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Industrial Applications of Affective Engineering

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ISBN 978-3-319-04797-3 ISBN 978-3-319-04798-0 (eBook)
DOI 10.1007/978-3-319-04798-0
Springer Cham Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014935146

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

The concept of emotion-based design, production, and marketing was considered or dreamed in Japan in the 1950s. Since then, numerous methods have been studied to support humans in decision making, e.g., artificial neural networks and living structures as well as artificial intelligence were investigated in the 1960s and 1970s. Various methodologies such as fuzzy sets were also proposed during the same period. In parallel, in economics and marketing, people recognized that the influence of human psychological behaviors and preferences plays a pivotal role in decision making. Daniel Kahneman was awarded the Nobel Memorial Prize in Economic Sciences for his contributions in this line of research. Indeed, emotional experience is important in shaping our future behaviors.

Researchers started to investigate the practical use of human emotion and affective recognition in design in the 1980s. Such research was then extended from design and questionnaire-based analyses to more physiological, biometrical, and bio-measuremental experiments. Recently, studies on human emotions and affective senses have become prosperous. As highlighted in the book titled "Descartes' Error: Emotion, Reason, and the Human Brain" by Antonio R. Ramasio, human emotions play an important role in our thinking, and our rational behaviors are greatly governed by emotions. Therefore, it is imperative to take human affective feelings into consideration when we tackle problems in various domains.

In essence, affective (or Kansei) engineering is a scholarly field that focuses on discovering and utilizing the value of human emotions for the development or improvement of products or services, i.e., by incorporating human affective feelings and impressions into the product or service design, development, and delivery cycle. Indeed, the concept of affective engineering has become increasingly important in the economic value chain. This is apparent when the Ministry of Economy, Trade, and Industry of Japan launched the "Kansei Value Creation Initiative," and placed "Kansei" as the fourth value axis in the product or service value chain. In other words, the affective value now joins the other three axes (performance, reliability, and price) to help organizations maintain and improve their competitiveness, i.e., producing products or services not only come with high performance, high quality and reliability, and low price, but also with high human affective values. As a result, affective values need to be embedded into the whole economic value chain, ranging from upstream goods such as materials

and components to downstream goods such as finished products, services, and contents.

This edited book stems from the First International Symposium on Affective Engineering (ISAE2013) held at Kitakyushu, Japan, from 6 to 8 March, 2013. ISAE2013 managed to attract numerous participants from different backgrounds, which included academics, engineers, and practitioners to present and exchange knowledge, experience, results, and information related to the broad aspects of methodologies and applications of affective engineering. Following the success of ISAE2013, participants have been invited to extend their research works and contribute their findings as book chapters. Following a review process, a total of 22 chapters have been selected for inclusion in this edited book.

This book consists of two parts, i.e., methodology and application. Each part has 11 chapters. In Part I (Methodology), attempts and efforts in the design and development of a variety of methodologies related to affective engineering are presented. These include

- controlling the temperature and realizing a comfortable space based on human brainwaves;
- proposing a new method that is useful for estimating human social emotions by measuring micro body movements;
- developing a bi-level human migration model based on conjectural variations equilibrium;
- evaluating signs in the artisanal sign-making area with the aim to improve the level of customer satisfaction;
- defining the design subjects for creating attractive products and improving user experience without relying on designers' heuristics;
- devising an icon strategy to cultivate and attract consumers' loyalty that helps a company able to differentiate its products from others in the market;
- analyzing aesthetic experience as a Kansei element and a cognitive process in product design and development;
- understanding Kawaii (an affective value) feelings pertaining to shapes, colors, sizes, texture, and tactile sensation caused by product materials;
- evaluating the emotions for traditional Vietnamese clothes for women based on computer vision and machine learning methods;
- assessing the sound effects in e-book reader software packages based on near-infrared spectroscopy;
- investigating the relationship between cognitive style and webpage perception from people with different cultures.

In Part II (Applications), the effectiveness and usefulness of a variety of affective engineering models and techniques in practical environments covering different domains are presented. These include

- studying how the backrest structure affects the sitting comfort of a meeting chair based on body pressures and contact areas between user and the chair;
- using affective values as a key factor to luxury brand building by focusing on the Swiss watch industry;

- evaluating the transient signals of different button sounds by utilizing the wavelet transform method;
- investigating the differences in the production processes of high-end garments manufactured in Japan and Italy;
- adapting customers for online shopping of clothes by the ability to identify the fabric used and the prior knowledge in fabric;
- administering self-report and physiological measures to understand color-related emotions in different environments;
- gaining an insight into probable human-centered design trends by analyzing movie scenes;
- analyzing the volatile compounds of white mother chrysanthemum flower on sleep quality;
- examining emotional characteristics in response to various shades of white that could help in designing white-based products;
- understanding the differences in skin physiology parameters and affective values in skincare products;
- devising a machine learning model to extract important information pertaining to useful product features based on customers' reviews.

We would like to express our sincere gratitude to all authors who have contributed their works for inclusion in this book. We would also like to extend our appreciation to the editorial team at Springer who have diligently helped in making this book a reality. We hope that this book will serve as a useful reference for readers to learn solid knowledge pertaining to different methodologies of affective engineering and apply the acquired knowledge to undertake challenges in various industrial domains.

31 December, 2013

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Part I
Methodology

A Bio-Signal-Based Control Approach to Building a Comfortable Space

Junzo Watada, Chee Peng Lim and Yung-chin Hsiao

Abstract It is difficult to define a comfortable space for people. This is partly because comfort relates to many attributes specifying a space, partly because all people have different preferences and also because even the same person changes his or her preference according to the state of health, body conditions, working state, and so on. Various parameters and attributes should be controlled in order to realize such a comfortable space according to the database of past usages. Information obtained from human bodies such as temperature, blood pressure, and alpha waves can be employed to adjust the space to the best condition. The objective of the paper is to present the possibility that a space is able to be adjusted to a human condition based on human brainwaves.

Keywords Affective engineering • Living body measurement • Fuzzy control • Neural network • Comfortable space

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_1,

1 Introduction

In today's stressfull society, comfortable space and life are important to eliminate intense stress on us. We should create a suite of new technological tools to realize a comfortable space. In this chapter, the comfortable space means one where a person feels at ease and free from stress when he/she stays there although each person has a different feeling about being comfortable. It is hard to realize a comfortable space for all humans. Therefore, we should build a comfortable space from each person's viewpoint. It is hypothesized that a machine or a system is able to recognize and evaluate the state of a person from his/her behavior, voice, and other measurements by automatically gathering data and recognizing patterns from the collected data. If we can measure an electroencephalogram (brainwaves, heart beats, sweat, saliva, etc.) by an instrument, the obtained information can be employed to realize a comfortable space.

The objective of this chapter is to show the possibility that the measurement of human senses enables us to realize a comfortable space for any person even if the person changes his/her comfortable feeling toward the changing environment or condition [1, 2].

2 Affective Engineering

Affective information means total information of human senses. Affective engineering is "a technology, method, or theory to translate human affective information or image to production of real things or to design of objects." It is vague and uncertain that a customer has an image or expectation about some product. Again, affective engineering is a technology to build such affective information or vague image in product design in some way [3]. The objective of this paper is to employ brainwaves obtained from a person to adjust the environment of a space to the most comfortable state that he/she feels. There are many measurements from a human body which can be used for the control of a space, for instance, heart beats, sweat, saliva, etc.

In [4] bio-potential signals, which included electroencephalographic (EEG), electrooculargraphic (EOG), and electromyographic (EMG) signals from psychological experiments were collected. The EEG signals were analyzed in three different frequency bands, namely a low-frequency band including δ and θ waves, a middle-frequency band including the *alpha* wave, and a high-frequency band including the *beta* wave. The aim of the experiment was to recognize different types of emotions based on bio-potential signals, which included joy, anger, sadness, fear, and relax. To stimulate the emotions, a number of commercial films were broadcasted on TV. The support vector machine (SVM) was used as the emotion classifier. The results showed that multi-modal bio-potential signals were useful for emotion recognition, and the SVM was deemed suitable as the underlying classifier for the emotion recognition tasks. In another experiment [5] with a similar experimental setting, the aim was to recognize pleasure and unpleasure emotions. To generate pleasure and unpleasure, A bio-signal-based control approach to

building comfortable space three stimuli, classical music as well as music mixed with noise (e.g., industrial noise) were played. The SVM and a neural network were used for the classification tasks. The experimental outcome showed that both methods produce similar results.

A Bayesian network was deployed for emotion recognition using EEG signals [6]. Audio and visual pictures were used to induce emotions, such as joy, neutral, anger, sad, and surprise. EEG signals were transformed into power spectrum using the fast Fourier transform method, while low-frequencies EEG artifacts were eliminated. The results showed that, while the probability values for many different emotions were different, those of anger and sadness were similar. On the other hand, machine learning techniques were employed to predict a learner's emotions in an intelligent tutoring system based on EEG signals [7]. The emotion states that were of interest included anger, boredom, confusion, contempt, curious, disgust, eureka, and frustration. The best classification accuracy yielded by the k-nearest neighbor algorithm was above 82 %.

A wavelet-chaos-based method was applied to detection of seizure and epilepsy using EEG signals and sub-bands [8]. Specifically, the δ, θ, α, β, and γ sub-bands of EEG signals were examined, and quantified in terms of correlation dimension (CD) and the largest Lyapunov exponent (LLE). It was found that, subject to a large number of EEG segments, the average values of CD were useful for differentiating three groups of subjects (healthy subjects, epileptic subjects during a seizurefree interval, and epileptic subjects during a seizure) based on β and γ sub-bands, while those of LLE was useful for differentiating these three groups of subjects using α sub-band. EEG signals were also used as a source to detect deceptive and truthful responses [9]. The main objective was to extract joint time-frequency EEG features through wavelet analysis. During the experiment, EEG signals were recorded from four electrode sites when five subjects went through a modified version of the guilty knowledge test. The results from the wavelet analysis revealed significant differences between deceptive and truthful responses.

Another application of EEG signals as a source for biometric identification was investigated [10]. Gaussian mixture models and the maximum a posteriori model adaptation were deployed for person authentication, that is, accepting or rejecting a person claiming an identity. A series of experimental simulations was performed to demonstrate the potential of the proposed method. Nevertheless, the database used was too small to render any conclusive lessons in regard to person authentication.

3 Brainwaves

In affective engineering, physiological measurement is widely employed such as impression method, psychological measure, and so on to quantize affective information. In physiological measurement, emotional quantity includes automatic nerve responses or brainwaves against an external stimulus. In this chapter, we employ the measurement of brainwaves.

3.1 Electroencephalogram

The electroencephalogram is explained in its operations and functions shortly in the following.

3.1.1 Spontaneous Electroencephalogram

It is not easy to interpret the cognitive meaning of an electroencephalogram (brainwave). Nevertheless, some characteristics of the electroencephalogram have been explained quantitatively. The electroencephalogram is a kind of oscillated brainwaves. Such brainwaves can be characterized using amplitude and frequency. Specifically, in many researches, electroencephalograms are classified according the difference of frequencies and compared with consciousness states (wake levels).

