. Among these words, the following 4 words had a correlation coefficient of over 0.3: Bright colored – Dark colored, Rugged – Even, Large embossing – Small embossing, and Deep embossing – Shallow embossing. Another group of 4 words, which included Moist – Dry, Rough – Smooth, Elastic – Inelastic, and Stuffed – Hollow, were significant although their correlation coefficients did not exceed 0.3.

In the absolute evaluation type 2, 9 affective words had a significant correlation with design variables. Among these words, like in the absolute evaluation type 1, the following 4 words had a correlation coefficient of over 0.3: Bright colored – Dark colored, Rugged – Even, Wide spacing of embossed area – Narrow spacing of embossed area, and Deep embossing – Shallow embossing. The following 5 words were significant although their correlation coefficients did not exceed 0.3: Moist – Dry, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, and Bent with many wrinkles – Bent with only a few wrinkles.

In the relative evaluation type, 9 affective words had a significant correlation with design variables. Among these words, the following 6 words had a correlation coefficient of over 0.3: Bright colored – Dark colored, Sticky – Not sticky, Rough – Smooth, Rugged – Even, Large embossing – Small embossing, and Deep embossing – Shallow embossing. In the case of Moist – Dry and Bent with many wrinkles – Bent with only a few wrinkles, the significance was identified although the correlation coefficients did not exceed 0.3. As regards this analysis, Table 5.8/Table 5.9 present correlation coefficients for each semantic differential method.

Table 5.8. Correlation coefficients for each semantic differential method by affective word (part 1)

Evaluation type		Bright colored	Looking warm	Polished	Warm	Sticky	Moist	Slick	Rough	Rugged	Elastic
Absolute evaluation type 1	Correlation coefficient	-0.513**	0.111	0.018	0.002	0.106	-0.294**	0.114	0.192*	0.383**	-0.294**
	Significance probability	.000	.185	.849	.980	.251	.000	.215	.021	.000	.000
	N	144	144	144	144	144	144	144	144	144	144
Absolute evaluation type 2	Correlation coefficient	-0.381**	0.003	0.000	-0.114	-0.095	-0.174*	0.223*	0.102	0.331**	-0.296**
	Significance probability	.000	.969	1.000	.214	.303	.037	.014	.222	.000	.000
	N	144	144	144	144	144	144	144	144	144	144
Relative evaluation	Correlation coefficient	-0.614**	0.046	0.058	0.111	0.317**	-0.282**	0.440**	0.344**	0.401**	-0.075
	Significance probability	.000	.583	.526	.229	.000	.001	.000	.000	.000	.372
	N	144	144	144	144	144	144	144	144	144	144

* p<.05, ** p<.01

Table 5.9. Correlation coefficients for each semantic differential method by affective word (part 2)

Evaluation type		Soft	Stuffed	Wide spacing of embossed area	Large embossing	Regular Embossing pattern	Deep embossing	Large deformation in embossed edge	Bent with many wrinkles	Stitch line Matching well with material	Natural seams
Absolute evaluation type 1	Correlation coefficient	0.151	-0.253**	-	0.577**	-	0.521**	0.025	0.154	-	-
	Significance probability	.072	.002	-	.000	-	.000	.766	.065	-	-
	N	144	144	-	144	-	144	144	144	-	-
Absolute evaluation type 2	Correlation coefficient	0.174	-0.224**	-	0.426**	-	0.539**	0.099	0.285**	-	-
	Significance probability	.037	.007	-	.000	-	.000	.236	.001	-	-
	N	144	144	-	144	-	144	144	144	-	-
Relative evaluation	Correlation coefficient	-0.180*	-0.109	-	0.383**	-	0.593**	0.028	0.236**	-	-
	Significance probability	.031	.195	-	.000	-	.000	.737	.004	-	-
	N	144	144	-	144	-	144	144	144	-	-

* p<.05, ** p<.01

5.4. Discussion

This study attempted to quantitatively analyze which one among the conventional three semantic differential survey methods is more advantageous for affective evaluation. Three statistical methods, namely, ANOVA (the Kruskal-Wallis test), a post analysis and a correlation analysis were used for the analysis. ANOVA was conducted to see whether there was a significant difference in the scores of an affective word among 6 samples while each of the 3 semantic differential methods was applied. As a result, in the relative evaluation type, 18 out of 20 affective words showed a significant difference of scores among samples.

On the other hand, 13 affective words showed a significant difference of scores among samples in the absolute evaluation type 1, and 12 affective words did in the absolute evaluation type 2. Among 20 affective words, the following 11 words showed a significant difference of scores among samples in all the 3 semantic differential methods: Bright colored – Dark colored, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Bent with many wrinkles – Bent with only a few wrinkles, and Stitch line matching well with material – Stitch line matching poor with material. When it comes to validity, these 11 affective words can be regarded as highly valid irrespective of semantic differential methods. The ANOVA result revealed that the relative evaluation type produced the best result and the absolute evaluation type 1 and 2 yielded similar results.

In order to compare the semantic differential methods with respect to effectiveness, a post analysis was conducted for the significant difference of scores among samples. For all the affective words showing a significant difference of scores among samples, the post analysis distinguished up to 3 groups. In other words, 6 samples were significantly divided into either 2 or 3 groups. In the relative evaluation type, among 18 affective words showing a significant difference of scores among samples, 14 words divided the samples into 3 groups. In the absolute evaluation type 1, among 13 words, which were regarded as significant, only 1 word divided the samples into 3 groups and the remaining 12 words divided the samples into 2 groups. In the absolute evaluation type 2, among 12 words, which were regarded as significant, only 1 word divided the samples into 3 groups and the remaining 11 words divided them into 2 groups.

It turned out that the relative evaluation type distinguished the maximum number of sample groups in all of 18 affective words, which were regarded as significant. Both the absolute evaluation type 1 and 2 distinguished 3 groups in one affective word. However, the relative evaluation type also distinguished 3 groups in that word. Accordingly, there was no affective word for which either the absolute evaluation type 1 or 2 alone distinguishes 3 sample groups. Thus, the post analysis confirmed that the relative evaluation type was the most advantageous semantic differential method for deriving a result from an affective engineering.

Finally, a correlation analysis was performed to identify the relevance between affective words and design variables. Affective evaluation aims to identify the relationship between users' affect and design variables of the product and to propose a design that enables users to experience the affect. In this regard, the relevance between the evaluation score of an affective word score and a design variable is important to derive a more accurate evaluation result. The main goal of the correlation analysis was to examine which semantic differential method was most appropriate to show the relevance between an affective word and a design variable. The numbers of affective words showing significant relevance between an affective word score and a design variable related to it were 8, 9 and 9 in the absolute evaluation type 1, type 2 and the relative evaluation type, respectively. Both ANOVA and the post analysis revealed that the relative evaluation type yielded a better result than the remaining two semantic differential methods. On the other hand, in this analysis, those 3 methods showed similar results with respect to significance.

However, if the sizes of correlation coefficients were considered, the relative evaluation type also showed the best result in this analysis. In both the absolute evaluation type 1 and 2, 4 affective words had a correlation coefficient of over 0.3. In the relative evaluation type, 6 affective words had a correlation coefficient of over 0.3. Accordingly, if not only significance but also its magnitude was also considered, the relative evaluation type produced the best result.

In all of the 3 analyses, the relative evaluation type had the best result. This is attributable to the characteristics of that semantic differential method. The relative evaluation type evaluates a sample by comparing it with another sample. While the absolute evaluation type 1 evaluates one sample at a time, the relative evaluation type compares two samples continuously and in details, which increases the difference of scores among samples. The absolute evaluation type 2 evaluates all the samples for one affective word simultaneously. In this case, samples can also be compared while being evaluated in comparison with the absolute evaluation type 1. Nevertheless, as a multiple number of samples are compared simultaneously, samples are less discriminated than in the relative evaluation type, where only two samples are compared.

Accordingly, the relative evaluation type is the best method of evaluating samples while ensuring the discrimination among them. Based on the above three analyses, there was nothing to choose between the absolute evaluation type 1 and 2. In ANOVA and the post analysis, the absolute evaluation type 1 showed a little better result than the absolute evaluation type 2. On the other hand, in the correlation analysis, the absolute evaluation type 2 produced a better result than the absolute evaluation type 1. However, there was no significant difference. Consequently, it is hard to tell which of these two methods is better. If the results of the three quantitative analyses are used to determine the order of priority for the semantic differential methods, the relative evaluation type is best and the remaining two methods are too close to tell which one is better.

However, if the evaluation time is considered along with the analysis results, a different result may be derived. As the duration of evaluation was not quantitatively measured in this study, the evaluation time of each semantic differential method was not clearly recorded. However, it could be confirmed that the relative evaluation type took about 3~5 times longer than the absolute evaluation type 1. It also turned out that the absolute evaluation type 2 took longer than the absolute evaluation type 1. There are two reasons why the relative evaluation type took longer.

First, more evaluation rounds were conducted. The relative evaluation type is based on the pairwise comparison. In other words, the absolute evaluation type 1 needs 6 rounds of evaluation for 6 samples, while the relative evaluation type requires a total of 15 rounds of evaluation in the form of Sample 1 – Sample 2, Sample 1 – Sample 3, ..., Sample 4 – Sample 6 and Sample 5 – Sample 6. The relative evaluation type contains 2.5 times more evaluation rounds than the absolute evaluation type 1. This difference increases if the number of samples increases. It is because the number of evaluation rounds in the pairwise comparison is determined by the equation $C_{(n,2)} = \frac{n!}{2!(n-2)!}$. If 7 samples are evaluated, the absolute evaluation type 1 needs 7 rounds of evaluation, while the relative evaluation type requires 35 rounds of evaluation. Thus, the difference increases up to 5 times.

Second, the pairwise comparison is a continuous and comparative evaluation of two samples. In the absolute evaluation type 1, samples are evaluated one by one. For this reason, there is no need to compare samples. On the other hand, the relative evaluation type based on the pairwise comparison demands that each affective word is evaluated while comparing two samples continuously. Such a difference seemed to make a difference in evaluation time. The absolute evaluation type 2 also requires the evaluation of all samples for one affective word. In this regard, samples are compared, although not in the same extent as in the relative evaluation type. In addition, the absolute evaluation type 1 and 2 have the same number of questions.

However, each participant in the absolute evaluation type 2 needs to complete 20 rounds of evaluation, which is based on the number of affective words, not 6 rounds, which is derived based on the number of samples. For this reason, the absolute evaluation type 2 took a longer time. Now, it is clear why the absolute evaluation type 2 tended to take longer than the absolute evaluation type 1. Thus, when the semantic differential methods were compared only in terms of evaluation time, the absolute evaluation type 1 took the shortest time. The absolute evaluation type 2 took longer than the absolute evaluation type 1. The relative evaluation type required a significantly longer time than the remaining two methods. In the statistical significance analysis using the Kruskal-Wallis test, there were only two affective words of ‘Looking warm – Looking cool’ and ‘Warm – Cool’ that were not significant in all three semantic differential evaluation methods. The common feature of both words is that both words are related to temperature. From these results, it was confirmed that it is not easy to evaluate the affect associated with temperature. When comparing the difference of significance between absolute evaluation 1 and absolute evaluation 2, it is confirmed that there are differences in total 4 affective words. Among them, ‘Polished – Not polished’ and ‘Rough – Smooth’ showed meaningful results in absolute evaluation 2, but not in absolute evaluation 1. And ‘Moist – Dry’ and ‘Natural seams – Unnatural seams’ showed meaningful results in absolute evaluation 1, but not in absolute evaluation 2. Among 4 affective words, ‘Rough – Smooth’ also showed difference significance between absolute evaluation 1 and absolute evaluation 2 in correlation analysis. But in this case, ‘Rough – Smooth’ showed meaningful result in absolute evaluation 1, not in absolute evaluation 2. This is the opposite result of the Kruskal-Wallis test.

Chapter 6. Improving the Explanatory Power of Models using Clustering Analysis

6.1. Introduction

The purpose of affective evaluation is to apply the results to product design by adjusting the design parameters in the direction reflecting general consumers' impressions about the product by identifying it from the affective perspective. The major drawback of affective evaluation with general users is the lack of consistency. It is demonstrated by the fact that the explanatory power of a model constructed based on general users' evaluation is lower than that constructed based on expert evaluation (Bahn, Lee, Nam, & Yun, 2009; Kim, Lee, Lee, Shin, & Yun, 2017). There are two reasons for the low explanatory power of a model based on user evaluation.

The first reason is insufficient command of affective vocabulary. Soufflet et al. (2004) found that experts have a better command of affective vocabulary than general users. This means that experts are more accurate and clear about the aspects focused on by specific affective words than general users are when using them in relation to product-specific affective vocabulary. It was revealed in a study that experts outperform general users in nuance differentiation because they have a better command of vocabulary (Soufflet et al., 2004). From this, it can be inferred that this difference in the command of vocabulary is translated into the difference in the explanatory power between the models constructed based on expert and general user reviews. The second reason for the difference in the explanatory power is the presence or absence of clear criteria for product evaluation (reference). Experts seem to have clearer evaluation criteria; they tend to evaluate with more consistency than general users when reviewing products in their respective fields of expertise. It may be assumed that the lower or higher consistency in evaluation results is responsible for the difference in the explanatory power between expert and user evaluations.

This study aims to present a method to derive a model with a high explanatory power that is applicable to product design in real settings by overcoming the inconsistent evaluation tendency of general users. The key idea of the proposed method lies in dividing the evaluation case groups into two or more groups on the basis of the evaluation scores for specific affective vocabulary. This methodological design is based on the assumption that general users lack in consistency of evaluation compared with experts.

Experts are more likely to show a significant correlation between the product-specific affective vocabulary score and the actual evaluation performance because they have a better command of affective vocabulary. General users tend to have a lower significant correlation between the product-specific affective vocabulary score and the actual evaluation performance for the sample concerned because they have a lower command of affective vocabulary. The proposed method is designed to deliberately enhance the probability of significant score–performance correlation. By classifying an evaluation case into two or more score-based subgroups, group-differentiated affect models can be derived, and the explanatory power of each group is enhanced when compared with that of the pre-cluster group. We derived the results of affective modeling on the basis of the entire data pool of general users, cluster analysis, affective modeling based on score-based clustering, and affective modeling based on the expert data pool, and discussed their differences.