3.1.2 Electrical Voltage Related to Events

In order to find the meaning of an electroencephalogram, it is significant to analyze brainwaves recorded in an electroencephalograph when a stimulus is given, for example, when an experimenter gives light flash or large sound to a test subject. Such brainwaves are named event-related potential (ERP) or evoked potential since they come out from a specific stimulus or event. Comparing with the resulted brainwaves, an electroencephalogram a brain produces spontaneously is named a spontaneous or freely electroencephalogram or back brainwave.

The electroencephalograph is obtained by duplicating various amplitudes of frequencies. It is hard to clarify their characteristics by observing and measuring an electroencephalogram obtained by giving a stimulus sound to a test subject because the effects would be buried under such a spontaneous electroencephalogram. It is possible to abstract the effect from duplication of electroencephalographs at the same timing because the same kind of results by the same strength of stimuli removes the influence of the spontaneous electroencephalograms. Such spontaneous electroencephalograms are leveled by duplicating such noises. Then, the ERP can be clearly obtained. The widely adapted interpretation of the electroencephalogram is to understand as electronic activities of a brain and the duplication of many small voltages from synapses.

The 10/20 method is widely employed as the positions of electrodes, which is the standard of International Electroencephalogram Society. But it is not necessary to measure all of them. Both sides of the frontal part, whole temporal, centered temporal, and central portions are used widely [3].

3.1.3 Types of Electroencephalograms

Brainwaves are categorized into four groups such as δ brainwaves, θ brainwaves, α brainwaves, and β brainwaves. Brainwaves with lower frequencies than α

brainwaves are named slow brainwaves and ones with higher frequencies than α brainwaves are fast brainwaves.

The frequency of α brainwaves is from 8 to 13 Hz. The brainwaves emerge in the brain of a person who is in the rest state such as concentrated state, meditation state and relaxed state.

β brainwaves are from 15 to 40 Hz, and they show the characteristics of a strongly engaged mind. When a person is engaged in some activities, he/she shows β brainwaves.

δ brainwaves are from 0.5 to 4 Hz. These brainwaves are obtained in unconscious and deep sleep states. They never go down to zero, which implies a brain-dead state. But, a deep dreamless sleep would take a person down to the lowest frequency, typically 2–3 cycles a second.

θ brainwaves are from 4 to 8 Hz. A person who has daydream shows θ brainwaves. A person who is driving on a freeway, and then discovering that he/she cannot recall the last five miles, is often in a θ state.

It is not easy to adjust the temperature itself directly by measuring an electroencephalogram. In this research, the measurement of an electroencephalogram is employed to distinguish the objective person's state at work or at rest.

3.2 Illustration of Experimental Environment

The brainwaves, body temperature, blood pressure, and heart beat are measured according to the response of various stimuli changes when a person is in a space where various attributes of the space can be changed including light intensity, light color, an air condition system, image media, and a massage system. The space is named an affective space.

Figure 1 shows the environment of an experiment that a test subject puts on the electroencephalogram electrodes. He undergoes the measurement of brainwaves in a relaxed state. The affective space is shown in Fig. 2 too.

4 Fuzzy Control

Fuzzy control is widely employed in industries in early days since the proposal of a fuzzy system in 1965. Fuzzy control is a kind of intelligent control methods. Rules employed in the fuzzy control are written in the if-then format, and they are approximately reasoned to provide a suitable control signal. As one rule can cover a wide range of control, it is possible to appropriately control the controlled object using few rules so as that it mimics human operations [11].

In addition, when the rules are overlapping with each other, the plural rules can compensate the action of control with each other. Even if some rules do not work well, other plural rules can compensate these rules and produce the expected control signal.

Fig. 1 An experimental space and a test subject

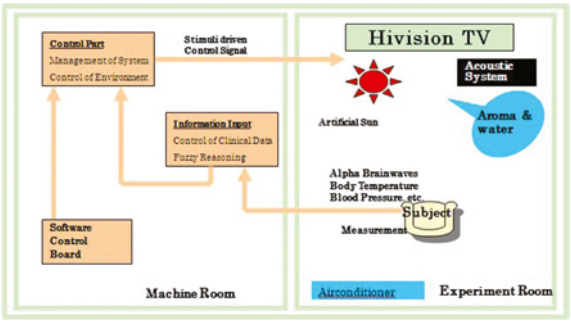


Fig. 2 Illustration of an experimental space

It is not necessary in a fuzzy controller to model a controlled object precisely. In other words, if it is possible to obtain response results, an object can be adjusted perfectly without understanding the controlled object. Of course, it is not possible to provide the if-then rules without understanding basic response and actions of the controlled object. In this chapter, we employed fuzzy control to adjust the room temperature according to the measurement of brainwaves from a test subject.

5 Building a Fuzzy Control System Using Brainwaves

It is possible to know the present state of a test subject by measuring his/her brainwaves and analyzing the characteristics of brainwaves. In this paper, a fuzzy controller is employed to adjust an environment to the most comfortable state based on the measurement.

In this chapter, we select one attribute out of various features that represent a comfortable space. That is, in building a comfortable space, room temperature is employed as a controlled parameter and the most comfortable space will be

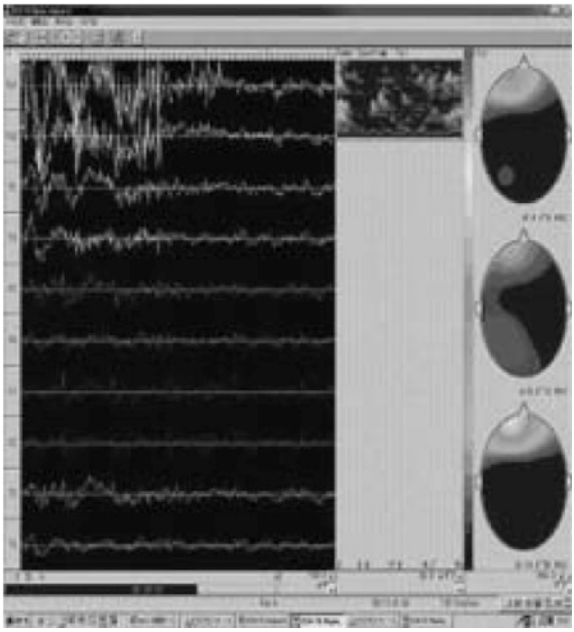


Fig. 3 Measurement result of α waves

realized for a test object by adjusting the room temperature. This means to build the affective information system realizing that a person in a space will be made most comfortable by controlling the temperature of the space.

5.1 Method to Select Characteristic Features

Brainwaves were measured with an interval of 5.12 s for 1,200 times, that is, about 100 min (=5.12 $\times$ 1200). In the experiment, a subject repetitively carried out works and rests for a certain interval. In the experiment, his/her α brainwaves were measured as shown in Fig. 3.

Each step is accomplished as in Table 1. But, each step is not conducted strictly because it takes 1 or 2 min to move one interval to another (see Fig. 4). He/she should prepare to change from the current state of works. It can be supposed for 1 or 2 min. Let us denote numerical data of the brainwaves as $X_j^1, (i = 1, \ldots, n)$ where $i =$ step number.

5.2 Procedure of Obtaining Brainwaves

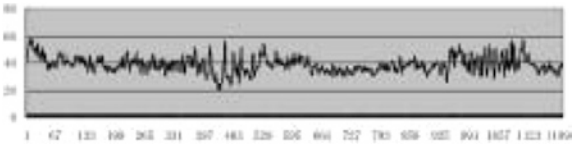
The procedure of obtaining brainwaves is illustrated as follows.

Table 1 Table of brainwave frequency

1	−360	Step 1: Working interval (30 min)
361	−540	Step 2: Rest interval (15 min)
541	−900	Step 3: Working interval (30 min)
901	−1,080	Step 4: Rest interval (15 min)
1,081	−1,200	Step 5: Working interval (30 min)

(1 Step = 5.12 s)

Fig. 4 Graph of measured brainwaves



Step 1. Calculate the mean using all numerical data and shift the mean of all sample voltages so as to become 0. Calculate the absolute value as shown in Fig. 5a. The calculation is as follows:

$$X_j^2 = |X_i^{(1)} - X_{ave}| \tag{1}$$

Step 2. The resulting measurement of the brainwaves shows that the amplitude of brainwaves becomes larger. Calculate the mean of every 40 steps where one step means 10 ms in order to remove random errors. The calculation is shown as follows:

$$X_j^3 = \frac{1}{S} \sum_{T=T(j-1)+1}^{T(j)} \left(X_j^{(2)} (j = 1, \cdots, n), T(j) = S_j \right) \tag{2}$$

Step 3. Calculate the mean value of the results obtained in Step 2. The result is shown in Fig. 5b. The calculation can be written as follows:

$$X_j^{(4)} = |X_j^{(3)} - X_{ave}| \tag{3}$$

Step 4. A total of 33 % of the maximum value obtained in Step 3 is set as the threshold of full stop θ; Set each step value to 1 when the value is greater than θ and 0 when the value is less than the threshold θ, respectively. The result is as shown in Fig. 5c. The calculation is shown as follows:

$$X_j^{(5)} = \begin{cases} 1 : X_j^{(4)} \geq \theta \\ 0 : X_j^{(4)} \leq \theta \end{cases} \tag{4}$$

5.3 Result of Selection of Characteristic Features

Figure 5c shows three characteristic terms, that is, (1) between steps 1 and 10, (2) between steps 11 and 14, and (3) between steps 24 and 218.

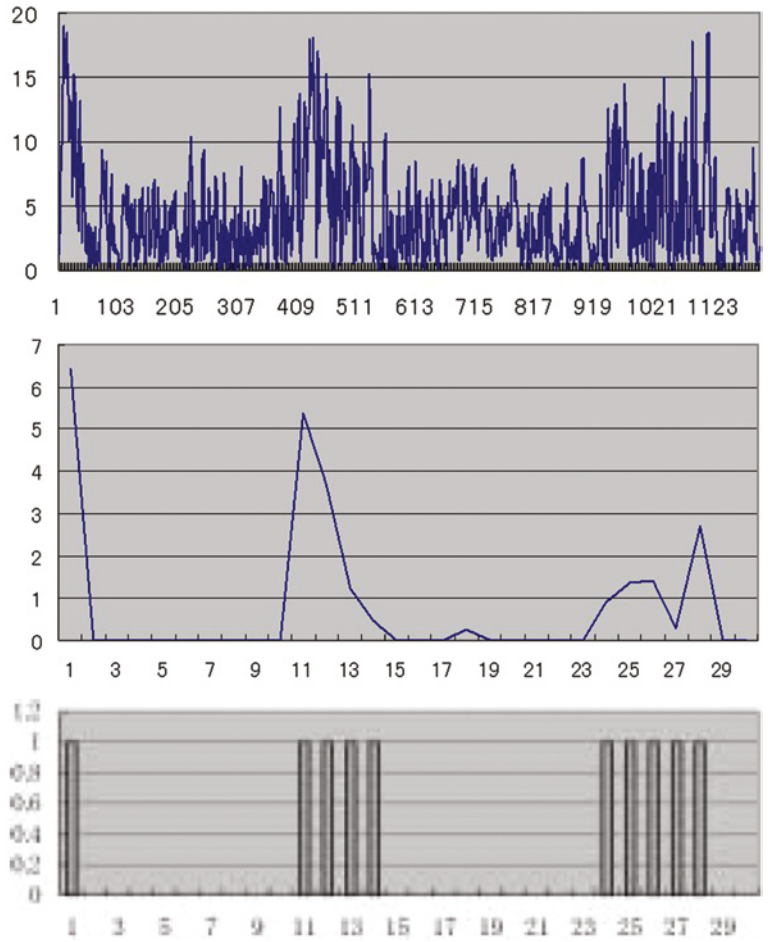


Fig. 5 Value obtained at each step in the procedure of brainwaves. (**a**) Graph obtained by Step 1. (**b**) Graph obtained by Step 3. (**c**) Graph obtained by Step 4

1. The interval between steps 1 and 10 can be explained as the interval of starting to work and the object did not feel any stress during working. As such, the brainwaves were not yet decreasing sufficiently.
2. The interval between steps 11 and 13 can be explained as the subject had rest and the α brainwave is appropriate. On the other hand, in step 14, the subject started working. In this state, the subject just started the work so the α brainwaves did not decrease from the relaxed state to the stressed state.
3. The interval between steps 24–28 can be explained as the subject had appropriate α brainwaves between steps 24 and 27, as similar to that in the interval between steps 11 and 13. But in step 28, the subject just started rest so the state of the subject was not changed sufficiently from the relaxed state to the stressed state. Therefore, the α brainwaves did not decrease as it was expected.

Table 2 Table of control rules

		Δx_1				
		PB	PS	ZO	NS	NB
x_1	NB			PB		
	NS			PS		NS
	ZO	PB	PS	ZO	NS	NB
	PS	PS		NS		
	PB			NB		

5.4 Rule Table Employed

In the experiment, a fuzzy controller is employed to adjust the temperature in the room. The fuzzy controller is configured as follows:

The rule table employed is shown as in Table 2, where x_1 denotes the present temperature and Δx_1 denotes the change of the present temperature.

In a rule table employed, notations *N*, *P*, *B,* and *S* denote negative, positive, big, and small, respectively. The words are expressed using membership functions. In other words, *NB* means big in the negative value and *PS* means small in the positive value. *ZO* means about zero. In this paper, the detail of fuzzy control is not explained. Please refer to books such as Ref. [11].

In the experiment notation, *a* means 25 and 18 for rest and working of the subject, respectively. The detail explanation will be given in Sect. 5.6.

5.5 Membership Function

Parameters of membership functions employed in the experiment are shown in Fig. 6a–c. In the experiment notation, 25 and 18 indicate the rest and working of the subject, respectively. A detailed explanation is given in Sect. 5.7.

5.6 Algorithm of Control System

Step 1. Input the degree of the present temperature.

Step 2. Change the value into 1 and 0 according to working and rest of the subject using the characteristic abstraction of brainwaves.

Step 3. Using data obtained in Step 2,

(a) As value 1 shows that the subject is in the rest state, set the optimum temperature to 25 °C in order to make the subject relaxed. So the temperature of the space is controlled as it becomes 25 °C by a fuzzy controller. Value α in Fig. 5a–c is set to 25.

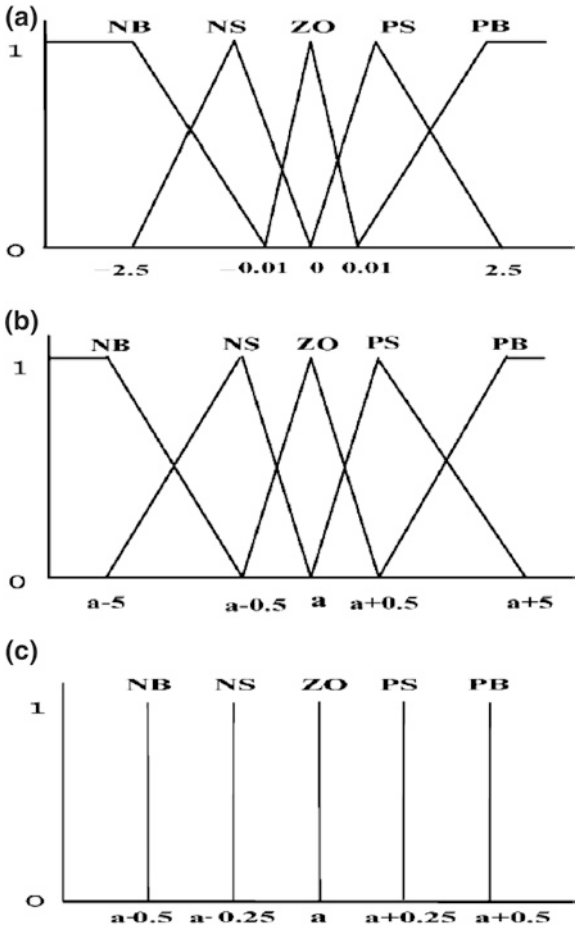


Fig. 6 Fuzzy Control. (**a**) Membership function of a temperature. (**b**) Membership function for the change in temperature. (**c**) Membership function of the output temperature

(b) As value 0 shows that the subject is in the working state, set the optimum temperature to 18 C degree in order to make the subject work comfortably. So the temperature of the space is controlled as it becomes 18 C degree by a fuzzy controller. Value α in Fig. 6a–c is set to 18.

5.7 Simulation Results

The simulation is pursued according to the algorithm of a control system shown in Sect. 5.6. Figure 7 shows the results. The temperature of the room started from 20 °C and the temperature of the room is optimally adjusted according to the state of the subject using the measurement of the α brainwaves. As Fig. 7 shows, the temperature of the room is optimally controlled according the state of the subject.

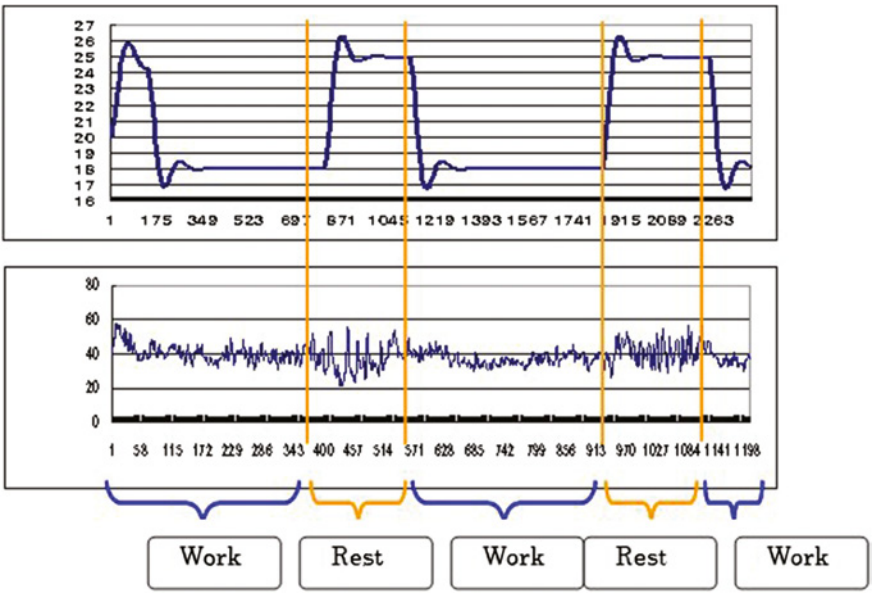


Fig. 7 Comparison between result and α brainwaves

In the interval between steps 0 and 100, the temperature of the room was adjusted to 25 °C because the subject just started the work and the α brainwaves did not decrease before feeling stress.

Section 5.4 explains how the space temperature is adjusted to the same value according to the subject state. In this section, the optimal temperature is obtained from database which contains the historical change of the temperature in the condition of a day such as time, weather, and the state of a person. It should be explained how to decide an appropriate value with the lack of data. A neural network is employed to compensate the lack of data. The smart house adjusts the room temperature to some optimal value which is obtained from a database. When the database does not have appropriate value, the neural network compensates the unavailable value using the neighboring values.

6 Control on the Basis of Database

In temperature control by fuzzy controller, it is possible to employ the database of temperature in order to simply the input of the objective temperature. In this chapter, we employed the neural network to complement the lack of the data in the database.

6.1 Features of a Neural Network

Neural network is a parallel processing model with many processing units that perform computation simultaneously. Each processing unit is an artificial neuron. A human brain consists of 14 billion neurons which process information in parallel. The neural network has the learning ability. It adjusts its connecting weights according to the outside environment. This is also known as the self-organizational ability.

6.1.1 Neuron Model

An artificial neural network model has physiological features of a biological network consisting of multiple input nodes and one output node. Each neural network has units that are connected with each other, as the retina. Units are connected by a line corresponding to nerve fiber. As a real neuron, the connection between neurons is one way such as a signal flows to one direction as a synaptic connection. Some weight (connection weight:w_i) is multiplied with the connected unit. The weight shows the strength between two units.

Weighted inputs ($w_i u_i$) are summed to produce U and transformed by response function (f), then the output (y) is obtained as follows:

$$y = f(U), \quad \text{where } U = \sum_i w_i u_i \tag{5}$$

Furthermore, the output (y) shows positive for a stimulus signal and is negative for an inhibitive signal. The weighted value is positive for a stimulus signal and is negative for an inhibitive signal. According to the adjustability of synaptic connection, the weight value can be learned.

6.2 Back Propagation

The back propagation algorithm is a learning algorithm with a teacher proposed by D.E. Rumelhart in 1986 for a neural network with hierarchical structure consists of input, hidden, and output layers. The backpropagation algorithm is a special case of learning methods for minimizing an evaluation criterion which was known as the probabilistic descent method proposed by Amari in 1967 and Ya.Z. Tsypkin in 1966. The backpropagation algorithm is employed to have neighboring values in order that the neural network can compensate an unavailable value.

Table 3 Database of neural temperature for each sex and each month (°C)

Month	1	2	3	4	5	6	7	8	9	10	11	12
Male	21.8	22.0	22.2	22.3	n.d.	23.1	23.5	23.6	22.8	22.2	n.d.	22.4
Female	23.2	23.4	23.6	23.7	n.d.	24.2	24.8	25.6	24.3	23.6	n.d.	23.6

n.d. denotes "not defined."

6.3 Algorithm of Control Method Using Database

First, we build the database of objective temperature for each sex, and for each month. Table 3 shows the database of neutral temperature for each sex and each month (°C). The parameters of a neural network employed in the experiment are as follows:

1. The number of units in the hidden layer = 4
2. The number of units = 10.
3. The initial weighted value is between −1 and 1.
4. The initial threshold value is between −1 and 1.
5. Learning rate = 0.2
6. Total number of learning cycles = 100,000
7. The condition of learning termination is till the error is less than 0.001.

We employed the teaching data illustrated in Table 3 as the neural temperature for each sex and each month. The input is sex and month. Man is 1 and woman is 0, and month is denoted by 1 January–12 December.

Excluding months 5 May and 11 November, the objective temperature is set to 2. But, for months 5 May and 11 November, there are no values in Table 3. Therefore, we employed the neural network to compensate the value of the objective temperature using the database.