6.2. Method

The environment in which the affective evaluation was performed, the type of the evaluation sample, the specific design parameter values of each evaluation sample, information on the participants, the method of interaction between the participants and the evaluation samples, the evaluation method, and the evaluation questionnaire were explained.

6.2.1. Evaluation Environment

As in the experiment of Chapter 4, samples were evaluated on a stand with a front height of 640 mm, rear height of 865 mm, side width of 510 mm, and an angle of 25°. The stand was concealed by a dark-colored cover so that the effects of light emitted and the color of the stand were suppressed. The seat for the participants was placed 890 mm from the right side of the stand so that it was in the same position as when they sat in the driver's seat in a car. The height of the seat was 430 mm, and the height of the sample placed on the stand was 960 mm. Thus, the relative height of the seat and sample was 530 mm.

When evaluating the samples, participants were instructed to evaluate the samples in two poses: a sitting position and a standing position. The evaluation in the sitting position assumes that the participant is seated in the driver's seat. In this posture, the participant could move the chair back and forth when evaluating. When evaluating the samples in a standing position, participants could only evaluate them from the front side, not the rear side. Nine LED lamps were used to provide maximum brightness for the place where the evaluation is conducted. The LED lamps are five times brighter than the same number of regular fluorescent lamps. With the LED lamps, the evaluation venue could achieve a brightness of 1000 lux. Information on the evaluation environment described so far is summarized in Figure 6.1.

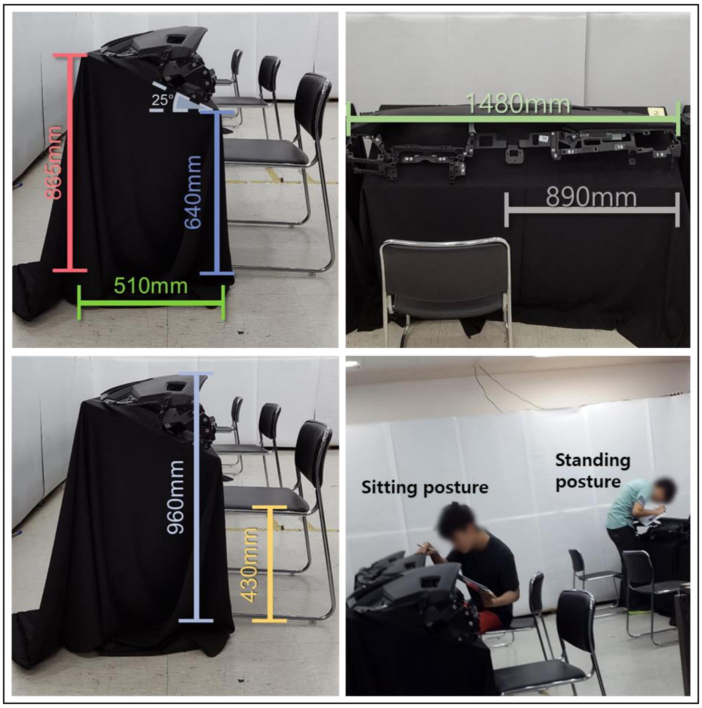


Figure 6.1. Information on the evaluation environment

6.2.2. Samples

In this study, a total of 12 different leather samples were used for evaluation. One of them is natural calf leather, and the others are artificially made leathers. Each leather is used for wrapping over an instrument panel. Therefore, participants evaluated multiple instrument panels wrapped in different leathers. The instrument panel is a section of the front of the driver's seat and front passenger's seat equipped with various instruments necessary for driving. The 12 instrument panels wrapped with different leathers are shown in Figure 6.2.

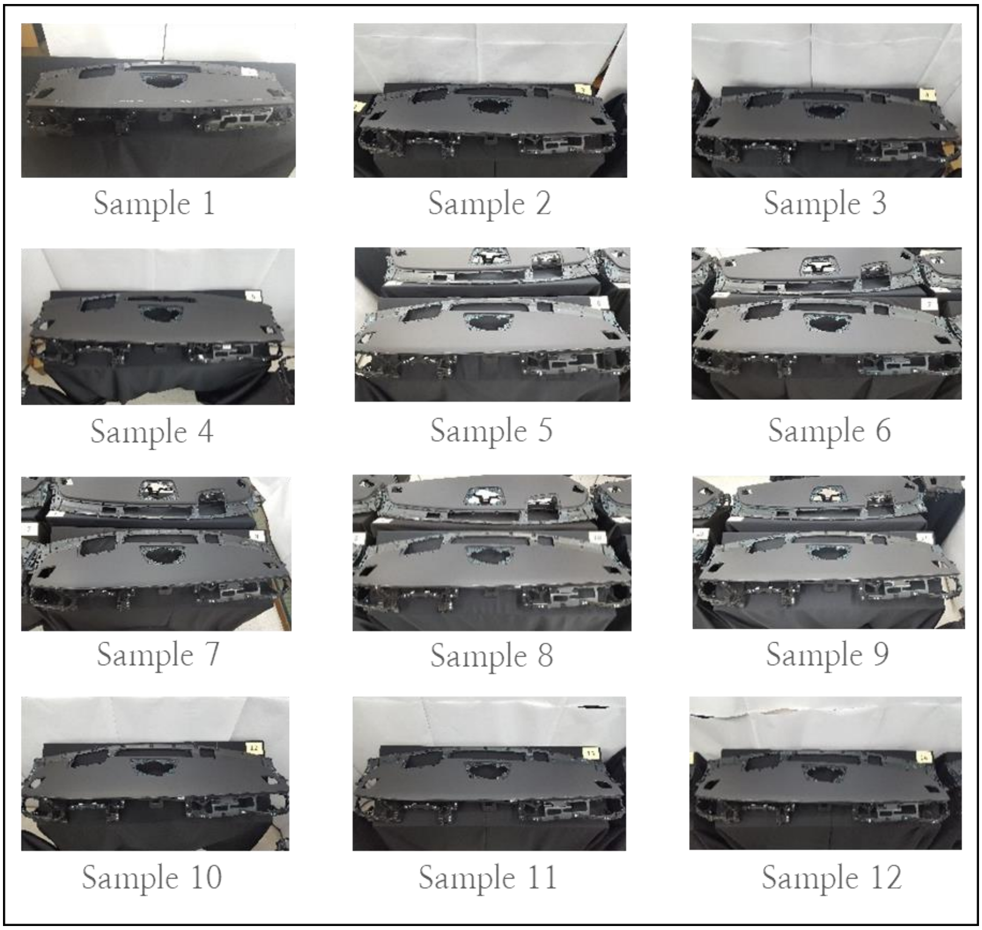


Figure 6.2. 12 instrument panel samples

6.2.2.1. Design Parameters of Samples

By adding two design parameters (thickness and absorbency) to the design parameters in Chapter 5, a total of 11 design parameters were measured in each sample: gray scale, gloss, roughness average, thickness, thermal conductivity, absorbency, water vapor transmission rate, static friction coefficient, squeak, softness, and Young's modulus. The design parameters were selected mainly for parameters related to automobile interior materials. These design parameters can be divided into seven categories: visual characteristic, surface pattern/grain, thickness, thermal characteristic, reactivity to moisture, friction characteristic, and tensile characteristic. As the first category, gray scale and gloss were selected as design parameters related to visual characteristics of leathers.

As the second category, roughness average (Ra) was selected as a design parameter related to the grains of leathers (Kim et al., 2018). As the third category, thickness was selected as a design parameter related to the thickness of leathers (Kim et al., 2018). As the fourth category, thermal conductivity was selected as a parameter related to the thermal characteristic of leathers (Kim et al., 2018). As the fifth category, absorbency and WVTR were selected as design parameters related to reactivity to moisture (Kim et al., 2018). As the sixth category, the static friction coefficient (Kim et al., 2018) and squeak were selected as design parameters related to the friction characteristics of leathers. Finally, as the seventh category, softness and Young's modulus were selected as design parameters related to the tensile characteristic.

As 9 of the 11 design parameters have been introduced in Chapter 5, the definitions and measurement methods of the remaining 2 design parameters are as follows. Thickness means the length of the gap between the bottom and top of the leathers. It was measured by using DES-3010, which is a sheet material thickness measuring tool. Absorbency indicates how much moisture a leather can absorb in 30 minutes. The value obtained by dividing the weight of the water absorbed by the leather by the original weight of the leather was defined as the measured value. The 11 design parameter values for the 12 samples are summarized in Table 6.1 and Table 6.2.

Table 6.1. The values of design parameters by sample (part 1)

Sample No.	Gray scale	Gloss	Ra (μm)	Thickness (mm)	Thermal conductivity (W/mK)	Absorbency
1	4.113	1.3	5.177	0.666	0.114	1.132
2	3.18	1.1	21.073	1.061	0.122	1.02
3	4.547	0.9	11.134	0.878	0.12	1.244
4	4.817	0.6	15.178	0.94	0.122	1.521
5	4.427	1.83	11.009	1.198	0.123	0.381
6	3.367	1.4	12.842	1.131	0.126	1.082
7	4.867	1.2	16.155	1.448	0.131	0.844
8	4.52	1.73	9.198	0.92	0.117	0.173
9	3.14	1.2	15.495	0.856	0.119	1.196
10	4.49	1.4	5.332	0.919	0.119	0.846
11	3.187	1.1	18.086	1.093	0.123	0.934
12	3.14	1.1	16.966	1.178	0.123	1.113

Table 6.2. The values of design parameters by sample (part 2)

Sample No.	WVTR (g/m^2day)	Static friction coefficient	Squeak	Softness (mm)	Young´s Modulus (kgf/cm^2)	Artificial/ Natural
1	431	0.423	0.051	4.4	318.162	Artificial
2	553	0.326	0.055	4.1	161.414	Artificial
3	389	0.494	1.122	4.1	262.186	Artificial
4	1150	0.457	0.388	4.57	203.507	Natural
5	389	0.296	0.069	4.2	240.27	Artificial
6	304	0.325	0.064	3.5	172.342	Artificial
7	716	0.493	0.043	3.9	298.331	Artificial
8	318	0.521	1.03	3.43	243.997	Artificial
9	617	0.374	0.068	3.9	314.744	Artificial
10	389	0.356	0.072	3.93	206.746	Artificial
11	629	0.355	0.075	3.7	470.573	Artificial
12	640	0.382	0.052	4.1	125.126	Artificial

6.2.3. Participants

A total number of 64 people participated in the evaluation, including 36 customers and 28 designers. All customers were not experts in vehicle interiors, and all designers were staff of companies related to automotive interior products. The gender ratio of the customers was 28 males to 10 females. The gender ratio of the designers was 18 males to 10 females. Thus, both groups had more male participants than female participants. The average age of the customers was 34.26 years (SD = 9.39), and their average driving career spanned 9.09 years (SD = 7.28). The average age of the designers was 38.25 years (SD = 5.75), and their average driving career spanned 14.43 years (SD = 6.24). Among the 38 customers, 5 participants were excluded for analysis because they were outliers.

6.2.4. Interaction Methods between Samples and Participants in Evaluation

In order to evaluate the instrument panels (IPs) wrapped in leathers, the participants were provided guidance on several interaction methods. After interacting with the IPs using those methods, the participants rated how much each IP induced the feeling of each affective word. Interaction methods are divided into two subcategories. One sub-interaction method is the tactile interaction method, and the other sub-interaction method is the visual interaction method. Four types of interactions were used in tactile interaction: holding the palm on the surface, rubbing the surface with the palm, rubbing the surface with the fingertip, and pressing the surface with the fingertip. Three types of interaction were used in visual interaction: getting a closer look at the surface, viewing the surface from a distance as a whole, and viewing the surface at an angle. All participants used all the interaction methods mentioned above for each sample and then rated each affective word for each sample.

6.2.5. Evaluation Method and Questionnaire

In order to evaluate the affective evaluation words which are supposed to be associated with the IPs, semantic differential methods were used. Affective evaluation words were extracted from Chapter 3, and 22 questions were drafted by using them in the form of the semantic differential method. Each question is composed of a pair of words that have opposite meanings. Out of 22 word pairs, 20 pairs are identical with the affective words used in Chapters 4 and 5. The remaining two affective word pairs, 'Luxurious – Non-luxurious' and 'Like natural tactility – Like artificial tactility' are affective evaluation word pairs that measure the degree of 'luxuriousness' and 'natural tactility'. These two feelings are the target affects that are judged to be related to the leathers. When a participant evaluates a sample, they can select one of the 11 spaces between two words depending on the degree to which the sample causes the affect. The definition of each question is shown in Table 6.3.

Table 6.3. List of affective words and related parts

Evaluated part	Evaluation words
Overall surface	Bright colored – Dark colored
	Looking warm – Looking cool
	Polished – Not polished
	Warm – Cool
	Sticky – Not sticky
	Moist – Dry
	Slick – Not slick
	Rough – Smooth
	Rugged – Even
	Elastic – Inelastic
	Soft – Solid
	Stuffed – Hollow
	Wide spacing of embossed area – Narrow spacing of embossed area
	Large embossing – Small embossing
	Regular embossing pattern – Irregular embossing pattern
	Deep embossing – Shallow embossing
Edge	Large deformation in embossed edge – Small deformation in embossed edge
Bent	Bent with many wrinkles – Bent with only a few wrinkles
Stitch line	Stitch line matching well with material – Stitch line matching poor with material
Seam	Natural seams – unnatural seams
Overall IP	Luxurious – Non luxurious
	Like natural tactility – Like artificial tactility

Experimenters instructed participants in the evaluation experiment about the evaluation process. Each participant evaluated a total of 12 instrument panel samples which were wrapped in different leathers. The presentation order of samples was counter-balanced across participants to reduce the order effect, and participants evaluated each sample only once. They evaluated the samples through visual and tactile interaction methods, as described above. For each sample evaluation, the participants were instructed to perform all the seven interaction methods and then evaluate the sample. To minimize psychological and physical stress, every participant could take a break at any time they wanted. The total evaluation time was approximately 1 hour for each participant including the instruction and break time.