6.4 Results

Figure 8 shows the error rate in the computation where the vertical axis is the error rate and the horizontal axis is the number of learning cycles. Figure 8 shows that even in May and November where data are not available, the temperature is properly obtained through the neural network compensation. Even if we have few data on some features, we can compensate such missing data through the backpropagation learning of a neural network and the compensation by the neural network allows effective and efficient controlling of the comfortable space within a short time.

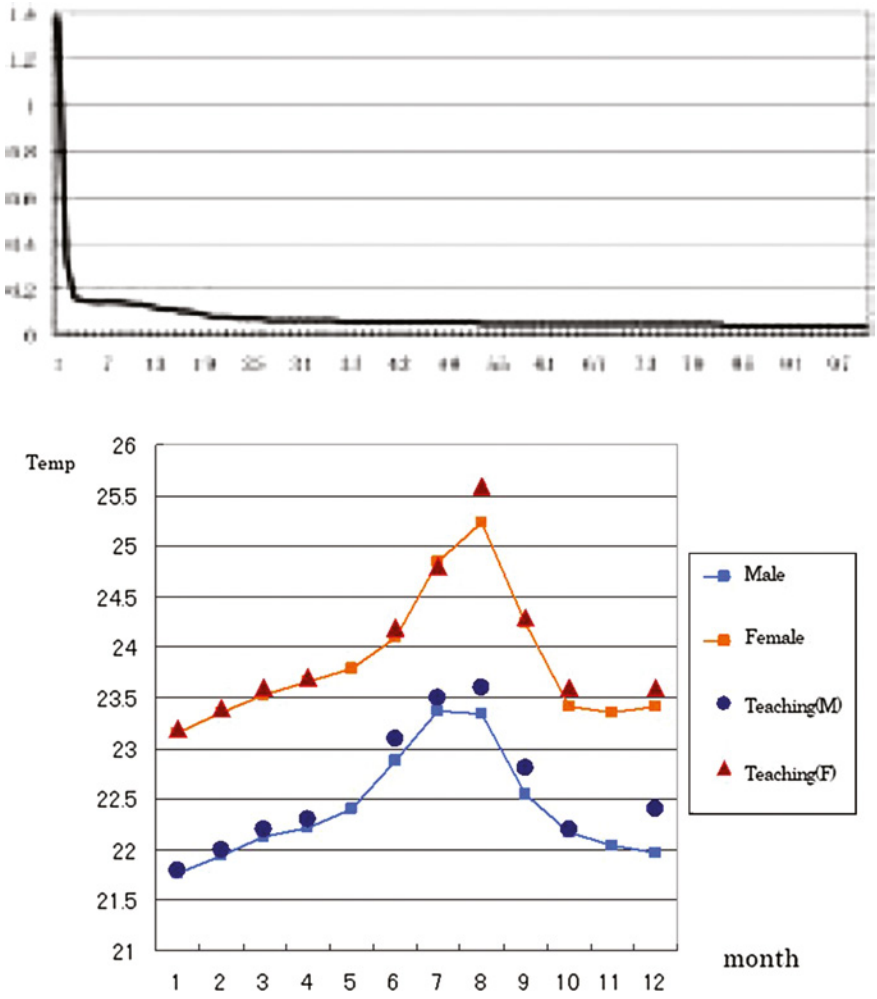


Fig. 8 Result obtained by neural network

7 Conclusions

The temperature of the space is effectively controlled using the measurement of α brainwaves of a test subject according to his/her state such as in a working state or in a rest state. The proposed method can be extended to other human parameters such as humidity, smell, and so on. We may also use other parameters of a human body

including electrocardiogram, sweat analysis, saliva analysis, and so on. This system enables us to control a human environment according to the state of a person.

Nevertheless, there are several issues that should be considered. One issue is how the temperature should be set for plural persons in a room. One solution is to set the mean value for all persons there. In this case, it will have the possibility that all people would not be satisfied. In the measurement of brainwaves, many people may not be able to produce clear brainwave signals.

The brainwaves, body temperature, blood pressure, and heart beat are measured according to the response of various stimuli changes when a person is in a space where various attributes of the space can be changed, including light strength, light color, an air-conditioning system, image media, and a massage system. The space is named affective space.

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A New Social Emotion Estimating Method by Measuring Micro-movement of Human Bust

Eui Chul Lee, Mincheol Whang, Deajune Ko, Sangin Park and Sung-Teac Hwang

Abstract In this study, we propose a new micro-movement analyzing method of the human bust to estimate social emotions with human relations. In previous research for quantitatively measuring human intention and emotion, physiological sensors such as ECG, PPG, GSR, SKT, and EEG have been analyzed. However, these methods cannot avoid the measurement burden caused by sensor attachment. This may result in negative emotions that skew the true evaluation. To solve these problems, we focus on micro-body movement responding emotions. Micro-body movements are determined by analyzing successive image frames captured from a conventional webcam. The amount of the bust micro-movement is then obtained by subtracting two adjacent image frames. Based on the interval between the two image frames, the amounts of micro-movement per several frequency bands can be acquired. Because the calculated successive values of bust micro-movement are in the form of 1D temporal signal, it can be general method for all conventional temporal signal processing. The results showed less micro-movement in the case of an intimate relation group compared with the case of a non-intimate one.

Keywords Human body • Micro-body movement • Social emotion • Image subtraction • Frequency Analysis

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_2,

1 Introduction

In previous research, many types of physiological signals (ECG (electrocardiography), PPG (photoplethysmography), GSR (galvanic skin response), SKT (skin temperature), and EEG (electroencephalography)) have been adopted for quantitatively measuring human intention and emotion [1]. In the case of an ECG or PPG, the heart rate can be determined by analyzing successive pulse-to-pulse intervals [2]. Additionally, amplitude levels are parameters measuring respective skin responses and temperatures when using GSR and SKT. EEG data can be interpreted by using various types of methods in the time or frequency domain. However, the aforementioned methods are inconvenient to measure based on the fact that sensors must be attached that can inadvertently cause a negative emotion causing noise in the readings.

Recently, camera vision-based physiological data acquisition methods were proposed, which is free from conventional physiological sensors. The CardioCam was proposed for measuring human heart rates by ICA (independent component analysis)-based color channel analyses without any sensor attachment [3]. Additionally, many smartphone applications have been released that measure heart rates in real time by using both built-in backside cameras and white illuminators [4]. In these applications, the brightness levels of successive images were observed to change because the amount of illuminative reflection was continuously and regularly changed according to the blood flow. Although the mentioned methods are meaningful because no sensors have to be attached, they only decode heart rates.

Various types of micro-movements of the human body offer significant measurements without sensor attachments. In this study, we defined the measurements of human body movement (as shown in Fig. 1) that can clarify the dependency (or independency) of each part's micro-movement. As shown in Fig. 1, the hierarchical model could well explain the dependency of micro-movements between body parts. For example, the amount of facial micro-movements can be calculated by summing the bust amount and the facial self-amount. In Fig. 1, the hierarchical model was defined as "Full body > (Bust > Arm = (Face > (Eye = Mouth)))." Because the measurement of full body micro-movement was not suitable with a camera, comparatively higher ranked "Bust" micro-movement information can be chosen in this research for purpose of estimating social emotion.

To measure the amount of micro-movements, the region of interest (ROI) was defined at first in the captured bust image frame on the basis of face position as detected from the adaptive boosting (Adaboost) method [5]. The amount of bust micro-movement was then calculated by subtracting two successive images. According to the interval between two image frames, the amounts of micro-movement per several frequency bands could be acquired. The results of feasibility tests for comparison between intimate and non-intimate groups showed that more less movement in case of intimate relation group was occurred compared with the case of non-intimate one.

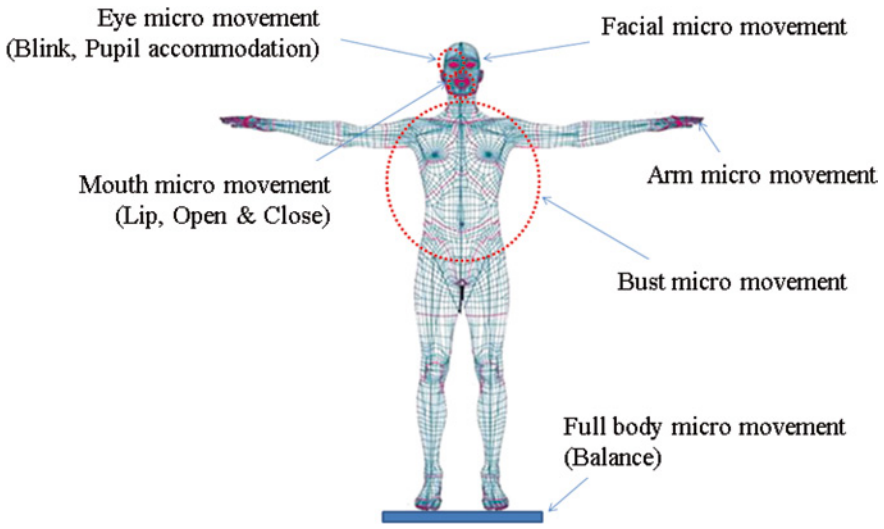

Fig. 1 Definition of various micro-movements of human body

2 Proposed Method

First, face region was detected in the 1st frame of upper body image by using OpenCV [6] Adaboost face detector. The Adaboost method used a strong classifier generated by combining simple weak classifiers to detect face on an input image [5]. Although this algorithm took much training time, it had advantages such as rapid time required for detection and good detecting performance. It took 29ms per an image in average to detect facial region in 1/4 decimated image. Figure 2 showed face detection in red rectangle as an example.

After face detection shown in Fig. 2, the candidate region for subtracting image to calculate bust micro-movement was defined by expanding 160 pixels directed to horizontal directions of facial region rectangle as shown in green rectangles of Fig. 2.

To measure the amount of micro-movement, the camera vision analysis program was implemented. In the analyses, the captured color image was converted to gray level one because color component was not important in terms of estimating motion. The average amount of micro-movement at F frequency band (O_{FHz}) could be calculated as following equation.

$$O_{F_{Hz}} = \frac{1}{WH} \sum_{j=y}^{H} \sum_{i=x}^{W} \left| I_n(i,j) - I_{R/F}(i,j) \right| \tag{1}$$

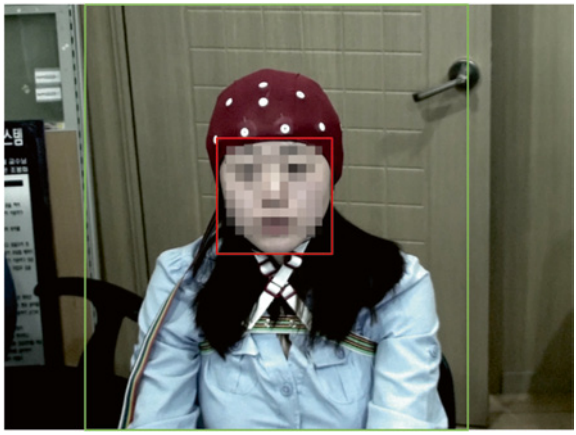

Fig. 2 Face detection results using Adaboost. (*Red* Detected facial region, *Green* Defined candidate region of bust micro-movement)

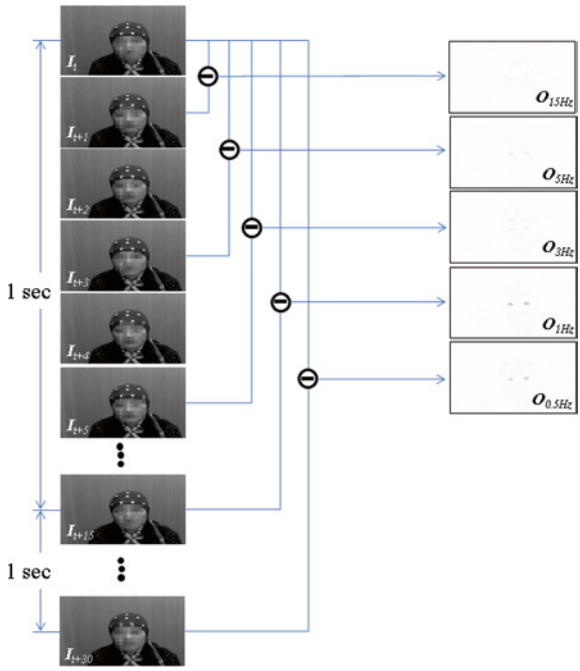

Fig. 3 Conceptual diagram of proposed micro-movement calculation method (rightmost *white* background images are inverted ones for visibility)

In Eq. (1), W and H were the horizontal and the vertical length of the bust micro-movement candidate region, respectively. And $I_n(i, j)$ meant pixel value of ith column and jth row of nth image frame. R was a frame rate of the used camera. In our method, the frame rate was 15. The conceptual diagram of proposed method for extracting micro-movement was shown in Fig. 3.

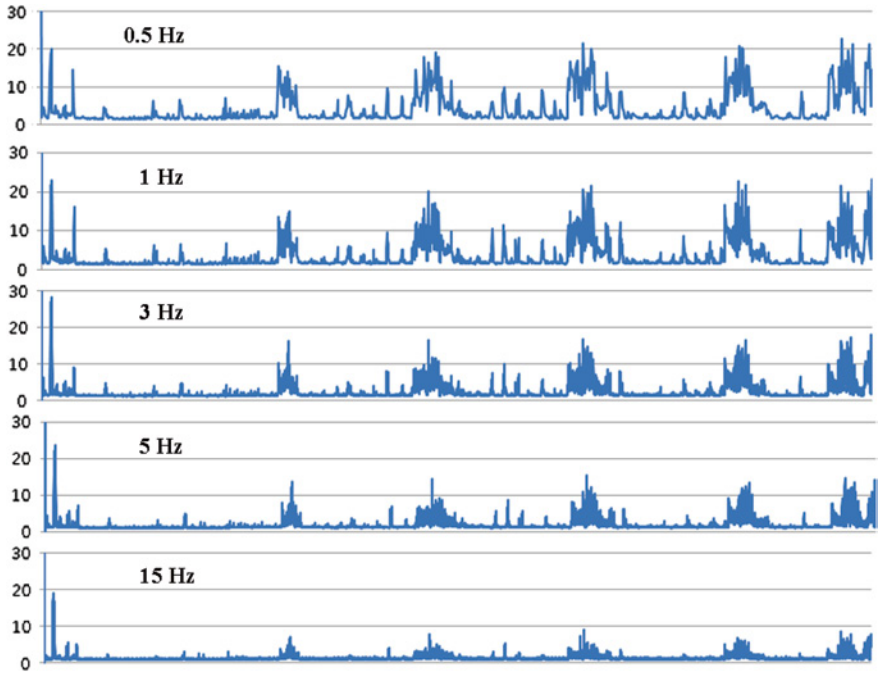

Fig. 4 Example of the amounts of micro-movements at several frequency bands

Since the extracted continuous O values in Eq. (1) generate 1D temporal signal as shown in Fig. 4, it could be analyzed by using same way of conventional signal analyses methods. In addition, the micro-movement information could be analyzed at the various frequency bands. This frequency analysis method was a different contribution point of this chapter from the previously presented method [7]. For example, intended big gesture could be well extracted at low-frequency band, and then, their regions might be a role of mask region for rejection of micro-movement measurement at high-frequency band. Although previous background subtraction methods for object detection had problem in continuous change of background or complex background modeling, our proposed method was independent upon background changes because it used only the latest two image frames.

The proposed method can be used to any body part in Fig. 1. If the particular body part's detection method is previously performed, its micro-movements or muscle movements can be measured and analyzed. For example, if Adaboost (Adaptive boosting)-based face detection method is used, only micro-movement of facial region can be analyzed. Figure 5 showed many kinds of micro-movement detecting results by using the program. In this figure, bright regions were regions in micro-movement.

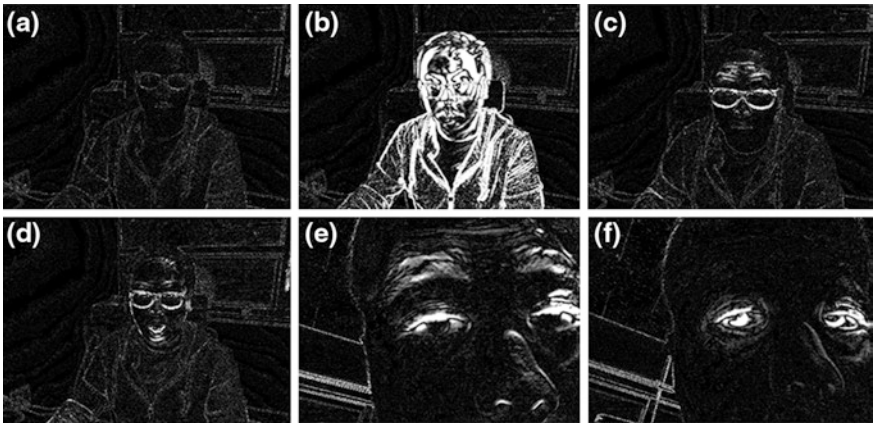

Fig. 5 Feasibility test of detecting micro-movements [7]. **a** Almost no micro-movement. **b** Bust micro-movement. **c** Upper facial muscle movement. **d** Mouth movement. **e** Eye blink. **f** Pupil movements caused by changing gaze direction

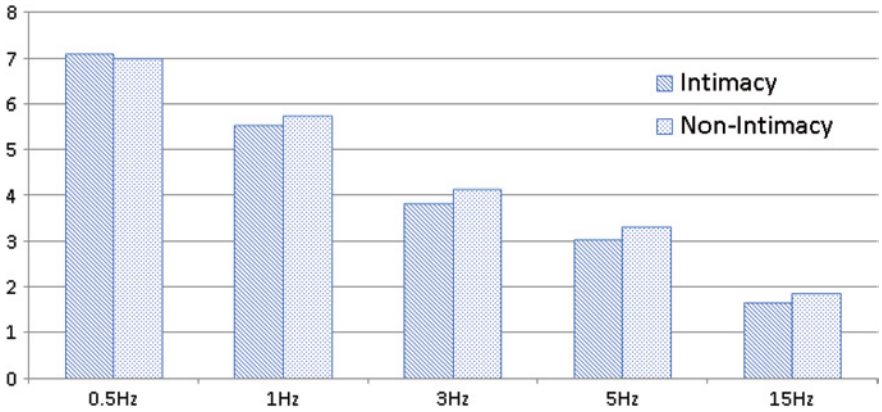

Fig. 6 The average amounts of micro-movements for two social emotion: groups such as intimacy and non-intimacy relations at various frequency bands

3 Experimental Result

Micro-body movement has been assumed as an intrinsic response of social emotion in this study. Our proposed method allowed social interaction free from senor attachment and compared intimate with non-intimate social emotion groups. For that, 4 subject pairs were participated in which each pair had a conversation about a given topic during 25 minutes, where 2 subject pairs had intimate relation with each other, while another 2 subject pairs had no social relation. During conversations, upper body image was captured by using a conventionally used webcam as resolution of

640 pixels by 480 pixels and 15 frames per second. Then, the captured image frames were analyzed for obtaining the amount of micro-movements at five frequency bands such as 0.5, 1, 3, 5, and 15 Hzs.

The extracted average amounts of micro-movements at various frequency bands were shown in Fig. 6. According to this result, we found that the amounts of micro-movement for intimate social relation were less than the case of non-intimate one excepting for 0.5 Hz band. Also, we recognized that more difference between two groups was appeared at higher frequency bands. From this result, non-intimate social emotion was assumed to be induced more amount of micro-movement of human bust. However, this result should be verified by statistical significances or exploring correlations with various conventionally used bio-signal-based emotion estimation features.

4 Conclusion

We proposed a new method for estimating social emotion by analyzing micro-body movement. Allowing social interaction without measurement burden from sensor attachment, our method took advantage of observing social emotion development. Micro-body movement could be classified into two levels of intimacy. Our study successfully analyzed micro-movement of human bust from successive image frames captured by conventional webcam. For that, the amount of bust micro-movement was measured by subtracting adjacency two image frames. Because the measured successive values of bust movement were the form of 1D temporal signal, all of conventional temporal signal processing methods might be used. Results showed that micro-movement in case of intimate relation was less than in the case of non-intimate emotion.

In future works, we will experimentally validate connectivity between each part's micro-movement of human body and various kinds of conventional physiological responses. For example, we will analyze correlation between pulse-to-pulse interval and the amount of bust micro-movement after acquiring both ECG signal and bust movement for specific social emotion. Also, higher frequency band signal will be partially rejection filtered by masking big gesture section extracted from low-frequency band.

Acknowledgement This work was supported by the Global Frontier R&D Program on <Human-centered Interaction for Coexistence> funded by the National Research Foundation of Korea grant funded by the Korean Government (MEST) (2012-055701).

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Affective Engineering in Application to Bi-Level Human Migration Models

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Abstract In this paper, we develop a bi-level human migration model using the concepts of affective engineering (*Kansei* Engineering) and conjectural variations equilibrium (CVE). In contrast to previous existing works, we develop a bi-level programming model in a natural form. The upper level agents are municipalities of competing locations, whose strategies are investments into the infrastructures of the locations (cities, towns, etc.). These investments aim at making the locations more attractive for both residents and potential migrants from other locations, which clearly demands affective engineering tools. At the lower level of the model, the present residents (grouped into professional communities) are also potential migrants to other locations. They make their decision where to migrate (if at all) by comparing the expected values of the utility functions of the outbound

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_3,

and inbound locations, estimated by taking into account their group's conjectures concerning equilibrium migration flows between the involved locations. The utility functions reflect the affective engineering technique because their values are based on the potential migrants' affection to the target locations. Applying a special technique to verify the consistency of the conjectures (influence coefficients), the existence and uniqueness results for the consistent conjectural variations equilibrium (CCVE) are established.