6.2.6. Selection of the Variables (Affective Words) for Cluster Analysis

On the basis of the results derived in Chapter 2, we selected 'luxuriousness' and 'natural tactility' as the target affect's determinant of the impression of the experiment participants about the IP leather sample. The cluster analysis was performed on the basis of the relationships between these two target affects and the product-specific affective vocabulary. Of the 20 affective words selected in Chapter 2, one word was chosen, and cluster analysis was performed on the basis of the relationships between this word and the two target affects. The criteria for selecting the affective word to be used as the basis for the cluster analysis were set on the basis of the results of Experiments 1 and 2. The affective words shown to have significant correlations in the statistical analysis obtained in Experiments 1 and 2 were 'Bright colored – Dark colored', 'Rugged surface – Even surface', and 'Large embossing – Small embossing'. Given that this study was designed to analyze one case, only one of these three words had to be chosen. The selection, which was performed in consultation with three affective engineering researchers, was 'Large embossing – Small embossing'. The term 'Large embossing – Small embossing' was predicted to have a greater influence because it is influenced by both visual and tactile senses, whereas 'Bright colored – Dark colored' is influenced by the visual sense alone, and 'Rugged surface – Even surface' by the tactile sense alone. Besides, given its association with the affective design parameter 'embossing', being more accurate and clear was predicted also in terms of the relationship with the design parameters.

6.3. Results

On the basis of the differences in the latent factors influencing the preference within the evaluator of customer, the customers were divided into two groups according to the evaluation pattern by cluster analysis. Regression analysis was performed for the two groups of customers and the expert group to grasp the affective structures of luxuriousness and natural tactility. From the result of the regression analysis, key design parameters that influence luxuriousness and natural tactility were identified. Detailed information of the results in these analysis is contained in Appendix D.

6.3.1. Regression Analysis for Customer before Grouping

In order to derive the affective structure for luxuriousness in the case of customers, a linear regression analysis was performed for the total raw data. The dependent variable was the score of luxuriousness, and the independent variables were the 20 affective evaluation words discussed above: Bright colored – Dark colored, Looking warm – Looking cool, Polished – Not polished, Warm – Cool, Sticky – Not sticky, Moist – Dry, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Large deformation in embossed edge – Small deformation in embossed edge, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material and Natural seams – Unnatural seams.

As a result, a total of four affective evaluation word pairs were found to have a significant effect on luxuriousness (Adj. $R^2 = 0.236$). The four significant affective word pairs were 'Sticky – Not sticky', 'Stitch line matching well with material – Stitch line matching poor with material', 'Natural seams – Unnatural seams' and 'Rough – Smooth'. Further, five affective evaluation word pairs were found to have a significant effect on the feeling of natural leather (Adj. $R^2 = 0.110$): 'Stitch line matching well with material – Stitch line matching poor with material', 'Large deformation in embossed edge – Small deformation in embossed edge', 'Natural seams – Unnatural seams', 'Rough – Smooth' and 'Deep embossing – Shallow embossing'.

6.3.2. Grouping Customers

In the case of experts, most participants rated leather samples consistently. Hence, certain samples were consistently well valued, whereas other specific leather samples were consistently poorly rated. Therefore, there was consistency in the types of samples that satisfied or failed to meet the target affects, which are natural tactility and luxuriousness. However, in the case of customers, preference for samples was different for each participant, with the result that no sample was consistently highly valued or poorly valued. The existence of this consistency represents the sophistication of the constructed model. Therefore, the constructed model derived from the experts had a high explanatory power, whereas the explanatory power of the model derived from the customers was not high.

This result is considered to be due to the fact that experts have consistent evaluation criteria, but the customers have more than two evaluation criteria. To increase the explanatory power of the model among the customers, the customer group was divided into several subgroups. The affective word, which is used as a basis for sub-grouping through cluster analysis, was determined as ‘Large embossing – Small embossing’ through the discussion in Chapter 6, Section 6.2.6. In the case of the experts, there was a tendency to evaluate luxuriousness and natural tactility only for samples with small embossing.

On the other hand, in the case of the customers, luxuriousness and natural tactility could be perceived highly in both the samples with small embossing and those with large embossing, and it was judged that luxuriousness and natural tactility were evaluated by applying different standards according to the size of the embossing. After customers determined the degree of luxuriousness and natural tactility, a cluster analysis was performed on the basis of the evaluation pattern when the size of the embossing was large and when it was small. On the basis of the result, the customer group was divided into two subgroups. Hierarchical cluster analysis, known as an exploratory cluster analysis method, was performed to determine the appropriate number of clusters.

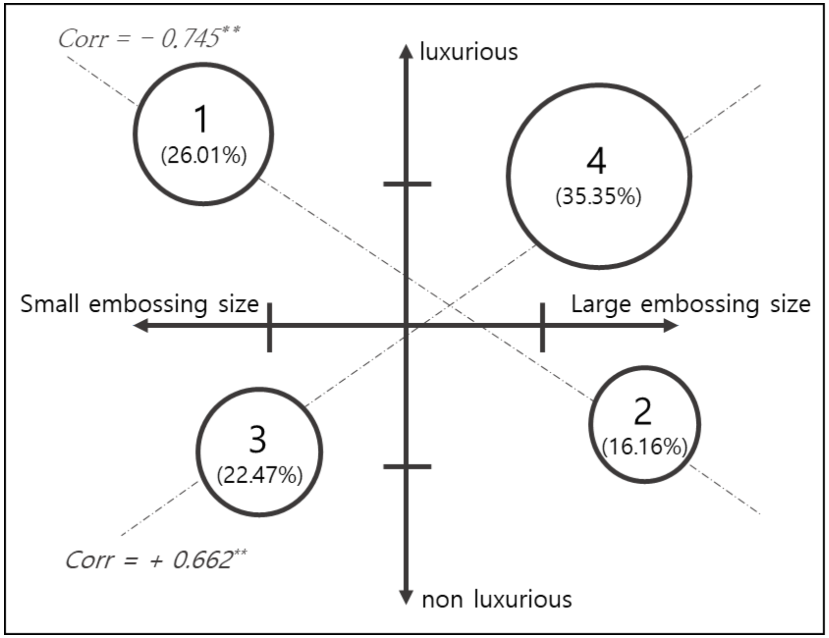
The variables to be analyzed were ‘Large embossing – Small embossing’, ‘Luxurious – Not luxurious’, ‘Large embossing – Small embossing’ and ‘Like natural tactility – Like artificial tactility’. Ward's method was adopted for the classification, as it has the advantage of dividing the size of each cluster equally as much as possible by minimizing the variation within the cluster. The disadvantage of this method is that it is greatly influenced by the outlier. However, this was compensated for by performing the outlier removal procedure before the analysis. The squared Euclidean distance, which is mainly used for Ward’s method, was utilized as a measure. As a result of the hierarchical cluster analysis, the customer evaluation group was classified into four clusters on the dendrogram for both luxuriousness and natural tactility. These four clusters can be divided into a cluster favoring small embossing, a cluster not favoring small embossing, a cluster favoring large embossing, and a cluster not favoring large embossing (Table 6.4).

Table 6.4. Scores of hierarchical cluster analysis of luxuriousness and natural tactility

	Cluster No.	Score of 'Large embossing'	Score of luxuriousness	Frequency
Luxuriousness	1	3.388	7.931	116
	2	7.361	4.500	72
	3	1.802	5.349	86
	4	8.180	7.287	122
	Cluster No.	**Score of 'Large embossing'**	**Score of natural tactility**	**Frequency**
Natural tactility	1	2.669	3.946	110
	2	8.517	3.034	98
	3	2.868	7.737	88
	4	7.705	6.932	100

Considering the number of clusters derived from the hierarchical cluster analysis, a K-means cluster analysis was performed. As with the hierarchical cluster analysis, 'Large embossing – Small embossing', 'Luxurious – Not luxurious', 'Large embossing – Small embossing' and 'Like natural tactility – Like artificial tactility' were chosen as the variables of the K-means cluster analysis. It was observed that the clusters derived from the K-means cluster analysis had the same meaning as those from the hierarchical cluster analysis, and the separation of the clusters became clearer. Luxuriousness was divided into a cluster that evaluated IPs as more luxurious when the embossment was felt to be smaller, and a cluster that evaluated IPs as more luxurious when the embossment was felt to be bigger.

Among them, the percentage of those that evaluated IPs as more luxurious when the embossment was felt to be bigger was 57.82%. Natural tactility was also divided into a cluster that evaluated the surface of IPs as having a more natural leather feel when the embossment was perceived to be smaller, and a cluster that evaluated the surface of IPs as having a more natural leather feel when the embossment was perceived to be bigger. Among them, the percentage of those that evaluated the surface of IPs as having a more natural leather feel when the embossment was felt to be bigger was 53.79% (Figure 6.3).



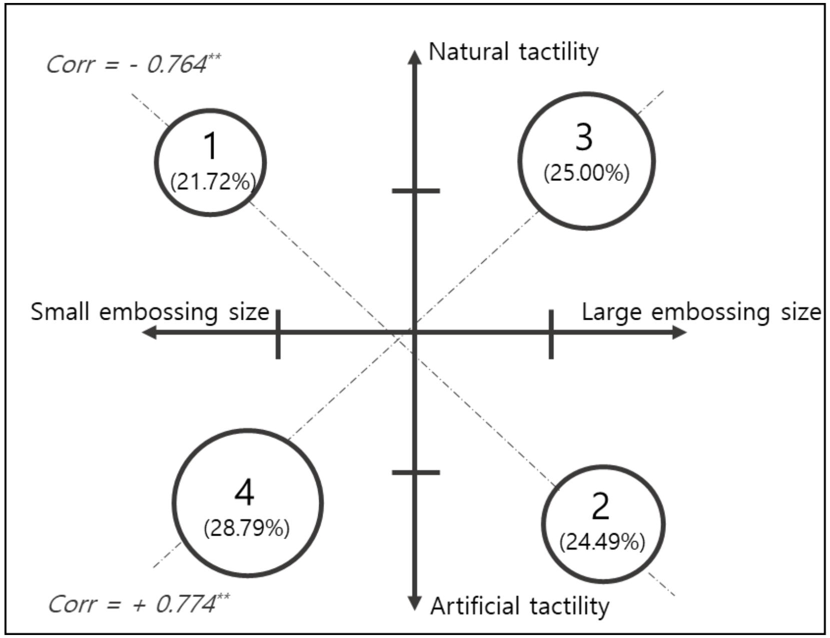


Figure 6.3. Analysis result of k-means clusters of luxuriousness and natural tactility

6.3.3. Regression Analysis

6.3.3.1. The Affective Structure of Luxuriousness

In order to derive the affective structure for luxuriousness, a linear regression analysis was performed for the total raw data. The dependent variable was the score of luxuriousness, and the independent variables were the 20 affective evaluation words discussed above: Bright colored – Dark colored, Looking warm – Looking cool, Polished – Not polished, Warm – Cool, Sticky – Not sticky, Moist – Dry, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, soft – Solid, Stuffed – Hollow, Wide spacing of embossed area – Narrow spacing of embossed area, Large embossing – Small embossing, Regular embossing pattern – Irregular embossing pattern, Deep embossing – Shallow embossing, Large deformation in embossed edge – Small deformation in embossed edge, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material and Natural seams – Unnatural seams. In the case of customer group 1, two affective evaluation words were found to have a significant effect on luxuriousness (Adj. $R^2 = 0.569$).

The two significant affective words were 'Large embossing – Small embossing' and 'Rough – Smooth'. Customer group 1 rated IPs as more luxurious when the embossment of leather was felt as smaller and smoother. In the case of customer group 2, three affective evaluation words were found to have a significant effect on luxuriousness (Adj. $R^2 = 0.490$). The three significant affective words were 'Large embossing – Small embossing', 'Sticky – Not sticky' and 'Stuffed – Hollow'. Customer group 2 rated IPs as more luxurious when it was felt that the embossment of leather was big, the surface of leather was non-sticky, and the inside of the leather was full.

In the case of the expert group, eight affective evaluation words were found to have a significant effect on luxuriousness (Adj. $R^2 = 0.454$). Comparing the number of affective words that influence the structure of luxuriousness, it was found that the expert group considers more affective factors when evaluating luxuriousness than customer groups do. The eight significant affective words were ‘Deep embossing – Shallow embossing’, ‘Rugged – Even’, ‘Slick – Not slick’, ‘Sticky – Not sticky’, ‘Moist – Dry’, ‘Soft – Solid’, ‘Natural seams – Unnatural seams’ and ‘Bent with many wrinkles – Bent with only a few wrinkles’. Among them, especially ‘Natural seams – Unnatural seams’ and ‘Bent with many wrinkles – Bent with only a few wrinkles’ had a very large effect on the structure of luxuriousness.

The expert group rated IPs as more luxurious when it was felt that the depth of the embossing of leather was shallow and flat, the surface of the leather was moist, soft, not slick, and not sticky, the joint of the leather has a sense of unity, and the bent surface of the leather has fewer wrinkles. This means that experts evaluated luxuriousness consistently and comprehensively by considering more affective factors than did the customers.

6.3.3.2. The Affective Structure of Natural Tactility

In order to derive the affective structure for natural tactility, a linear regression analysis was performed for the total raw data. The dependent variable was the score of natural tactility, and the independent variables were the 20 affective evaluation words used in the structure analysis of luxuriousness. In the case of customer group 1, four affective evaluation words were found to have a significant effect on natural tactility (Adj. $R^2 = 0.617$): ‘Large embossing – Small embossing’, ‘Deep embossing – Shallow embossing’, ‘Elastic – Inelastic’ and ‘Rough – Smooth’. Customer group 1 rated IPs as more like natural leather when it was felt that the embossment of the leather was small and shallow and the surface of the leather was elastic and soft. In the case of customer group 2, three affective evaluation words were found to have a significant effect on natural tactility (Adj. R^2 = 0.618).