Keywords Bi-level human migration model • *Kansei* (Affection) utility functions • Variational inequality formulation • Consistency criterion • Consistent conjectural variations equilibrium

1 Introduction

Migration problems have been actively studied in many countries throughout the world, as the information/migration prediction data are extremely useful on a large economic scale. Migration prediction data can stipulate development of facilities necessary to advance employment, education, and ecology. Reciprocally, locations with more advanced infrastructure, higher employment capacities, ecologically friendly environments, etc., can generate the affection of the inhabitants and thus attract more potential migrants. However, overloaded housing/infrastructure facilities may reduce the comfort in everyday life, thus contradicting the Kansei engineering principles. Therefore, one can expect a trade-off in the investments into a locations infrastructure, balanced at a conjectural variations equilibrium state.

Various migration theories have been developed over time. In a shorter historical aspect, however, one may rely on the excellent fundamental survey Akkoyunlu and Vickerman [1].

In the works by Bulavsky and Kalashnikov [2, 3], a new array of conjectural variations equilibria (CVE) was introduced and investigated in which the influence coefficients of each agent affected the structure of the Nash equilibrium. In particular, constant conjectural influence factors were used in the human migration model examined in [4]. More precisely, the potential migration groups were taking into account not only the current difference between the utility function values at the destination and original locations but also the possible variations in the utility values implied by the change of population volume due to the migration flows. These conjectured variations could be described with an aid of the so-called *influence coefficients*. In other words, we did not consider a perfect competition but rather a generalized Cournot-type model (in contrast to the classic Cournot model).

In their previous papers [5, 6], the authors extended the latter model to the case where the conjectural variation coefficients may not only be constants but also functions of the total population at the destination and of the group's fraction in it. Moreover, we allow these functions to take distinct values at the abandoned location and at the destination, which should elevate the models flexibility. As an experimental

verification of the proposed model, we developed a specific form of the model based upon relevant population data of a three-city agglomeration at the boundary of two Mexican states: Durango (Dgo.) and Coahuila (Coah.). Specifically, we considered the 1980–2005 dynamics of population growth in three cities—Torreón (Coah.), Gómez Palacio (Dgo.), and Lerdo (Dgo.)—and proposed utility functions of three various types for each of the three cities. To our knowledge, these types of utility functions were not used in previous literature dealing with the human migration model. After collecting the necessary information about the average movement and transportation (i.e., migration) costs for each pair of cities, we applied the above-mentioned human migration model to this example. Numerical experiments were conducted, with interesting results concerning the probable equilibrium states.

The novel approach of the recent paper by Kalashnikov et al. [7] lies in the proposed definitions of consistent conjectures and in the outskirt of possible ways to calculate the consistent conjectures and the related consistent conjectural variation equilibrium state (CCVES).

Motivated by the ideas of bi-level structures of migration processes (the upper level competition among municipalities and the lower level equilibrium among the potential migrants), we proposed a new (bi-level) formulation of the human migration model. Under general enough assumptions, we also proved the existence of solutions to the bi-level program. The results of the numerical experiments (which are still underway) will only be outlined.

Sections 2 and 3, in primarily following the previous papers by Kalashnikov et al. [5, 6] and Kalashnikov et al. [7], describe the proposed bi-level human migration model, define the conjectural variation equilibrium at the lower level, and cite Theorems 3.1 and 3.2 from [5, 6], which establish the existence and uniqueness of the lower level equilibrium as a solution of an appropriate variational inequality problem. The consistency of the conjectures and the existence of the corresponding bi-level equilibrium are discussed in Sect. 4. In contrast to the previous paper [8], here we extend the lower lever (and thus, also the upper level) utility functions from linear to quadratic ones. The conclusions (Sect. 5), acknowledgments, and the list of references complete the paper.

2 Problem Statement and Preliminaries

Similar to [4–6], consider a closed economy with:

- n locations, denoted by i;
- K classes of population, denoted by k;
- $\bar{Q}_i^k$ initial fixed population of class k in location i;
- Q_i^k final population of class k in location i;
- s_{ij}^k migration flow of class k from origin i to destination j;
- $c_{ij}^k\left(s_{ij}^k\right) = b_{ij}^k s_{ij}^k + \frac{1}{2} a_{ij}^k \left(s_{ij}^k\right)^2$ migration cost for residents from group k moving from location i to location j.

Assume that the migration cost reflects not only the cost of physical movement but also the personal and psychological (affection) cost as perceived by a class when moving between locations. The utility u_i^k (attractiveness of location i as perceived by class k) depends on the population at destination, that is, $u_i^k = u_i^k(Q_i^k)$. This assumption is quite natural: indeed, in many cases, the cities with higher population provide much more possibilities to find a job, better medical service and household facilities, a developed infrastructure, etc., which is readily described by the principles of *Kansei* Engineering. On the other hand, when the infrastructure development lags behind the modern city demands, the higher population may lead to certain decrease in the living standards, in the inhabitants' affection to their place, and hence, of the affection utility values.

These affection utility functions also incorporate parameters reflecting the scale of investments made by the location's authorities in order to improve the infrastructure, employment capacities, household construction, power supply, and so on, based upon the principles of *Kansei* Engineering. Exactly these amounts of investment play the role of the municipality strategies in the game at the upper level.

First, we describe the lower level problem. The conservation of flow equations, given for each class k and each location i, and the inequalities forbidding repeated or chain migration are listed below:

$$Q_i^k = \bar{Q}_i^k + \sum_{j \neq i} s_{ji}^k - \sum_{j \neq i} s_{ij}^k, \quad i = 1, \ldots, n, \tag{1}$$

and

$$\sum_{j \neq i} s_{ij}^k \leq \bar{Q}_i^k, \quad i = 1, \ldots, n, \tag{2}$$

with $s_{ij}^k \geq 0$, $\forall k = 1, \ldots, K$; $j \neq i$. Denote the problem's feasible set by

$$M = \{(Q, s) |\ s \geq 0,\ (Q, s) \text{ satisfies } (1) - (2)\}. \tag{3}$$

Equation (1) states that the population of class k at location i is determined by the initial population of class k at location i plus the migration flow into i of that class minus the migration flow *out* of i for the same class. Equation (2) postulates that the flow out of i by migrants of group k cannot exceed the initial population of group k at i, because no chain migration is allowed in this model.

Assume that the migrants are rational and affection-motivated and that migration continues until no individual has any affection to the target location and thus any incentive to move, since a unilateral decision will no longer yield a positive net gain (the gain in the expected affection utility value minus the migration cost).

In order to extend the human migration model from [4], here we introduce the following concepts.

Definition 1 Let $w_{ij}^{k+} \geq 0$ be an influence coefficient taken in account by an individual of class k considering a possibility of moving from i to j. This coefficient is defined by his/her assumption that after the movement of s_{ij}^k individuals of class k from i to j the total population of class k at j equals:

$$\bar{Q}_j^k + w_{ij}^{k+} s_{ij}^k. \tag{4}$$

At the same time, let $w_{ij}^{k-} \geq 0$ be an influence coefficient conjectured by an individual of group k planning to move from i to j, determined by the assumption that after the movement of s_{ij}^k individuals, the total population of class k in i will remain

$$\bar{Q}_i^k - w_{ij}^{k-} s_{ij}^k. \tag{5}$$

We accept the following assumptions concerning the affection utility functions and expected variations in the utility values:

A1. The affection utility $u_i^k = u_i^k\left(Q_i^k\right)$ is a monotone decreasing and continuously differentiable function.

A2. Each person of group k, when considering his/her possibility of moving from location i to location j, takes into account not only the difference in the affection utility values at the initial location and the destination, but also both the expected (negative) increment of the affection value at the destination j:

$$s_{ij}^k w_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k}, \tag{6}$$

and the expected (positive) affection utility value increment in the abandoned location i:

$$-s_{ij}^k w_{ij}^{k-} \frac{\partial u_i^k}{\partial Q_i^k}. \tag{7}$$

3 Definition of Equilibrium

In this section, we will define what we understand as the conjectural variations equilibrium (CVE) both at the lower and the upper level of the new migration model.

3.1 Definition of Equilibrium at the Lower Level

At the lower level, we use the same concept of CVE as defined in our previous works [5–7].

Definition 2 A multiclass population and flow pattern $(Q^*, s^*) \in M$ *are the equilibrium at the lower level,* if for each class $k = 1, \ldots, K$, and for every pair of locations (i, j), $i, j = 1, \ldots, n$; $i \neq j$, the following relationships hold:

$$u_i^k - s_{ij}^{k*} w_{ij}^{k-} \frac{\partial u_i^k}{\partial Q_i^k}(Q^*) + b_{ij}^k + a_{ij}^k s_{ij}^{k*} \begin{cases} = u_j^k + s_{ij}^{k*} w_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k}(Q^*) - \lambda_i^k, \text{ if } s_{ij}^{k*} > 0; \\ \geq u_j^k + s_{ij}^{k*} w_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k}(Q^*) - \lambda_i^k, \text{ if } s_{ij}^{k*} = 0; \end{cases} \tag{8}$$

and

$$\lambda_i^k \begin{cases} \geq 0, \text{ if } \sum\limits_{\ell \neq i} s_{ij}^{k*} = \bar{Q}_i^k; \\ = 0, \text{ if } \sum\limits_{\ell \neq i} s_{ij}^{k*} < \bar{Q}_i^k. \end{cases} \tag{9}$$

□

In order to proceed with the equilibrium existence and uniqueness results, we need an extra assumption to hold.

A3. We assume that the influence coefficients are functions depending upon the current population at the location in question and the migration flow from location i to location j, satisfying the following conditions:

$$s_{ij}^k w_{ij}^{k+}(Q, s) = v_{ij}^{k+} s_{ij}^k + \sigma_{ij}^{k+} Q_j^k, \tag{10}$$

and

$$s_{ij}^k w_{ij}^{k-}(Q, s) = v_{ij}^{k-} s_{ij}^k + \sigma_{ij}^{k-} Q_i^k, \tag{11}$$

where

$$v_{ij}^{k\pm} \geq 0, \ \sigma_{ij}^{k\pm} \geq 0, \ k = 1, \ldots, K; \ i \neq j. \tag{12}$$

Taking into account assumption A3 and omitting for shortness the argument Q^* in the utility functions, we turn (8) into:

$$u_i^k - s_{ij}^{k*} v_{ij}^{k-} \frac{\partial u_i^k}{\partial Q_i^k} + \sigma_{ij}^{k-} Q_i^{k*} \frac{\partial u_i^k}{\partial Q_i^k} + b_{ij}^k + a_{ij}^k s_{ij}^{k*} = u_j^k + s_{ij}^{k*} v_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k} + \sigma_{ij}^{k+} Q_j^{k*} \frac{\partial u_j^k}{\partial Q_j^k} - \lambda_i^k, \quad \text{if} \quad s_{ij}^{k*} > 0; \tag{13}$$

and

$$u_i^k - s_{ij}^{k*} v_{ij}^{k-} \frac{\partial u_i^k}{\partial Q_i^k} + \sigma_{ij}^{k-} Q_i^{k*} \frac{\partial u_i^k}{\partial Q_i^k} + b_{ij}^k + a_{ij}^k s_{ij}^{k*} \geq u_j^k + s_{ij}^{k*} v_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k} + \sigma_{ij}^{k+} Q_j^{k*} \frac{\partial u_j^k}{\partial Q_j^k} - \lambda_i^k, \quad \text{if} \quad s_{ij}^{k*} = 0. \tag{14}$$

Assume that the affection utility function associated with a particular location and a single class can depend upon the population associated with every class and each location, that is, compose a vector-function $u = u(Q)$. Also suppose that the cost

associated with migration between two locations as perceived by a particular class can depend, in general, upon the flow of each class between every pair of locations, i.e., compose an aggregate vector-function $c = c(s)$. Finally, let us form an auxiliary vector of the appropriate size as follows:

$$d(Q, s) := \left(d_{ij}^k(Q, s)\right), \tag{15}$$

where

$$d_{ij}^k(Q, s) := s_{ij}^k v_{ij}^{k-} \frac{\partial u_i^k}{\partial Q_i^k} - \sigma_{ij}^{k-} Q_i^k \frac{\partial u_i^k}{\partial Q_i^k} + s_{ij}^k v_{ij}^{k+} \frac{\partial u_j^k}{\partial Q_j^k} + \sigma_{ij}^{k+} Q_j^k \frac{\partial u_j^k}{\partial Q_j^k}. \tag{16}$$

Now, we are in a position to formulate the following result established in the previous papers [5, 6]:

Theorem 1 *A population and migration flow pattern satisfy the equilibrium conditions (8) and (9) if, and only if it solve the variational inequality problem*

$$\left\langle -u\left(Q^*\right), Q - Q^* \right\rangle + \left\langle c\left(s^*\right) - d\left(Q^*, s^*\right), s - s^* \right\rangle \geq 0, \quad \forall (Q, s) \in M. \tag{17}$$

□

The existence of at least one solution to the variational inequality (17) follows from the general theory of variational inequalities, under the sole assumption of continuous differentiability of the utility functions u and continuity of migration cost functions c, since the feasible convex set M is compact (*cf.*, for example, Kinderlehrer and Stampacchia [9]).

From now on, we omit the superscript k for simplicity purpose. The uniqueness of the equilibrium population and migration flow pattern (Q^*, s^*) follows under the assumption that the compound operator

$$\begin{pmatrix} -u(Q) \\ c(s) - d(Q, s) \end{pmatrix} : R^{K \times n} \times R^{K \times n \times (n-1)} \to R^{K \times n} \times R^{K \times n \times (n-1)}, \tag{18}$$

involving the utility and migration cost functions, is strictly monotone over the feasible set M:

$$\left\langle \begin{pmatrix} u\left(Q^1\right) \\ c\left(s^1\right) - d\left(Q^1, s^1\right) \end{pmatrix} - \begin{pmatrix} -u\left(Q^2\right) \\ c\left(s^2\right) - d\left(Q^2, s^2\right) \end{pmatrix}, \begin{pmatrix} Q^1 - Q^2 \\ s^1 - s^2 \end{pmatrix} \right\rangle > 0, \quad \forall \begin{pmatrix} Q^1 \\ s^1 \end{pmatrix} \neq \begin{pmatrix} Q^2 \\ s^2 \end{pmatrix}, \tag{19}$$

that is,

$$\begin{aligned} &- \left\langle u\left(Q^1\right) - u\left(Q^2\right), Q^1 - Q^2 \right\rangle + \left\langle c\left(s^1\right) - c\left(s^2\right), s^1 - s^2 \right\rangle \\ &- \left\langle d\left(Q^1, s^1\right) - d\left(Q^2, s^2\right), s^1 - s^2 \right\rangle > 0, \quad \forall \begin{pmatrix} Q^1 \\ s^1 \end{pmatrix} \neq \begin{pmatrix} Q^2 \\ s^2 \end{pmatrix}. \end{aligned} \tag{20}$$

The latter is a consequence of the following classical result of the Theory of Variational Inequality Problems (*see*, for example, Kinderlehrer and Stampacchia [8]):

Theorem 2 *Consider the variational inequality: Find a* $y^* \in M \subset R^m$ *such that*,

$$\left\langle F\left(y^*\right), y - y^* \right\rangle \geq 0, \quad \forall y \in M. \tag{21}$$

If the operator $F : R^m \to R^m$ *is strictly monotone over M, that is,*

$$\left\langle F\left(y^1\right) - F\left(y^2\right), y^1 - y^2 \right\rangle > 0, \quad \forall y^1, y^2 \in M,\ y^1 \neq y^2, \tag{22}$$

then the variational inequality (21) *has at most one solution.* □

Having established the existence and uniqueness of the (lower level) equilibrium among the potential migrants, we may pass to the concept of the upper level equilibrium among the municipal authorities.

3.2 Definition of Equilibrium at the Upper Level

We assume that the affection utility function associated with location i and class k of potential migrants has the form (which is an extension of the linear utility function used in the previous work [8])

$$u_i^k\left(Q_i^k\right) = A_i^k - \frac{B_i^k}{R_i} Q_i^k - \beta_i^k \left(Q_i^k\right)^2, \tag{23}$$

where $A_i^k > 0$, $B_i^k > 0$, $\beta_i^k > 0$ are parameters related to the environment facilities for the potential immigrants of group k in location i. For instance, the economical sense of A_i^k could be the average cost of a household in location i in a district where the typical representatives of class k prefer to settle down, while B_i^k might be interpreted as an inverse affection coefficient for the immigrants of group k: that is, the lower the value of B_i^k, the higher the degree of affection revealed by the average family of the specimen of class k to the growing population of location i. Finally, the parameter R_i reflects the amount of investment by the authorities of location i into the improvement in the environment for the newcomers and the regular inhabitants: The higher the invested amount, the lower the negative effect of the growing population on the location's attractiveness and affection grade for both the current and potential inhabitants.

Now supposing that the investment volumes $R_i > 0$ are used as strategies of the players (municipal authorities of the locations involved), it is standard to define an equilibrium state in the (upper level) game.

Definition 3 An investment vector $R^* = \left(R_1^*, \ldots, R_n^*\right)$ is called the *equilibrium at the upper level* if for any location i, $i = 1, \ldots, nc$, the municipal authority's

utility function $U_i = U_i\left(R_i, R^*_{-i}\right)$ attains its maximum value exactly at $R_i = R^*_i$, if it is assumed that all the rest of the players are stuck to their investment values $R^*_{-i} = \left(R^*_1, \ldots, R^*_{i-1}, R^*_{i+1}, \ldots, R^*_n\right)$. Here, the municipality affection utility function $U_i = U_i(R)$ is the weighted sum of the location's utility functions of all the classes of potential migrants determined below:

$$U_i(R) := \frac{Q^{1*}_i}{Q^*_i} u^1_i\left(Q^*\right) + \cdots + \frac{Q^{K*}_i}{Q^*_i} u^K_i\left(Q^*\right), \tag{24}$$

where Q^* is the equilibrium of the lower level population values, which (due to Theorems 3.1 and 3.1) exists uniquely for any (fixed) vector of investments R involved into the structure of locations' affection utility functions (23). □

4 Existence of a Bi-level Equilibrium with Consistent Conjectures

The consistency of conjectures (or, the influence coefficients) arises naturally as an important issue. Indeed, the existence of at least one equilibrium for arbitrary influence coefficients obliges one to select some justified conjectures so that the above concept of the equilibrium make sense. In this section, we propose a concept of consistency and formulate the existence result for the consistent conjectural variations equilibrium (CCEV).

Based upon the consistency criterion proposed in [10], we formulate the following definition. Here, for simplicity, we recall our assumption that the affection utility function for each location i and every potential migrant group k are quadratic of the form $u^k_i\left(Q^k_i\right) = A^k_i - \frac{B^k_i}{R_i} Q_i - \beta^k_i \left(Q^k_i\right)^2$, with $A^k_i > 0,\ B^k_i > 0, R_i > 0,\ \beta^k_i > 0$; next, $a^k_{ij} > 0$ for each quadratic migration cost function; and finally, conjectures (influence coefficients) are constant with zero elasticity, i.e., $\sigma^{k,\pm}_{ij} = 0$, and $v^{k+}_{ij} = v^{k-}_{ij} = v^k_{ij} > 0$, for all i, j, k.

Definition 4 At a lower level equilibrium (LLE) pattern $(Q^*, s^*) \in M$, the influence coefficients $v^k_{ij} \equiv w^k_{ij} \frac{B^k_j}{R_j}$, $k = 1, \ldots, K$; $i, j = 1, \ldots, n$; $i \neq j$, are referred to as *consistent*, if the following equalities hold:

$$w^k_{ij} = \frac{1}{2\frac{B^k_j}{R_j \beta^k_j} + \sum_{\substack{\ell \neq j \\ \ell \neq k}} \frac{1}{w^k_{\ell j} + \frac{a^k_{\ell j} R_j}{B^k_j}}}. \tag{25}$$

The LLE with consistent conjectures is called a *consistent conjectural variations equilibrium state* (CCVES) in application to the above-described human migration model. □

Now, we are in a position to formulate the following existence result.

Theorem 3 *Under assumptions* A1, A2, *and* A3*, and if all the investment sums are bounded (i.e.,* $0 < R_i \le R$, $i = 1, \dots, n$*), then there exists a consistent conjectural equilibrium state (CCVES) in application to the above-described bi-level human migration model.* □

When proving Theorem 4, we established that certain infinite-dimensional mappings involved in Eq. (4) are continuous and contracting over corresponding compact subsets. This allows one to find, for each fixed group k of potential migrant and each destination location j, good approximations for the consistent conjectures (influence coefficients) $v_{ij}^k \equiv w_{ij}^k \frac{B_j^k}{R_j}$, $k = 1, \dots, K$; $i, j = 1, \dots, n$; $i \ne j$, by applying a simple iteration procedure:

$$w_{ij}^{k,(m+1)} = \frac{1}{2\frac{B_j^k}{R_j \beta_j^k} + \sum_{\substack{\ell \ne j \\ \ell \ne i}} \frac{1}{w_{\ell j}^{k,(m)} + \frac{a_{\ell j}^k R_j}{B_j^k}}}, \quad m = 0, 1, \dots, \tag{26}$$

with $w_{ij}^{k,(0)} = 0$, $k = 1, \dots, K$; $i, j = 1, \dots, n$; $i \ne j$.

The convergence of process (26) is established in the following theorem.

Theorem 4 *For each fixed group k of potential migrants and every pair location-destination (i,j),* $i \ne j$*, the approximate conjectures (influence coefficients) obtained by formulas (26) converge (as* $m \to \infty$*) to the unique solution of system* (25). □

In our future research, we are going to extend the obtained results to the case of not necessarily quadratic affection utility functions and discontinuous conjectures (influence coefficients). However, some of the necessary technique can be developed now, in the case of quadratic utilities and continuous conjectures. To do that, for fixed values of k and j, we denote the value of the inverse of the derivative of the affection utility function by

$$\tau := \left[\frac{du_j^k}{dQ_j^k} \left(Q_j^k \right) \right]^{-1} < 0, \tag{27}$$

and rewrite the consistency equalities (25) in a more general form:

$$w_{ij}^k = \frac{1}{-\frac{2}{\tau \beta_j^k} + \sum_{\substack{\ell \ne j \\ \ell \ne i}} \frac{1}{w_{\ell j}^k - \tau a_{\ell j}^k}}, \tag{28}$$

where $\tau \in (-\infty, 0]$. When $\tau \to -\infty$, then the solution of system (28) tends to the unique limit solution $v_{ij}^k \equiv w_{ij}^k \frac{B_j^k}{R_j} = 1$, $k = 1, \dots, K$; $i, j = 1, \dots, n$; $i \ne j$. In other words, for all the finite values of the parameter $\tau \le 0$, we can prove the following result.