The three significant affective words were ‘Large embossing – Small embossing’, ‘Slick – Not slick’ and ‘Stitch line matching well with material – Stitch line matching poor with material’. Customer group 2 rated IPs as more like natural leather when it was felt that the embossing of the leather was large, the surface of leather was not slick, and the stitch line matched the material well.

In the case of the expert group, seven affective evaluation words had a significant effect on natural tactility (Adj. R^2 = 0.407). As with the result of luxuriousness, compared to the customer groups, more affective evaluation words were selected as significant factors. The seven significant affective words were ‘Deep embossing – Shallow embossing’, ‘Rugged – Even’, ‘Slick – Not slick’, ‘Sticky – Not sticky’, ‘Moist – Dry’, ‘Natural seams – Unnatural seams’ and ‘Bent with many wrinkles – Bent with only a few wrinkles’.

The expert group rated IPs as having more natural tactility when it was felt that the embossing of leather was shallow and the surface of the leather was flat, moist, not slick and not sticky, the joint of leather had a sense of unity, and the bent surface of the leather had fewer wrinkles. It can be seen that the evaluation criteria of natural tactility are very similar to those of luxuriousness. In addition, the experts evaluated natural tactility by comprehensively considering various affective factors compared to the customers.

6.3.4. Developing Affect Prediction Model

The mathematical models for predicting the target affects (luxuriousness and natural tactility) were derived through design parameters and detailed affects (15 affective evaluation words). The effect of each design parameter related to the wrapping leathers of IPs on the target affects was estimated and compared.

6.3.4.1. Prediction Model of Luxuriousness

In the case of customer group 1, 'WVTR', 'roughness average (Ra)' and 'squeak' were derived as design parameters having a significant effect on luxuriousness. The greater the value of WVTR, the smaller the value of Ra, and the greater the value of softness, the more luxuriousness was felt. Of the three design parameters, the influence of Ra was greatest (47.74%), the influence of WVTR was 33.65%, and the influence of squeak was 18.61%. The explanatory power of the design parameters was 81.8% (Adj. R^2=0.818).

$$\text{Luxuriousness} = 7.535 - 0.286 * \text{Ra} + 0.004 * \text{WVTR} + 1.399 * \text{squeak}$$

In the case of customer group 2, 'squeak', 'absorbency' and 'softness' were derived as design parameters having a significant effect on luxuriousness. The smaller the value of squeak and softness and the greater the value of absorbency, the more luxuriousness was felt. Of the three design parameters, squeak (34.80%) had the greatest influence, and the influences of the remaining two design parameter were as follows: absorbency (33.96%) and softness (31.24%)). The explanatory power of the three design parameters was 60.9% (Adj. R^2=0.609).

$$\text{Luxuriousness} = 10.880 - 1.309 * \text{squeak} + 1.362 * \text{absorbency} - 1.383 * \text{softness}$$

In case of the expert group, 'roughness average (Ra)' and 'WVTR' were derived as design parameters having a significant effect on luxuriousness. The greater the value of WVTR and the smaller the value of Ra, the more luxuriousness was felt. Of the two design parameters, Ra (61.10%) had greater influence than WVTR (38.90%). The explanatory power of the two design parameters was 70.0% (Adj. R^2=0.700).

$$\text{Luxuriousness} = 7.118 - 0.215 * \text{Ra} + 0.003 * \text{WVTR}$$

6.3.4.2. Prediction Model of Natural Tactility

In the case of customer group 1, 'roughness average (Ra)', 'WVTR' and 'squeak' were derived as design parameters having a significant effect on natural tactility. The smaller the value of Ra and the greater the value of WVTR and squeak, the more natural tactility was perceived. Of the three design parameters, Ra (47.38%) had the greatest influence on natural tactility. The influence of WVTR was 28.71%, and the influence of squeak was 23.91%. The explanatory power of the three design parameters was 73.8% (Adj. R^2=0.738).

$$\text{Natural tactility} = 7.037 - 0.288 * \text{Ra} + 0.004 * \text{WVTR} + 1.829 * \text{squeak}$$

In the case of customer group 2, ‘squeak’, ‘roughness average (Ra)’ and ‘softness’ were derived as design parameters having a significant effect on natural tactility. The smaller the value of squeak and softness and the greater the value of Ra, the more natural tactility was felt. Of the three design parameters, the influences of Ra and squeak were similar: Ra (37.71%), squeak (37.65%). The influence of softness was 28.64%. The explanatory power of the three design parameters was 69.1% (Adj. R^2=0.691).

$$\text{Natural tactility} = 11.158 + 0.161 * \text{Ra} - 1.811 * \text{squeak} - 1.811 * \text{softness}$$

In the case of the expert group, ‘roughness average (Ra)’ and ‘WVTR’ were derived as design parameters having a significant effect on natural tactility. The smaller the value of Ra and the greater the value of WVTR, the more natural tactility was felt. Ra (59.59%) had greater influence than WVTR (40.41%). The explanatory power of the two design parameters was 59.4% (Adj. R^2=0.594).

$$\text{Natural tactility} = 6.828 - 0.244 * \text{Ra} + 0.003 * \text{WVTR}$$

6.4. Discussion

This study proposed a method to provide more significant results by enhancing the explanatory power of a model and experimentally tested the proposed method by means of a case study. The proposed method was designed to select one affective word from the candidate words and to perform a cluster analysis of the selected affective word and the target affects, followed by the derivation of affective and predictive models from the performance of the subgroups based on the results of the cluster analysis. The product used for case study was a leather car instrument panel (IP).

The results obtained from the pre-cluster all-group models had low explanatory power: 23.6% for the luxuriousness model and 11.0% for the natural tactility model. In contrast, in the affective models, which were derived from the two subgroups formed through the cluster analysis, the luxuriousness models of Group 1 and Group 2 showed explanatory powers of 56.9% and 49.0%, respectively, and the natural tactility models, 61.7% and 61.8%.

This verified that the proposed method, which divides the general user group into subgroups in accordance with product-specific criteria, is capable of constructing a model with high explanatory power. However, this method also has a blind spot. An affective word used as a reference evaluation word for a cluster analysis invariably has higher influence. With regard to the target affect 'luxuriousness', 'Large embossing – Small embossing' and 'Rough – Smooth' were found to have a significant influence on the affective model for 'luxuriousness' in Subgroup 1, and 'Large embossing – Small embossing', 'Sticky – Not sticky', and 'Stuffed – Hollow' in Subgroup 2. In both groups, only 'Large embossing – Small embossing' was found to have a significant influence, with 78.77% and 69.40% on the two models, respectively. With this considerable influence, 'Large embossing – Small embossing' contributed to enhancing the explanatory power of the entire model.

This result shows the advantage inherent in the proposed method, because the user group is divided into subgroups on the basis of the affective word, thus exhibiting the relationship between the corresponding affective word and the target affect more clearly. In this method, consequently, the affective word selected is likely to influence the affective model irrespective of the selection. In other words, in using the proposed method, it is essential to decide the selection of affective words and the applicable selection criteria for a cluster analysis in order to create an efficient affective model with higher explanatory power.

The affective words as the criteria for the cluster analysis should be the words that are crucial for the expression of the corresponding product's target affects and predicted at the outset to show clear evaluation results. These conditions should be met first as the prerequisites for supporting the strong explanatory power of the affective words. For this reason, 'large embossing – small embossing' was selected as the basis for the cluster analysis from the candidate affective words that yielded significant results in Experiments 1 and 2, because it was expected to exert a great influence on the target affects.

The method used to derive an affective model by performing a cluster analysis based on a specific affective word can be viewed from a different perspective, although using only the affective word selected under specific criteria was presented above as a kind of guideline. If a product designer or an experimenter (researcher) considers a certain affect important, an affective model that reflects the great influence of that specific affect can be constructed by performing a cluster analysis based on an affective word associated with that affect. For example, if a product designer wants to apply the users' impression of the embossing size to the envisaged affective model, 'Large embossing – Small embossing' can be used as the criterion for clustering the entire user group into subgroups and to derive affective models on the basis of the results.

The product designer may draw, for example, the following conclusions based on the affective models derived from the subgroups: if users feel that the embossing on the leather IP too small, the surface should feel softer to amplify the luxuriousness of the leather IP; if users feel that the embossing on the leather IP too small, the surface texture should be rendered less sticky and the subsurface should feel more stuffed when pressed down to enhance the luxuriousness of the leather IP. To put it briefly, if a product designer wants to apply the affect to a product in such a way as to highlight that affect and thereby enhance user satisfaction, the designer can learn from the way other affects are applied in the proposed methodology.

In this paper, not only is the method shown to enhance the explanatory power of a user group model, but a comparison is made among the affective and predictive models derived from the user subgroups and the expert group. One of the noticeable differences between the user group and the expert group was the size of the explanatory power. The explanatory power for the affective models derived from the pre-cluster user group was 23.6% for luxuriousness and 11.0% for natural tactility, whereas it was 45.4% and 40.7%, respectively, for the expert group. The performance gap between the user group and the expert group ranges between 20 and 30%. As mentioned above, the expert group's higher performance is assumed to be attributable to better evaluation coherency and a better match between product understanding and affective vocabulary.

Another difference between the user and expert groups relates to the number of explanatory variables. The models derived from the expert group used more variables in explaining the models: for luxuriousness, the expert and user groups used eight and four affective words, respectively, to explain their respective models. Subgroups 1 and 2 used only two and three affective words, respectively, for model explanation. In the case of natural tactility, the expert and user groups used seven and five affective words, respectively, to explain their respective models. Subgroups 1 and 2 used only four and three affective words, respectively, for model explanation. This difference may be explained by the experts' professionalism of taking more affective elements into account when evaluating their impression of a product.

They have also gained and accumulated more project-specific knowledge and experience, which is reflected in their practice of using more diverse and differentiated terms. This can be compared to the fact that a sommelier, a wine professional, uses a wealth of terms and expressions when evaluating wine compared with a non-professional wine taster (Solomon, 1990).

Table 6.5. List of affective words that have a significant effect on models

Affect	Affects that have a significant effect on affective model of luxuriousness			Affects that have a significant effect on affective model of natural tactility			Number of groups
	Customer group 1	Customer group 2	Expert group	Customer group 1	Customer group 2	Expert group	
Soft			O				1
Moist			O			O	2
Bent with many wrinkles			O			O	2
Sticky		O	O			O	3
Elastic				O			1
Slick			O		O	O	3
Rough	O			O			2
Stuffed		O					1
Stitch line matching well with material					O		1
Deep embossing			O	O		O	3
Large embossing	O	O		O	O		4
Natural seams			O			O	2
Rugged			O			O	2

Another feature of the study is that there are few overlapping affective words between the customer groups and expert group in the affective model (Table 6.5). In the case of luxuriousness, only ‘Sticky – Not sticky’ was found to overlap customer group 2 and the expert group. In the case of natural tactility, only ‘Slick – Not slick’ overlapped customer group 1 and the expert group, and only ‘Deep embossing – Shallow embossing’ overlapped customer group 2 and the expert group. The difference in affective models between the customer groups and the expert group means that the popular preference differs from the preference of the experts who design the product in the actual field. This means that even if experts design products according to their own subjective judgment, the products cannot satisfy general customers. From this point of view, the result shows the necessity of affective evaluation for general customers.

Chapter 7. Developing a Positioning Map

7.1. Introduction

Positioning refers to a consumer's perception of a certain product, service, or brand that arises from the image built in the customer's mind (Trout & Ries, 1986). Consumers have different perceptions of the same product. That is too say, positioning is not limited to brand-customer relationships, but it also applies also to inter-brand relationships of comparing and competing with other products of the same type against a criterion or yardstick (Aaker & Shansby, 1982). Positioning map is a method of representing consumers' perceptions of goods or services in a two- or three-dimensional space based on the concept of positioning. Consumers' perceptions of a product can be visually represented on a positioning map, where the relative positions of the competing products are also visually mapped. Positioning the products of the same type in the same space provides some useful insights.

First, the relative positions between one's own and competitor's products can be identified. By comparing the relative positions, the cause(s) inducing customers' differentiated perceptions of the competing products can be inferred, and it is possible to specify a sort of blue ocean. If a blank location that is not occupied by any product is spotted on the positioning map, it may be considered whether a product launched there will turn out to be a market success. Lastly, a company can gauge the position toward which a product should be geared. If the attributes of a product considered desirable by consumers are the component elements of the dimension of the positioning map, the specific position of the positioning map will be the location where the product attributes are combined ideally. As examined, a positioning map is used as an effective marketing tool by visually representing consumers' different relative perceptions of a product.

The datasets for affective evaluation extracted in Experiment 3 also have a structure that lends itself well to generating a positioning map because each of the twelve samples has its own values with respect to various affects. Taking account of the product-specific affects can also be considered an advantageous marketing strategy. In view of these features, creating a positioning map that takes the affective elements of a product as a dimension is an analytical method that goes well with the goal of affective engineering methodology, which can be epitomized as "product development considering affect."

In this study, a positioning map was created using the data derived from the evaluations made in Experiment 3, whereby a component analysis was employed to reduce the number of the affective words, i.e., the number of variables for creating a positioning map. Then the positioning map was generated via multidimensional scaling based on the mean component score of each sample. The meaning of each dimension in this two-dimensional positioning map was deduced via correlation analysis. Additionally, we verified the correlation between the dimensions of the positioning map and "luxuriousness" and "natural tactility," which were selected as the target affects in the initial affective evaluation, by performing a correlation analysis between the luxuriousness and natural tactility scores obtained by the three groups (user subgroups 1 and 2 and the expert group) in Experiment 3 and the sample scores on positioning dimensions.

Table 7.1. List of affective words that have a significant effect on model

Affect	Affects that have a significant effect on affective model of luxuriousness			Affects that have a significant effect on affective model of natural tactility			Number of groups
	Customer group 1	Customer group 2	Expert group	Customer group 1	Customer group 2	Expert group	
Soft			O				1
Moist			O			O	2
Bent with many wrinkles			O			O	2
Sticky		O	O			O	3
Elastic				O			1
Slick			O		O	O	3
Rough	O			O			2
Stuffed		O					1
Stitch line matching well with material					O		1
Deep embossing			O	O		O	3
Large embossing	O	O		O	O		4
Natural seams			O			O	2
Rugged			O			O	2

7.2. Principal Component Analysis

Principal component analysis was performed to group various significant affective words to smaller number of groups to improve the understanding of the result of multi-dimensional scaling analysis. In chapter 6, among initially selected 20 affective words, 13 affective words were found to have a significant effect on the affective models. So the 13 affective words were selected for the principal component analysis. The selected words are as follows; Sticky – Not sticky, Moist – Dry, Slick – Not slick, Rough – Smooth, Rugged – Even, Elastic – Inelastic, Soft – Solid, Stuffed – Hollow, Large embossing – Small embossing, Deep embossing – Shallow embossing, Bent with many wrinkles – Bent with only a few wrinkles, Stitch line matching well with material – Stitch line matching poor with material, Natural seams – Unnatural seams (Table 7.1). The raw data of the customers and experts for 13 affective words were analyzed in the principal component analysis. And varimax rotation method was used.

As a result of analysis, 13 affective words of wrapping leathers of instrument panel was grouped into 4 components. The 4 components were as follows; surface-related characteristics, elasticity-related material characteristics, the feeling about overall completeness and humidity-related material characteristics. The affective words which belong to component 1 (surface-related characteristics) were 'Rugged – Even', 'Rough – Smooth', 'Large embossing – Small embossing', 'Deep embossing – Shallow embossing' and 'Slick – Not slick'. The affective words which belong to component 2 (elasticity-related material characteristics) were 'Stuffed – Hollow', 'Elastic – Inelastic', 'Soft – Solid' and 'Bent with many wrinkles – Bent with only a few wrinkles'. The affective words which belong to component 3 (the feeling about overall completeness) were 'Stitch line matching well with material –

Stitch line matching poor with material' and 'Natural seams – Unnatural seams'. Finally, the affective words which belong to component 4 (humidity-related material characteristics) were 'Sticky – Not sticky' and 'Moist – Dry'. Details of the results of the principal component analysis are shown in Table 7.2. And overall process of component analysis is shown in Appendix E.

Table 7.2. The result of principal component analysis

Principal Component	Affective word	Component			
		1	2	3	4
Surface -related characteristics	Rugged	.822	.000	-.055	.121
	Large embossing	.806	-.020	-.020	.169
	Rough (smooth)	.784	.004	-.039	.016
	Deep embossing	.772	-.071	-.001	.117
	Slick	-.474	-.135	.028	.172
Elasticity -related material characteristics	Stuffed	-.038	.806	.175	-.048
	Elastic	.084	.725	.230	.090
	Soft	-.165	-.606	.283	.093
	Bent with many wrinkles	.319	-.397	.055	-.043
Feeling about overall completeness	Stitch line matching well with material	.010	.025	.805	-.015
	Natural seams	-.069	.088	.777	-.111
Humidity -related material characteristics	Moist	-.042	.071	.040	.886
	Sticky	.222	-.070	-.191	.723

7.3. Multi-dimensional Scaling Analysis

Kruskal's non-metric multi-dimensional scaling (NMDS) was performed on the mean scores (Table 7.3) obtained from the principal component analysis of each sample derived in 7.2. The analysis results for the 12 samples are plotted on a two-dimensional (2D) map (Figure 7.1). The meaning of each dimension of the 2D map was worked out by calculating the correlation between the mean component score of each sample and the value of each dimension (Table 7.4). The correlation analysis revealed the values of the coordinates of dimension 1 to be significantly correlated with component 1 and 4 ($p<.05$), and those of dimension 2 with component 1 and 2, through without reaching a significance level of .05.

Table 7.3. The list of mean value of component score for each sample

Sample No.	Component 1 score	Component 2 score	Component 3 score	Component 4 score
1	-0.5575	0.1827	0.1631	0.0649
2	0.7971	0.1213	-0.1443	0.0786
3	-0.5846	-0.3551	0.1566	-0.1716
4	-1.1115	0.5090	-0.1918	-0.1802
5	-0.2690	-0.2078	0.0447	-0.1103
6	0.8917	0.1219	-0.1053	0.0763
7	0.6078	-0.0495	-0.1173	0.2132
8	-0.6150	-0.2500	-0.0242	0.0135
9	0.6404	-0.2318	0.0926	0.2340
10	-1.1427	-0.0841	0.1077	-0.3745
11	0.6283	-0.2481	0.3764	0.2423
12	0.7567	0.4756	-0.3527	-0.0728

Table 7.4. Correlation between component scores and coordinate values of dimensions

		The coordinate value of dimension 1	The coordinate value of dimension 2
Surface -related characteristics	Correlation Coefficient	-.990**	-.526
	Significance Probability	.000	.079
Elasticity -related material characteristics	Correlation Coefficient	-.085	.551
	Significance Probability	.792	.063
Feeling about overall completeness	Correlation Coefficient	.213	-.304
	Significance Probability	.506	.337
Humidity -related material characteristics	Correlation Coefficient	-.758**	-.419
	Significance Probability	.004	.176

* p<.05, ** p<.01

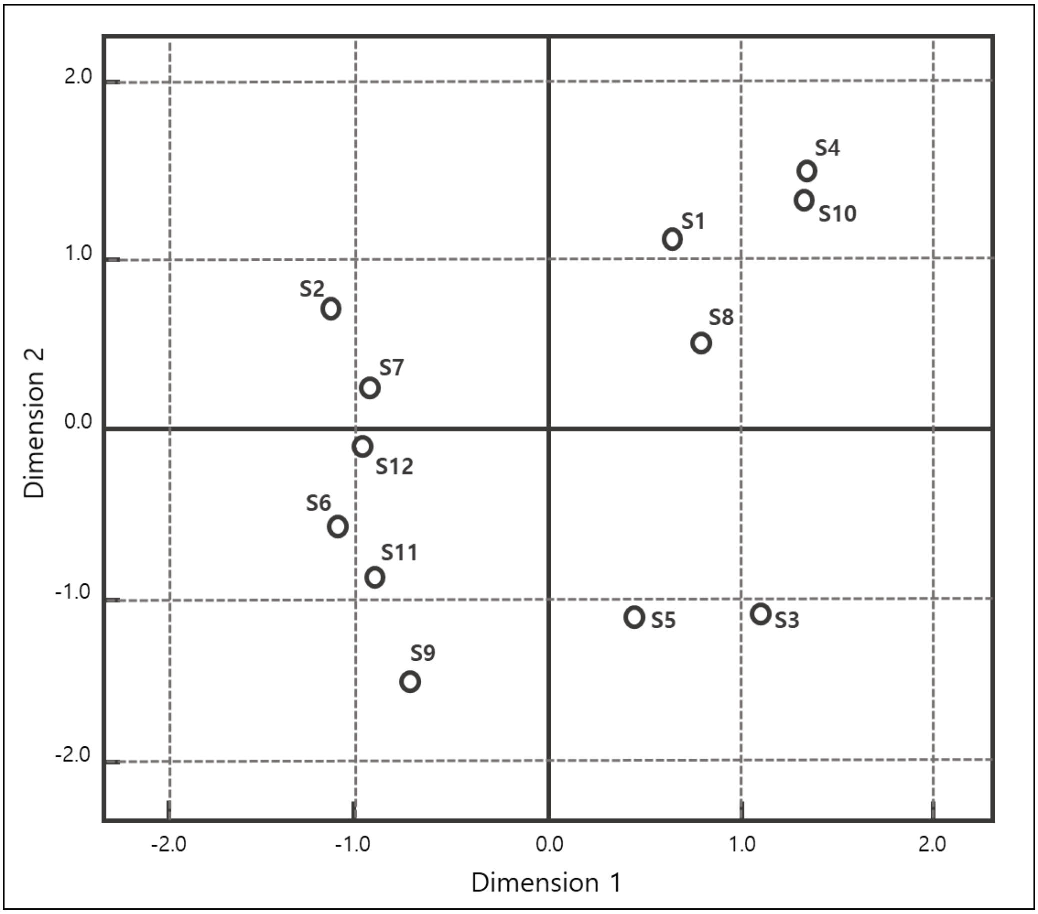


Figure 7.1. 2-dimensional positioning map from NMDS

7.4. Discussion

This study presented the process of generating a positioning map using the data obtained from the affective evaluations performed in Chapter 6. The relative positions of the 12 samples on the 2D plane were identified based on principal component analysis and non-metric multi-dimensional scaling. The meaning of each dimension of the 2D plane was identified by calculating the correlations between the mean component score and the values of the correlates of each dimension, and the results allowed the conclusion that dimension 1 can be defined as an effective dimension resulting from complex interactions between surface characteristics (component 1) and humidity-related material characteristics (component 4).

Of them, the surface characteristics (component 1) were estimated to be associated with the degree of softness of the surface, given the affective words constituting the related component. As for dimension 2, we conclude that it is an effective dimension resulting from complex interactions between surface characteristics (component 1) and elasticity-related material characteristics (component 2), albeit without statistical significance. This conclusion suggests that dimension 2 is also associated with the degree of surface softness. If dimension 1 is the affect associated with the tactile sensation and softness when brushing the surface with the hand, dimension 2 can be regarded as the affect associated with the interaction between the elasticity and softness of the surface when applying pressure on it.

In Chapter 3, when deriving the affective structure, smoothness was identified as the most important affective sub-element constituting the target affect luxuriousness. The results obtained in Chapter 3 can be verified to be consistent with the definitions made of the two dimensions of the positioning map generated in this study, since the association between smoothness and the affects of both dimensions was verified by the results obtained by reducing the dimensions for the 13 sub-affects to two dimensions verified. Although “visual” was found to outweigh tactile sense among the senses interacting with the product in Chapter 3, the overall interpretation made in this study gives more weight to touch. Component 3, which was found to be closely correlated with “visual” (visual aesthetics, feeling about the overall completeness), was not found to have a significant influence as a result of correlation analysis. Of the sub-elements pertaining to component 1 (surface-related characteristics), “large – small embossing” was found to be the only variable related to “visual,” which allows the assumption that the element that has the largest influence on “visual” is the size of embossing.

In Chapter 3, luxuriousness and natural tactility were selected as the target affects for the car instrument panel (the IT) based on the affective structure. Since luxuriousness and natural tactility were assumed to form sub-affects in Chapter 3, we identified their relationships with each dimension on the positioning map and the target affects. Given that the two dimensions of the positioning map were also derived by reducing the 13 sub-affects to two dimensions, it was judged that the correlation between the dimensions of the positioning map and the two target affects or absence thereof can be considered a method to validate the decision on the affective structure constructed in Chapter 3. As scores of luxuriousness and natural tactility, we used the score obtained for each sample in the affective evaluations made in Chapter 6.

Table 7.5. Correlation between luxuriousness / natural tactility and coordinate values of dimensions

			The coordinate value of dimension 1	**The coordinate value of dimension 2**
Luxuriousness	Customer group 1	Correlation Coefficient	.968**	.471
		Significance Probability	.000	.122
	Customer group 2	Correlation Coefficient	-.887**	-.257
		Significance Probability	.000	.419
	Expert group	Correlation Coefficient	.915**	.553
		Significance Probability	.000	.062
Natural tactility	Customer group 1	Correlation Coefficient	.975**	.376
		Significance Probability	.000	.228
	Customer group 2	Correlation Coefficient	-.956**	-.565
		Significance Probability	.000	.055
	Expert group	Correlation Coefficient	.921**	.497
		Significance Probability	.000	.100

* $p<.05$, ** $p<.01$

In the same manner that the general user group was divided into two subgroups in Chapter 6, a correlation analysis was performed between the scores of each of the three groups (user subgroup 1, user subgroup 2, and expert group) for luxuriousness and natural tactility and the dimension scores of each sample. The results are outlined in Table 7.5.

The analysis revealed dimension 1 to be significantly correlated with the scores for luxuriousness and natural tactility in all reviewer groups ($p<.05$). On the contrary, dimension 2 was significantly correlated with none of the cases. When the significant level was elevated to p=0.1, statistically significant results were yielded for natural tactility in general user subgroup 2, and for luxuriousness and natural tactility in the expert group. A positive correlation was found between the scores for dimension 1 and luxuriousness in general user subgroup 1 and the expert group, and a negative correlation was found between the scores for dimension 1 and luxuriousness of general user subgroup 2. This demonstrates that the perception of luxuriousness about the IT can be extremely different among genera users. This leads to the interpretation that general user subgroup 1 and the expert group prefer samples with soft, not sticky, and elastic material, whereas general user subgroup 2 rough, sticky, and flexible material.

Of the 12 samples, Sample #4 was made of real leather; it scored highest in both dimensions on the positioning map, i.e., real leather was evaluated as the material that gives the most luxurious look in by the criteria of general user subgroup 1 and the expert group. This can be brought into context with the selection of natural tactility in relation to material luxuriousness when deriving the target affects in Chapter 3.

Chapter 8. Conclusion

8.1. Summary of Study and Findings

This paper proposed methods to refine affective evaluation in five sub-studies related to affective evaluation and experimentally verified the processes leading to the results by applying the proposed methods to the affective evaluation of a car instrument panel (IT). The method to refine an evaluation process was proposed in three categories. The quantitative analysis method proposed as the first category can serve as a useful tool in expert decision-making during an affective evaluation. Expert affective evaluation is usually made by subjective judgement, and this method was proposed to address the drawback of subjective judgement. The study related to the first category was discussed in Chapters 3,4, and 5. The second category proposed was a method to enhance the effects of affective evaluation results. Here, effect refers to the degree of influence on the evaluation results when applying the evaluation results to product design and development processes in real settings. The study related to the second category was discussed in Chapter 6. As the third and last category, a new analysis method using the data extracted from affective evaluation in addition to conventional affective evaluation results. This method was designed as a method to make a more intensive use of the affective evaluation data collected at high cost, not limiting their use to deriving conventional evaluation results. The study related to the third category was discussed in Chapter 7.

In Chapter 3, we performed a network analysis based on online review data, proposed a process for constructing an affective structure with the analysis results applicable to an affective evaluation, and performed a case analysis using the IT as the review product. From the test drive reports collected from a relevant website, we extracted the texts related to the IT. After preprocessing the extracted texts and merging similar meaningful units together, we extracted 24 keywords and performed a network analysis on them, constructed a network, calculated the centrality values of each keyword, and checked the occurring frequency of each keyword. From the IP review analysis results, the leather material was decided as the IP product review object and luxuriousness was selected as the related affect along with the conclusion. Then it was concluded that the target affect luxuriousness can be composed of various affective sub-elements including smoothness and that natural tactility can be regarded as another target affect with respect to the luxuriousness of leather.

In Chapter 4, it was quantitatively examined whether the set of affective words selected in the affective engineering process can be used for affective evaluation. To this end, two evaluation criteria for term validity were established. One of them is term understandability designed to evaluate how well an experiment participant understands the affective words encountered while dealing with evaluation samples. The other is the inter-sample differentiability designed to evaluate how each of multiple samples differentiates itself from other samples in terms of the corresponding affect. To achieve the goal of this study, i.e., a quantitative analysis of the validity of affective words, we proposed five affective word analysis methods with respect to the two evaluation criteria presented above and verified the results of these five analysis methods based on the results of the affective evaluation of the IT's leather surface. The analysis yielded the finding that the affective words were not neatly divided into two groups of satisfying or failing all five analyses. Instead, the number of analyses satisfied varied between five (100%) and zero from an affective word to another. Based on the results of this quantitative analysis, the affective words could be given their respective rankings according to the number of the analyses satisfied.

In Chapter 5, a quantitative analysis was performed to determine which of the three commonly used semantic differential methods is best-suited for affective evaluation. To this end, we proposed three quantitative analysis methods based on statistical analysis and verified the degree of suitability of each semantic differential method for affective evaluation via case study using a leather IT. First, ANOVA (the Kruskal-Wallis test) was performed to check the number of the affective words that yielded significant inter-sample score differences in each method, on the assumption that the evaluation method the yields the greatest inter-sample score differences would produce evaluation results most accurately and clearly. The ANOVA revealed the relative evaluation type as the one that yielded the highest number of significant affective words. Then we performed a post hoc analysis to find out in how many groups the samples are divided in each method, on the assumption that the method that yields the largest number of sample groups would be the one with the highest discriminatory power and thus produce evaluation results most accurately and clearly. The post hoc analysis also revealed the relative evaluation type as the one that yielded the highest number of groups. Lastly, we performed a correlation analysis to compare each semantic differential method via correlations between design variables and affective words, on the assumption that the method that shows more clearly the correlations between design variables and affective words to be used for evaluation would be the more efficient method, given that the final product of affective evaluation is providing design guidelines considering affect. In the correlation analysis results, all three types yielded similar numbers of the affective words showing significant results. However, the relative evaluation type was observed to yield greater correlations than the other two methods. From the results of these three statistical analyses, the relative evaluation type was confirmed to be best-suited for affective evaluation. However, in terms of time to evaluation, the relative evaluation type can turn out to be inappropriate, given the limited time and cost that can be invested in affective evaluation. There is a need for the experimenter to actively decide whether to choose a relative or absolute evaluation type taking into account the number of the samples to be used for evaluation, the number of the affective words to be used for evaluation, and the number of the persons participating in the experiment. If there are large numbers of samples, participants, and affective words, a relative evaluation type prolongs evaluation time and is likely to disturb the flow of an efficient experiment.

In Chapter 6, we proposed a method to enhance the explanatory power of a model derived through affective evaluation. Unlike expert reviewers, general users have no consistent evaluation criteria and are less likely to obtain affective and predictive models with high explanatory power. To address this problem, we proposed a method to divide the sample evaluation cases of the user group among two or more subgroups based on specific criteria and to derive affective and predictive models from each subgroup. This method was experimentally tested by applying to the evaluation of a leather car instrument panel (IT), and the proposed method was confirmed to enhance the explanatory power of a model. Additionally, the models derived from the general user and expert groups were compared in this chapter. As a result, it was confirmed that the models derived from the expert group were more efficient for affective quality design in terms of the magnitude of explanatory power and the diversity of variables explaining the model, presumably due to the fact that experts have accumulated more product-specific knowledge and experience and have been intensely engaged at the product design and production stages.

In Chapter 7, a positioning map was generated using the data collected via the evaluation made in Chapter 6. We extracted four components by performing a principal component analysis on the 13 affective words verified to have significant influences on affective models. These four components were labeled as surface-related characteristics (component 1), elasticity-related material characteristics (component 2), feeling about the overall completeness (component 3), and humidity-related material characteristics (component 4). We generated a 2D positioning map after performing non-metric multi-dimensional scaling using the average component score of each sample, and identified the position of each sample on the 2D plane. The relationships between each dimension and component scores and those between each dimension and the luxuriousness and natural tactility scores were identified, which led to various discussions. A high correlation between dimension 1 and both the target affects, luxuriousness and natural tactility, was confirmed, and real leather was found to have the highest positive correlations with luxuriousness and natural tactility.

8.2. Contribution and Limitation

The contributions of this paper to the field of affective engineering can be summarized as follows: it proposed a new analysis method as an additional asset of the traditional affective engineering methodology, thus increasing the reliability and validity of the methodology itself and enhancing the efficiency of the results yielded by the methodology, and proposed a new analysis area thus far left unconsidered in the traditional affective evaluation methodology. Its two main limitations are the problem of generalizability, because it drew conclusion from one case study, and the researcher's burden related to actual affective evaluation due to additional analyses.

The affective structure for product characteristics and product-specific attributes could be elucidated in Chapter 3, which presented an online review data analysis method based on a network analysis. This is expected to serve as a useful data for review experts when making important decisions such as selecting major affects to be used for affective evaluation and deriving the related affective words. Using freely available online text data, it was possible to identify the overall impression or affective structure regarding a specific product. However, the following can be pointed out as minor limitations of this study: the sample size was small with 49 text data; the preprocessing of converting the raw data obtained on the internet into data amenable to network analysis is complicated and involves human resources; the shape of the affective structure varies from one researcher to another because an affective structure is constructed by the researchers subjective decision-making based on the analysis result data.

In Chapter 4, five methods to analyze the validity of affective words under two criteria were proposed and the validity level of each affective word could be determined. On the assumption that an affective word has a higher validity if it satisfies a higher number of analysis methods, it was checked how many analyses (out of five) an affective word satisfies. In this regards, the significance of this study lies in the fact that a priority order of the affective words to be used for evaluation was set so that a research has only to look at it to select affective words. To derive this result, however, it is necessary to carry out preliminary affective evaluation on a set of candidate affective words. That is, resources should be put into the preliminary evaluation at a level equivalent to the major evaluation, to derive the validity rankings of the candidate affective words. The need to carry out an additional evaluation with limited resources is inevitably an additional burden placed on the researcher.

Regarding the analysis method, two of the five analysis methods were related to coefficient of variance (CV). CV is a kind of standardization work to compare groups when the scale of the group is not the same. In this chapter, the reason for applying analyses using CV was that it cannot be known whether the scale of each affective word is the same. And because the mean value of each affective word is different, CV was used as a means to standardize it. However, it is necessary to discuss whether the scale is different for each affective word. The reason for assuming that each affective word has different scale in this study is because it appears that there are affective words which have different dimensions. For example, 'Rough – Smooth' and 'Stitch line matching well with material – Stitch line matching poor with material' are thought to have different dimensions. 'Rough – Smooth' is an affect which is felt instantly by sensation, while 'Stitch line matching well with material – Stitch line matching poor with material' is an affect derived through the subjects' thoughts. If there are is no difference in dimension of affective word, it is considerable to exclude the CV-related analyses.

In Chapter 5, the three semantic differential methods used for affective evaluation were compared, which allowed to determine the method type suitable for affective evaluation. As the first attempt ever to compare the performances of the three semantic differential methods under the same conditions, this study is significant in that it performed the first comparison study and verified the performance rankings among the semantic differential methods. It was also verified that the semantic differential method suitable for affective evaluation can vary according to the numbers of the samples used, affective words, and participants. However, instead of measuring the performance time of each semantic differential method, it was only numerically estimated, which also count towards the limitations of this study.

The motive for conducting the study described in Chapter 6 was the difficulty associated with deriving affective and predictive models with an adequate explanatory power through affective evaluation due to insufficient consistency in evaluation criteria among general users compared with experts. The proposed analysis method, in which the sample evaluations are performed by subgroups divided according to specific criteria, was tested in a case study and its effect of increasing the explanatory power was verified in real models. This method may be thought to be inadequate to be easily applied to real analysis, given that it is an artificial method and the resulting models can considerably vary depending on the subdivision criteria. Viewed from a different angle, however, this may serve as a new paradigm for analyzing affective models of user groups. Instead of checking which variables are significant in an experimentally derived model, a product designer can directly derive a model considering a strategically targeted specific variable. Using this method, a product design for improving affective quality while emphasizing a specific variable can be implemented. In the comparison of the models stemming from general users and experts, a significant difference in the number of variables influencing the model was observed. If this difference is due to the different points of view between users and experts, the expert model, however high its explanatory power is, cannot be regarded as representing actual users of the product. Therefore, there is a need to find a method to explain the affective quality of a product with an integrated model so that the user and expert models can play their respective roles in a mutually complementing manner.

In Chapter 7, we could generate a positioning map and identify the relative positions of the samples on a 2D plane. A positioning map can provide a visual guideline for the direction of the development and improvement of a current product if there is a product worthy of benchmarking or a directionality for product development is observed. However, when generating a positioning map, a considerable amount of information is expected to get lost in the process of reducing the 13 sub-affects to two dimensions. It is recommendable to find a method to ascertain the level of information lost or maintained on the positioning map generated.

8.3. Future Work

There is a need to repeatedly test the proposed method in the affective evaluation of other products. Since the case study was limitedly conducted on one item, a car instrument panel, the generalizability of the analysis methods proposed here has yet to be determined. Therefore, additional case studies will have to be conducted to find out whether the proposed methods can be applied to the affective evaluation of other products in order to establish its generalizability.

The motive for starting this study was the awareness of the limitation of the currently practiced methods of affective evaluation in capturing the affects experienced by product users. This limitation stems from the evaluation method. In a typical affective evaluation, participants are instructed to interact with the product and to evaluate the intensity of the affects presented to then as words related to specific affects. Since the task is to consciously catch the affects arising unconsciously, untrained general users find it difficult to accurately evaluate various affects. In this study, it was attempted to address this drawback of the current approach and overcome the limitation of perceived accuracy by adding a new quantitative analysis method and bringing a fresh wind to the existing analysis methods.

As a method to address these problems posed in a more dramatic way, a method of measuring bio-signals and capturing the interactions between product use and user's bio-signals may be proposed. Affective experience is accompanied by changes in our bio-signals. If the interactions between affective experience and bio-signals can be understood concretely, more valid affective evaluation results can be derived. Product evaluation through bio-signal measurement can provide the possibility to derive affective engineering modeling without using a descriptive method using affective words. This is because the interaction with the product through the senses can confirm the relationship between the design parameters and the bio-signals. Measuring bio-signals with apparatuses such as EEG and EMG has long been practiced. However, the related process is not easy to implement because noises interfere with bio-signals and attaching a necessary device is a complicated and bothersome undertaking. Therefore, this is not thought as a follow-up study in the near future, but a forward-looking research task that will have to be carried out gradually, overcoming technical hurdles one by one. Moreover, the method to understand the link between bio-signals and product use will likely develop in a completely different direction from the typical affective engineering methodology. In this sense, it may be reasonable to regard this as a proposal for a future study associated with a completely new affective evaluation approach.

In this study, the scope of study was set up to establish models to predict luxuriousness and natural tactility based on the relationship between affect and design parameters. However, it is necessary to confirm whether the products using the optional predictions of the design parameters derived from modeling are really accepted by consumers. Since the purpose of this study is to produce practical results, it is necessary to confirm that the results of the study are the same in the actual responses.

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Appendix A

Questionnaire form in Chapter 4

샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

Sample No. ________

	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	
	매우					중간					매우	
색감이 어두운												색감이 밝은
시원해 보이는												따뜻해 보이는
광택이 나지 않는												광택이 나는
시원한												따뜻한
끈적이지 않는												끈적이는
건조한												촉촉한
미끄럽지 않는												미끄러운
부드러운												거친
평평한												울퉁불퉁한
무른												탄력적인

샘플 평가

• 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5	
	매우					중간					매우	
단단한												푹신한
속이 빈												속이 찬
엠보 간격이 좁은												엠보 간격이 넓은
엠보가 작은												엠보가 큰
엠보 패턴이 불규칙적인												엠보 패턴이 규칙적인
엠보가 얕은												엠보가 깊은
엣지 부위에 엠보 변형이 적은												엣지 부위에 엠보 변형이 많은
굴곡부에 주름이 적은												굴곡부에 주름이 많은
스티치 라인이 재질과 잘 어울리지 않는												스티치 라인이 재질과 잘 어울리는
접합부가 일체감이 없는												접합부가 일체감이 있는

샘플 평가

- 평가한 어휘들에 대해 얼마나 평가하기 어려웠는지 (느끼기 어려운 감성이었는지) 체크해주시기 바랍니다.

평가 어휘	어휘 이해도						
	매우 어려웠음	어려웠음	조금 어려웠음	보통	조금 쉬웠음	쉬웠음	매우 쉬웠음
색감이 밝은 – 색감이 어두운	①	②	③	④	⑤	⑥	⑦
따뜻해 보이는 – 시원해 보이는	①	②	③	④	⑤	⑥	⑦
광택이 나는 – 광택이 나지 않는	①	②	③	④	⑤	⑥	⑦
따뜻한 – 시원한	①	②	③	④	⑤	⑥	⑦
끈적이는 – 끈적이지 않는	①	②	③	④	⑤	⑥	⑦
촉촉한 – 건조한	①	②	③	④	⑤	⑥	⑦
미끄러운 – 미끄럽지 않는	①	②	③	④	⑤	⑥	⑦
거친 – 부드러운	①	②	③	④	⑤	⑥	⑦
울퉁불퉁한 – 평평한	①	②	③	④	⑤	⑥	⑦
탄력적인 – 무른	①	②	③	④	⑤	⑥	⑦
푹신한 – 단단한	①	②	③	④	⑤	⑥	⑦
속이 찬 – 속이 빈	①	②	③	④	⑤	⑥	⑦
엠보 간격이 넓은 – 엠보 간격이 좁은	①	②	③	④	⑤	⑥	⑦
엠보가 큰 – 엠보가 작은	①	②	③	④	⑤	⑥	⑦
엠보 패턴이 규칙적인 – 엠보 패턴이 불규칙적인	①	②	③	④	⑤	⑥	⑦
엠보가 깊은 – 엠보가 얕은	①	②	③	④	⑤	⑥	⑦
엣지 부위에 엠보 변형이 많은 – 엣지 부위에 엠보 변형이 적은	①	②	③	④	⑤	⑥	⑦
굴곡부에 주름이 많은 – 굴곡부에 주름이 적은	①	②	③	④	⑤	⑥	⑦
스티치 라인이 재질과 잘 어울리는 – 스티치 라인이 재질과 어울리지 않는	①	②	③	④	⑤	⑥	⑦
접합부가 일체감이 있는 – 접합부가 일체감이 없는	①	②	③	④	⑤	⑥	⑦

샘플 평가

• 평가한 어휘들에 대해 얼마나 평가하기 어려웠는지 (느끼기 어려운 감성이었는지) 체크해주시기 바랍니다.

평가 어휘	어휘 이해도						
	매우 어려웠음	어려웠음	조금 어려웠음	보통	조금 쉬웠음	쉬웠음	매우 쉬웠음
색감이 밝은 – 색감이 어두운	①	②	③	④	⑤	⑥	⑦
따뜻해 보이는 – 시원해 보이는	①	②	③	④	⑤	⑥	⑦
광택이 나는 – 광택이 나지 않는	①	②	③	④	⑤	⑥	⑦
따뜻한 – 시원한	①	②	③	④	⑤	⑥	⑦
끈적이는 – 끈적이지 않는	①	②	③	④	⑤	⑥	⑦
촉촉한 – 건조한	①	②	③	④	⑤	⑥	⑦
미끄러운 – 미끄럽지 않는	①	②	③	④	⑤	⑥	⑦
거친 – 부드러운	①	②	③	④	⑤	⑥	⑦
울퉁불퉁한 – 평평한	①	②	③	④	⑤	⑥	⑦
탄력적인 – 무른	①	②	③	④	⑤	⑥	⑦
푹신한 – 단단한	①	②	③	④	⑤	⑥	⑦
속이 찬 – 속이 빈	①	②	③	④	⑤	⑥	⑦
엠보 간격이 넓은 – 엠보 간격이 좁은	①	②	③	④	⑤	⑥	⑦
엠보가 큰 – 엠보가 작은	①	②	③	④	⑤	⑥	⑦
엠보 패턴이 규칙적인 – 엠보 패턴이 불규칙적인	①	②	③	④	⑤	⑥	⑦
엠보가 깊은 – 엠보가 얕은	①	②	③	④	⑤	⑥	⑦
엣지 부위에 엠보 변형이 많은 – 엣지 부위에 엠보 변형이 적은	①	②	③	④	⑤	⑥	⑦
굴곡부에 주름이 많은 – 굴곡부에 주름이 적은	①	②	③	④	⑤	⑥	⑦
스티치 라인이 재질과 잘 어울리는 – 스티치 라인이 재질과 어울리지 않는	①	②	③	④	⑤	⑥	⑦
접합부가 일체감이 있는 – 접합부가 일체감이 없는	①	②	③	④	⑤	⑥	⑦

Appendix B

Questionnaire form of absolute type 1 in Chapter 5

샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

Sample No. ________

	-3 매우	-2	-1	0 중간	+1	+2	+3 매우	
색감이 어두운								색감이 밝은
시원해 보이는								따뜻해 보이는
광택이 나지 않는								광택이 나는
시원한								따뜻한
끈적이지 않는								끈적이는
건조한								촉촉한
미끄럽지 않는								미끄러운
부드러운								거친
평평한								울퉁불퉁한
무른								탄력적인

샘플 평가

• 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

Sample No. ________

	-3 (매우)	-2	-1	0 (중간)	+1	+2	+3 (매우)	
단단한								푹신한
속이 빈								속이 찬
엠보 간격이 좁은								엠보 간격이 넓은
엠보가 작은								엠보가 큰
엠보 패턴이 불규칙적인								엠보 패턴이 규칙적인
엠보가 얕은								엠보가 깊은
엣지 부위에 엠보 변형이 적은								엣지 부위에 엠보 변형이 많은
굴곡부에 주름이 적은								굴곡부에 주름이 많은
스티치 라인이 재질과 잘 어울리지 않는								스티치 라인이 재질과 잘 어울리는
접합부가 일체감이 없는								접합부가 일체감이 있는

Questionnaire form of absolute type 2 in Chapter 5

어셈블리형 샘플 평가

• 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

색감이 어두운	-3	-2	-1	0	+1	+2	+3	**색감이 밝은**
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

시원해 보이는	-3	-2	-1	0	+1	+2	+3	**따뜻해 보이는**
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

• 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

광택이 나지 않는	-3	-2	-1	0	+1	+2	+3	**광택이 나는**
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

따뜻해지지 않는	-3	-2	-1	0	+1	+2	+3	**따뜻해지는**
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

끈적이지 않는 -3 -2 -1 0 +1 +2 +3 **끈적이는**

매우 ⟵ 중간 ⟶ 매우

	-3	-2	-1	0	+1	+2	+3
1번 샘플							
2번 샘플							
3번 샘플							
4번 샘플							
5번 샘플							
6번 샘플							

건조한 -3 -2 -1 0 +1 +2 +3 **촉촉한**

매우 ⟵ 중간 ⟶ 매우

	-3	-2	-1	0	+1	+2	+3
1번 샘플							
2번 샘플							
3번 샘플							
4번 샘플							
5번 샘플							
6번 샘플							

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

미끄럽지 않은 -3 -2 -1 0 +1 +2 +3 **미끄러운**

매우 ⟵ 중간 ⟶ 매우

	-3	-2	-1	0	+1	+2	+3
1번 샘플							
2번 샘플							
3번 샘플							
4번 샘플							
5번 샘플							
6번 샘플							

부드러운 -3 -2 -1 0 +1 +2 +3 **거친**

매우 ⟵ 중간 ⟶ 매우

	-3	-2	-1	0	+1	+2	+3
1번 샘플							
2번 샘플							
3번 샘플							
4번 샘플							
5번 샘플							
6번 샘플							

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

평평한	-3	-2	-1	0	+1	+2	+3	울퉁불퉁한
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

무른	-3	-2	-1	0	+1	+2	+3	탄력적인
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

단단한	-3	-2	-1	0	+1	+2	+3	푹신한
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

속이 빈	-3	-2	-1	0	+1	+2	+3	속이 찬
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

엠보 패턴이 불규칙적인	-3	-2	-1	0	+1	+2	+3	엠보 패턴이 규칙적인
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

엠보 간격이 좁은	-3	-2	-1	0	+1	+2	+3	엠보 간격이 넓은
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

엠보 크기가 작은	-3	-2	-1	0	+1	+2	+3	엠보 크기가 큰
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

엠보 깊이가 얕은	-3	-2	-1	0	+1	+2	+3	엠보 깊이가 깊은
	매우 ←			중간			→ 매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

엣지 부위의 엠보 변형이 적은	-3	-2	-1	0	+1	+2	+3	**엣지 부위의 엠보 변형이 많은**
	매우	←		중간		→	매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

굴곡부에 주름이 적은	-3	-2	-1	0	+1	+2	+3	**굴곡부에 주름이 많은**
	매우	←		중간		→	매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

어셈블리형 샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

샘플 제시 순서 : 5 – 4 – 1 – 2 – 6 – 3

스티치라인이 재질과 어울리지 않는	-3	-2	-1	0	+1	+2	+3	**스티치라인이 재질과 어울리는**
	매우	←		중간		→	매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

접합부가 일체감 없는	-3	-2	-1	0	+1	+2	+3	**접합부가 일체감 있는**
	매우	←		중간		→	매우	
1번 샘플								
2번 샘플								
3번 샘플								
4번 샘플								
5번 샘플								
6번 샘플								

Questionnaire form of relative type in Chapter 5

샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

기준 샘플. ________ **평가 샘플.** ________

평가 샘플이 더

	-3 매우	-2	-1	0 중간	+1	+2	+3 매우	
색감이 어두운								색감이 밝은
시원해 보이는								따뜻해 보이는
광택이 나지 않는								광택이 나는
시원한								따뜻한
끈적이지 않는								끈적이는
건조한								촉촉한
미끄럽지 않는								미끄러운
부드러운								거친
평평한								울퉁불퉁한
무른								탄력적인

샘플 평가

- 본 가죽 샘플에 대한 시각적 또는 촉각적 느낌과 관련하여 각 어휘 쌍 별로 적절하다고 생각되시는 점수란 안에 표기해주세요.

기준 샘플. ________ **평가 샘플.** ________

평가 샘플이 더

	-3 (매우)	-2	-1	0 (중간)	+1	+2	+3 (매우)	
단단한								푹신한
속이 빈								속이 찬
엠보 간격이 좁은								엠보 간격이 넓은
엠보가 작은								엠보가 큰
엠보 패턴이 불규칙적인								엠보 패턴이 규칙적인
엠보가 얕은								엠보가 깊은
엣지 부위에 엠보 변형이 적은								엣지 부위에 엠보 변형이 많은
굴곡부에 주름이 적은								굴곡부에 주름이 많은
스티치 라인이 재질과 잘 어울리지 않는								스티치 라인이 재질과 잘 어울리는
접합부가 일체감이 없는								접합부가 일체감이 있는

Appendix C

Post Analysis (Tukey HSD) for Details of the Semantic Differential Methods

Bright colored – Dark colored

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4	-	5, 6	-	-
2	2, 3, 4	1, 6	6	-	-
3	1, 2, 4	-	3	-	5, 6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Polished – Not polished

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4, 5, 6	-	-	-	-
2	1, 2, 4	3, 5	6	-	-
3	2	4	1, 3, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Sticky – Not sticky

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4, 5, 6	-	-	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	1, 3	2, 5	4, 6	-	-

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Moist – Dry

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1	2, 3, 4, 5	6	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	2	4	1, 3, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Slick – Not slick

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4, 5, 6	-	-	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	6	5	1, 2	4	3

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Rough – Smooth

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4, 5, 6	-	-	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	3	4	1, 2, 5, 6	-	-

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Rugged – Even

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 4, 5	-	6	-	-
2	1, 2, 3, 4	5	6	-	-
3	3	2, 4	1, 5,	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Elastic – Inelastic

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 3, 4, 5	2	6	-	-
2	1, 2, 3, 4, 5	-	6	-	-
3	4	-	1, 2, 3, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Soft – Solid

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	2, 5, 6	1, 3	4	-	-
2	6	1, 2, 3	5	-	4
3	1, 6	-	2, 3	5	4

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Stuffed – Hollow

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 4, 5	2, 3	6	-	-
2	2, 4, 5	3	1, 6	-	-
3	4	5	2, 3	1	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Wide spacing of embossed area – Narrow spacing of embossed area					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	5	1, 2, 3, 4	6	-	-
2	1, 2, 3 4, 5	-	6	-	-
3	1, 2, 3, 4, 5	-	6	-	-

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Large embossing – Small embossing					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	1, 2, 3, 4, 5	-	6	-	-
2	1, 2, 3 4, 5	-	6	-	-
3	1	2, 3	4, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Regular embossing pattern – Irregular embossing pattern

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	6	-	1, 2, 3, 4, 5	-	-
2	6	-	1, 2, 3, 4, 5	-	-
3	6	-	1, 2, 3, 4, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Deep embossing – Shallow embossing

Type	Group 1	Boundary between group 1 and 2	Group 2	Boundary between group 2 and 3	Group 3
1	1, 2, 3, 5	4	6	-	-
2	1, 2, 3, 4, 5	-	6	-	-
3	3	5	1, 2, 4	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Large deformation in embossed edge – Small deformation in embossed edge					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	1, 2, 3, 4, 5, 6	-	-	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	2, 4	1	3, 5	-	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Bent with many wrinkles – Bent with only a few wrinkles					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	1, 2	4, 6	3, 5	-	-
2	1, 2, 5	4	3, 6	-	-
3	2	1	4, 5	3	6

1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6

Stitch line matching well with material – Stitch line matching poor with material					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	2, 3	1, 4	5	-	6
2	1, 2, 3, 4, 5	-	6	-	-
3	1, 2, 4	3	5	-	6
1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6					

Natural seams – Unnatural seams					
Type	**Group 1**	**Boundary between group 1 and 2**	**Group 2**	**Boundary between group 2 and 3**	**Group 3**
1	1, 2, 3, 5	4	6	-	-
2	1, 2, 3, 4, 5, 6	-	-	-	-
3	2	1	3, 4	5	6
1 - sample 1 / 2 - sample 2 / 3 - sample 3 / 4 - sample 4 / 5 - sample 5 / 6 - sample 6					

Appendix D

Affective model of customer group 1 – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.758	.574	.569	1.3748

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	9.518	.247		38.592	.000
	엠보가 큰	-.427	.042	-.642	-10.149	.000
	거친	-.141	.052	-.173	-2.730	.007

Affective model of customer group 2 – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.705	.496	.490	1.0772

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	3.999	.331		12.068	.000
	엠보가 큰	.370	.026	.685	14.184	.000
	끈적이는	-.093	.034	-.134	-2.722	.007
	속이 찬	.120	.035	.168	3.467	.001

Affective model of expert group – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.685	.469	.454	1.5200

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	7.109	.610		11.653	.000
	울퉁불퉁한	-.229	.048	-.255	-4.788	.000
	접합부가 일체감이 있는	.341	.047	.326	7.290	.000
	엠보가 깊은	-.145	.041	-.184	-3.541	.000
	끈적이는	-.257	.050	-.265	-5.179	.000
	촉촉한	.198	.052	.191	3.773	.000
	미끄러운	-.172	.043	-.176	-3.993	.000
	굴곡부에 주름이 많은	-.097	.036	-.120	-2.670	.008
	푹신한	.099	.044	.099	2.244	.026

Affective model of customer group 1 – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.791[a]	.625	.617	1.4159

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	7.802	.453		17.218	.000
	엠보가 큰	-.618	.054	-.826	-11.459	.000
	탄력적인	.149	.049	.140	3.027	.003
	엠보가 깊은	.156	.053	.193	2.956	.004
	거친	-.108	.052	-.119	-2.081	.039

Affective model of customer group 2 – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.789[a]	.623	.618	1.3487

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	2.801	.438		6.396	.000
	엠보가 큰	.559	.035	.722	16.110	.000
	미끄러운	-.113	.039	-.128	-2.921	.004
	스티치라인이 재질과 어울리는	.092	.045	.089	2.050	.042

Affective model of expert group – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.649[g]	.421	.407	1.8870

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	8.666	.723		11.991	.000
	울퉁불퉁한	-.268	.060	-.250	-4.465	.000
	접합부가 일체감이 있는	.298	.059	.237	5.070	.000
	끈적이는	-.341	.062	-.293	-5.484	.000
	엠보가 깊은	-.205	.052	-.218	-3.963	.000
	촉촉한	.197	.065	.159	3.011	.003
	미끄러운	-.161	.054	-.139	-2.996	.003
	굴곡부에 주름이 많은	-.118	.046	-.122	-2.583	.010

Prediction model of customer group 1 – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.931[a]	.867	.818	.658472

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	7.535	.667		11.302	.000
	WVTR	.004	.001	.647	4.325	.003
	Squeak	1.399	.521	.358	2.685	.028
	Ra	-.286	.047	-.918	-6.046	.000

Prediction model of customer group 2 – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.846[a]	.716	.609	.525134

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	10.880	2.034		5.349	.001
	Squeak	-1.309	.409	-.615	-3.199	.013
	Aspect of Absorbency	1.362	.504	.600	2.702	.027
	Softness	-1.383	.556	-.552	-2.490	.038

Prediction model of expert group – luxuriousness

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.869[a]	.755	.700	.586087

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	7.118	.536		13.276	.000
	WVTR	.003	.001	.634	3.312	.009
	Ra	-.215	.041	-.996	-5.201	.001

Prediction model of customer group 1 – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.900[a]	.809	.738	.870005

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	7.037	.881		7.988	.000
	WVTR	.004	.001	.509	2.840	.022
	Squeak	1.829	.689	.424	2.656	.029
	Ra	-.288	.063	-.840	-4.614	.002

Prediction model of customer group 2 – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.881[a]	.775	.691	.820470

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	11.158	3.169		3.521	.008
	Squeak	-1.811	.658	-.484	-2.753	.025
	Ra	.161	.052	.540	3.113	.014
	Softness	-1.811	.750	-.411	-2.414	.042

Prediction model of expert group – natural tactility

모형 요약				
모형	R	R 제곱	수정된 R 제곱	추정값의 표준오차
1	.817[a]	.668	.594	.829083

계수						
모형		비표준화 계수		표준화 계수	t	유의확률
		B	표준오차	베타		
1	(상수)	6.828	.758		9.004	.000
	Ra (?m)	-.244	.059	-.929	-4.169	.002
	WVTR (g/m2 day)	.003	.001	.630	2.829	.020

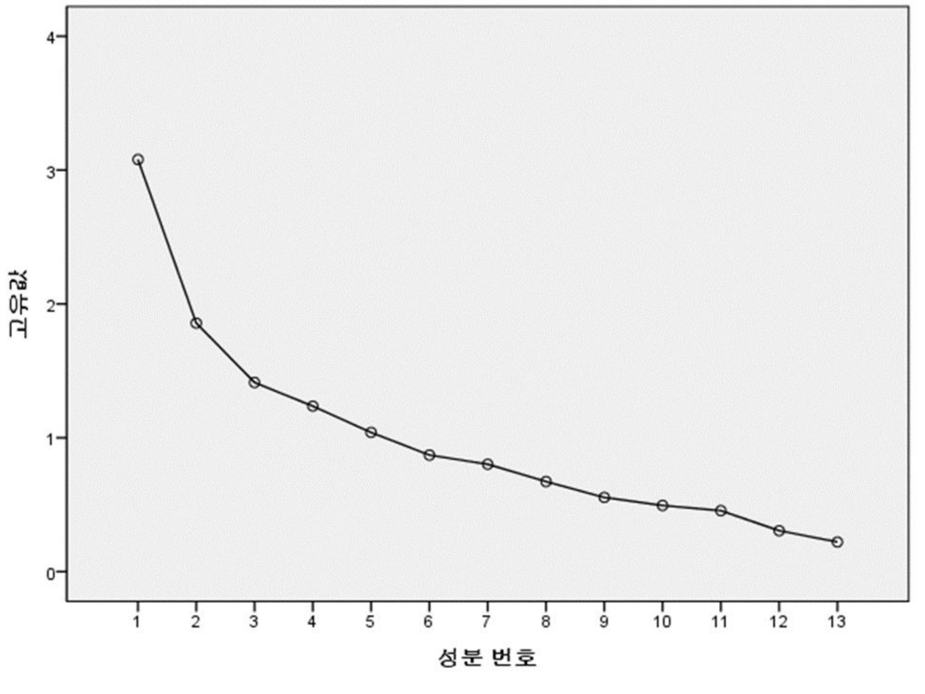
Appendix E

Process of principal component analysis (PCA)

KMO와 Bartlett의 검정		
표준형성 적절성의 Kaiser-Meyer-Oklin 측도		.686
Bartlett의 구형성 검정	근사 카이제곱	2179.370
	자유도	78
	유의확률	.000

설명된 총분산									
성분	초기 고유값			추출 제곱합 적재값			회전 제곱합 적재값		
	합계	%분산	%누적	합계	%분산	%누적	합계	%분산	%누적
1	3.079	23.684	23.684	3.079	23.684	23.684	2.954	22.723	22.723
2	1.857	14.281	37.965	1.857	14.281	37.965	1.741	13.393	36.116
3	1.413	10.868	48.833	1.413	10.868	48.833	1.462	11.244	47.361
4	1.236	9.510	58.342	1.236	9.510	58.342	1.428	10.982	58.342
5	1.040	7.998	66.340						
6	.871	6.697	73.037						
7	.802	6.169	79.207						
8	.673	5.176	84.383						
9	.554	4.262	88.644						
10	.494	3.800	92.444						
11	.455	3.502	95.947						
12	.306	2.352	98.298						

스크리 도표



Abstract (in Korean)

본 논문의 목적은 기존 감성 공학 방법론을 정교화 할 수 있는 정량적인 방법들을 제안하고, 사례 연구를 수행하여 제안한 방법들이 어떤 결과를 도출하는지 실증하는 것이다. 1980년 중반 이후 사용자 중심 제품 개발의 한 가지 방법론으로 인정받게 된 감성 공학 연구는 다른 공학 연구와 구별되는 몇 가지 차이점들을 가지고 있다.

한 가지 차이점은 감성 공학에서는 정성적인 연구의 비율이 상대적으로 크다는 것이다. 연구 범위, 연구 방법, 연구의 세부 계획, 평가 기준 등, 연구 전반에 걸쳐 연구자의 주관적 의사결정을 바탕으로 연구 계획을 수립하게 된다. 또 다른 차이점은 사람을 대상으로 하는 연구이기 때문에 평가 결과를 일반화하고, 정교화하기가 상대적으로 어렵다는 것이다. 이 2가지 차이점은 감성 공학 연구의 특징이면서, 한계점이라고 할 수 있다. 본 논문은 이 사실에 초점을 맞추어, 기존의 감성 공학 연구를 보조할 수 있는 총 5가지의 정량적인 분석 방법들을 제안하였다.

연구 1에서는 인터넷 리뷰 데이터를 대상으로 network analysis를 수행하여 감성 평가에 필요한 감성 구조 및 주요 감성을 도출하는 방법을 제안하고, 차량용 instrument panel을 대상으로 사례 연구를 진행하였다. 우선 인터넷에서 차량 실내 디자인과 관련된 리뷰들을 수집하여, 전처리 과정을 수행했다. 전처리된 자료를 대상으로 network analysis를 수행하여, 각 어휘 별 centrality 값을 구하고 연결성을 확인하였다. 이를 토대로, 고급감과 천연감을 차량용 instrument panel과 관련된 목표 감성으로 선정하였고, 두 목표

감성을 구성한다고 생각되는 하위 감성 어휘를 선정하였다.

연구 2에서는 감성 평가를 위해 선정된 개별 감성 어휘의 타당성을 정량적인 분석을 이용하여 확인하는 방법을 제안하고, 사례 연구에서 제안한 방법을 적용한 결과를 확인하였다. 본 연구를 위해 차량용 instrument panel을 대상으로 감성 평가를 수행했다. 감성 평가는 6개의 평가 샘플을 보고 만질 때 감성 어휘의 느낌을 받는 정도를 의미미분법 방식으로 측정하였으며, 추가적으로 감성 어휘 별 이해도와 샘플 간 구별성에 대한 주관적 인식에 대해 설문조사를 수행하였다.

평가 결과를 대상으로 총 5가지의 통계 분석을 수행하여, 감성 어휘 별 타당성을 확인하였다. 분석 결과, 5개 통계 분석 모두를 만족시키는 감성 어휘부터 하나의 통계 분석도 만족시키지 못하는 감성 어휘까지 감성 어휘가 일정한 분포를 형성하는 것을 확인하였다. 이를 통해, 제안한 방법을 기준으로 했을 때, 어휘 타당성의 정도가 감성 어휘 별로 차이가 나는 것을 확인할 수 있었다.

연구 3에서는 일반적으로 사용되는 3종류의 의미미분법 중 어떤 방식의 의미미분법이 감성 평가에 효과적인지를 사례 연구를 통해 확인하였다. 본 연구를 위해 차량용 instrument panel을 대상으로 감성 평가를 수행했다. 감성 평가는 절대평가 1, 절대평가 2, 상대평가의 3가지 방식의 의미미분법을 가지고 반복적으로 수행되었고, 총 3가지 정량적인 분석 방법을 활용하여 각 의미미분법 방식의 평가 우수성을 확인하였다.

분석 결과, 상대평가 방식이 나머지 2개의 절대평가 타입에 비해서 우수한

결과를 도출하는 것으로 나타났다. 그러나 상대평가 방식은 평가 시간이 오래 걸린다는 단점이 있었다. 평가 샘플의 개수, 실험참여자의 수, 실험 진행 시간 등 실험에 영향을 미칠 수 있는 다양한 요소를 고려하여 실험에서 사용할 의미미분법 타입을 결정해야 한다는 결론을 도출하였다.

연구 4에서는 감성 평가를 통해 도출된 데이터를 가공하여 유의미한 통계적 모델을 제시하는 방법을 제안하고, 사례 연구를 통해 제안한 방법의 결과를 확인하였다. 제품 평가에 대한 일반인 실험참여자들의 결과를 전문가와 비교하여 설명력의 차이를 확인하고, 일반 실험참여자들로부터 도출되는 모델의 설명력을 높이기 위한 방법을 제안하였다. 설명력을 높이기 위한 방법으로, 특정 감성 어휘를 평가한 기준으로 그룹을 나누는 방법을 제안하였다.

엠보 크기가 클 때, 목표 감성을 높게 평가하는 경우와 엠보 크기가 작을 때, 목표 감성을 높게 평가하는 경우로 평가 케이스를 나누어 각각에 대한 모델을 만들고, 만들어진 모델의 설명력을 확인했다. 제안한 방법을 적용했을 때의 설명력이 일반적인 분석으로 나온 설명력보다 좋다는 것을 확인하였다. 제안 방법의 문제점과 그에 대한 반론 등을 논의하였다. 그리고 전문가 평가 결과로부터 나온 모델과 일반 사용자 평가 결과로부터 나온 2가지 모델을 비교하여, 모델 간 차이점을 확인하고 그 차이의 원인을 고찰하였다.

연구 5에서는 연구 4에서 도출된 감성 평가 결과를 활용하여 포지셔닝 맵을 도출했다. 연구4의 결과로 13개의 감성 어휘가 감성 모델에 영향을 미치는 것으로 확인됐고, 이 13개 어휘를 대상으로 주성분분석을 수행하여 총 4개의 성분을 도출하였다. 도출된 4개 성분의 샘플 별 성분 점수를 대상으로

다차원 척도법을 수행하여 샘플 별 상대적 위치에 대한 포지셔닝 맵을 도출하였다. 포지셔닝 맵을 구성하는 2개의 차원을 연구 4에서 도출된 고급감 및 천연감 점수와 비교하여 그 타당성에 대해 논의하였다. 포지셔닝 맵 상에서의 12개 샘플의 상대적인 위치를 비교하였고, 샘플 간 상대적인 비교를 마케팅 및 제품 개발 측면에 적용하는 방안에 대해 논의하였다.

본 논문은 5가지의 정량적인 분석 방법을 제안하여 기존의 감성 공학 연구 방법론을 정교화하는 방안에 대해 논의하였다. 그리고 차량용 instrument panel을 대상으로 사례 연구를 진행하여 제안한 방법들을 실증하였다. 사용자 중심의 제품 개발이라는 개발 방향성이 제품 설계의 주요 철학으로 자리잡은 상황에서 신뢰도 및 타당성 높은 감성 평가 결과를 도출하여 이를 제품 개발에 적용하는 것은 시장에서 소비자의 선택 받기 위해 필수적인 요소라고 할 수 있다. 본 논문의 연구를 통해, 기존에 비해 타당성이 높고 유의미한 평가 결과를 도출할 수 있는 감성 공학 방법론을 개발할 수 있을 것으로 기대된다.

주요어 : 감성공학, 감성평가, 정량적 분석, 연결망 분석, 포지셔닝맵
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