Theorem 5 *For each fixed group k of potential migrants and every pair location-destination (i, j), $i \neq j$, and for any $\tau \in (-\infty, 0]$, there exists a unique solution of Eq. (28) as a collection of continuous functions $w_{ij}^k = w_{ij}^k(\tau)$, $i, j = 1, \ldots, n;\ i \neq j$. Furthermore, $w_{ij}^k(0) = 0$, and $v_{ij}^k(\tau) \equiv w_{ij}^k(\tau)\frac{B_j^k}{R_j} \to 1$ as $\tau \to -\infty$, for all $i, j = 1, \ldots, n;\ i \neq j$* □

5 Conclusions and Future Research

We investigated a human migration model based upon *Kansei* engineering principles and involving conjectures of the migration groups concerning the variations in the affection utility function values, both in the abandoned location and in the destination site. To formulate equilibrium conditions for this model, we used the concept of conjectural variation equilibrium (CVE). We established the existence and uniqueness results for the equilibrium in question, and introduced a concept of consistent conjectures (influence coefficients) together with the corresponding CVEs. The theorem guaranteeing the existence and uniqueness of a solution to each consistency system, and therefore the consistent conjectural variation equilibrium state (CCVES), was also proven.

We also notice that the human migration model with conjectural variations can be further extended and examined in the case when constraint (2) is replaced by a weaker condition, as in

$$Q_i^k \geq 0,\ i = 1, \ldots, n;\ k = 1, \ldots, K, \tag{29}$$

which allows us to consider the repeated or chain migration. In this case, the feasible set M ceases to be compact (remaining, however, convex), which makes the use of the general theory of variational inequality problems insufficient to demonstrate the existence of equilibrium. Then, subtler results obtained in Bulavsky et al. [11] and further developed in Isac et al. [4] can be used instead. Indeed, the existence of equilibrium will be guaranteed for various classes of affective utility functions and migration costs that are free of exceptional families of elements (EFE).

Acknowledgements The first author's research activities were financially supported by the R&D Department (Cátedra de Investigación) CAT-174 of the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), Campus Monterrey, and by the SEP-CONACYT grant CB-2008-01-106664, Mexico. The second and the fourth authors were also supported by the SEP-CONACyT grant CB-2009-01-127691 and the PAICYT project CE250-09, Mexico. The fourth author was supported by the SEP-CONACyT grant CB-2011-11-169765.

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Analysis and Evaluation of Business Signs Using Deviation Values

Masaaki Koyama, Yuki Takahashi and Hisao Shiizuka

Abstract This chapter proposes a new method for evaluating signs in the artisanal sign-making field. In particular, a quantitative evaluation method is used to identify sign evaluation items that can be used to improve the level of customer satisfaction (CS). Introducing the concept of "sign deviation values," the effectiveness of these methods is then examined based on the results of practical tests conducted at sign-makers' premises. The testing method initially involves deciding on items for evaluating signs, and using these items to evaluate actual signs, before and after improvements, to corroborate the effectiveness of the evaluation items. The deviation value method is then introduced to the sign evaluation to determine specific items that should be improved to increase the customer's level of satisfaction. By making comparison between the "before" and "after" versions, new scientific guidelines can be formulated for sign-making.

Keywords Business sign • Sign deviation value • Customer satisfaction

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_4,

1 Introduction

Regardless of their size, signs can have a tremendous effect on a retail shop's success. While there are many possible reasons for installing a business sign, the most important may be "to get people to discover the existence of the company/shop." The history of these signs in Japan is a long one, dating from around 694, when the capital was moved to Fujiwara-kyou, to 710 when it was moved to Heijou-kyou. In both cities, an officially issued thin wooden board called a "*hyouchou*" was used as a sign for shops. In the revised versions of the *Taihou Ritsuryou* (701) and *Ryounogige* (833) decrees, so-called "*hyou*" signs were set up to show the "*dai*" or the types of merchandise or goods being sold. These "*hyou*" are said to have been the beginning of today's signs [1].

The oldest sign extant in Japan is said to be the folding screen sign of the *manju* snack food shop Toraya Bunkozo that dates from the Kamakura Period (1185–1333). During that time, small wooden boards came into use to express the goods, services, etc., that were provided by a shop in easy-to-understand terms. In modern terminology, these would be the equivalent of "illustrated signs."

During the Kambun Era (1661–1672), signs with writing on them began to flourish. During this period, seal-engraving, woodcutting, and sign-making were all performed by the same artisan, but by the mid-1800s, artisans began to branch out and specialize. This might be considered similar to today's "outsourcing." During the Edo shogunate period, signs appeared that made use of plays on words such as puns and witticisms, as well as numerous expressions that are still used today, such as "*Kamban musume*" (a female employee who is a store's drawing card) and "*kamban wo orosu*" (to permanently close a business). These signs can be considered a fusion of artistic handcrafts, calligraphy, and the wit of shrewd merchants that took root in Japan's wonderful culture and led to the development of modern signs.

The creation of these signs up to the present day has a strong "artisanal" element, and it is no exaggeration to say that they are made by experts who have developed very special skills [2]. One sign can contain many elements that are not initially known to us, such as the sign elements that can be discovered by many people and the types of elements that are concealed in the signs [3].

This chapter proposes a new method for evaluating signs in this artisanal sign-making field. In particular, a quantitative evaluation method is used to identify sign evaluation items that can be used to improve the level of customer satisfaction (CS). Introducing the concept of "sign deviation values," the effectiveness of these methods is then examined based on the results of practical tests conducted at sign-makers' premises. The testing method initially involves deciding on items for evaluating signs, and then using these items to evaluate actual signs, before and after improvements, to corroborate the effectiveness of the evaluation items. The deviation value method is then introduced to the sign evaluation to determine specific items that should be improved to increase the customer's level of satisfaction. By making comparisons before and after the modifications, new scientific guidelines can be formulated for sign-making.

2 Test Processes and Composition

This chapter will first explain about the test processes and their composition. For simplicity, the examples used here will be of CS with convenience store signs.

In order for customers to become aware of a sign which consequently is reflected in an action such as entering a shop, the sign should first have meaning. Therefore, there must be a clear understanding of the level of CS with the current sign, and if the sign needs to be improved, it must be clear what parts and to what extent they should be improved.

2.1 Concept of Sign Deviation Values

In the process of deriving the level of CS with signs, the present chapter uses the concepts of deviation values of significance and CS to find relations between the two. This reason for this is that we can think of signs as being a medium that has some sort of capability, such as attracting customers or conveying attractiveness. In other words, getting people to notice a sign and draw them into a shop is such a capability of signs, and it is appropriate to connect this with the concept of deviation values.

2.2 Customer Satisfaction (CS)

CS, for example, purchasing a product, is a concept in which the customer purchases a product when feeling some sort of satisfaction with that product. In order to periodically evaluate the degree of satisfaction on the premises of the business, shop, etc., question items are formulated and used to help develop the next line of products.

The level of importance in these question items can be derived using the single correlation coefficient. For example, assume that the sales s_i and advertising costs a_i at a number of business establishments o_i are known. At such a time, by plotting the advertising costs on the x-axis and the sales on the y-axis, a simple correlation graph of the two can be obtained [8].

Generally, the single correlation coefficient is derived from the following equation:

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \times \sum (y_i - \bar{y})^2}} \tag{1}$$

The value of this single correlation coefficient r becomes $[-1, 1]$. It becomes positive as it approaches $+1$, and the distribution can resemble a rising curve. On

the other hand, it becomes negative as it approaches −1, and the distribution can resemble a downward-sloping straight line. Furthermore, if it is 0, it expresses a non-coefficient where there is absolutely no apparent relationship between the two.

2.3 Deciding on Question Items and Evaluation Methodology

First, a questionnaire about the evaluation items is conducted. Respondents may be asked to answer each question based on a 5-level hierarchy. For example, in order to examine customers' thoughts (level of satisfaction) for convenience stores, possible question items could include "items are always in stock," "the food is fresh", "the food has a good taste," "it does not take long to pay at the register," "the store has a good image," "employees have a good attitude," "products are laid out well," "there is a large variety of goods," and "the store provides an excellent range of services as an agent for other companies." These items are rated on a scale of 1–5, i.e., (1) strongly disagree; (2) somewhat disagree; (3) neither agree nor disagree; (4) somewhat agree; (5) strongly agree, and each question item is quantified.

2.4 Comprehensive Evaluation

Next, in order to make an overall evaluation of the convenience store, respondents are asked to give it a total score: (1) extremely bad; (2) somewhat bad; (3) average; (4) somewhat good; (5) excellent.

If this comprehensive evaluation is the same as the evaluation items shown in Sect. 2.3, then it can be incorporated into the analysis.

Using such a methodology, the results of the questionnaire can be tabulated.

Next, a score of 1–5 is given to each evaluation item, which is divided into "Bad," "Average," and "Good." The degree of satisfaction for each item can be obtained through this scoring system.

2.5 Creating Graph of Customer Satisfaction

Next, the simple correlation coefficient between the evaluation item and the total evaluation is calculated. By plotting the simple correlation coefficient on the x-axis and satisfaction level (the proportion of "good" scores) on the y-axis, a CS graph can be obtained.

2.6 Deriving the Degree of Improvement

In order to identify the items in need of improvement from the CS graph derived with the methodology described above, we introduce here the "CS deviation value" and the "significance deviation value." For this purpose, we assume that

the distribution of evaluation items is a bell-shaped curve (ideally, a normal distribution).

In most cases, the deviation value is the value that shows "the position of the evaluation value within the entire body" that is derived from the points assigned by each scorer using the two conditions of average score and standard deviation in the score distribution with a uniform standard (the same as a bell-shaped curve). The middle score is usually set at 50, and the width of the bell-shaped curve ("wide," "narrow") is converted into a uniform standard using the standard deviation. It is inferred whether there is a high bias or low bias from the central part of the distribution of evaluation values for each item, and this is given a numerical value. Naturally, the closer a deviation value is to the center of the bell-shaped curve, the larger will be the number of evaluations to which that value was assigned. With the standard deviation centered on 50, the bell-shaped curve should cover 99 % of the parent population between 25 and 75.

Therefore, the formulas for deriving the values of the "satisfaction" and "significance" deviations that are being discussed here can be defined as follows:

$$\text{Satisfaction deviation value} = 10 \times \frac{\text{satisfaction} - \text{average}}{\text{standard deviation}} + 50 \tag{2}$$

$$\text{Significance deviation value} = 10 \times \frac{\text{significance} - \text{average}}{\text{standard deviation}} + 50 \tag{3}$$

Using these equations, we can derive the deviation values for satisfaction and significance. Furthermore, we can use these two deviation values to create a "CS deviation value graph."

We can also derive the distance from the origin to each plotted point in the CS deviation value graph. Generally, with the horizontal axis as x and the vertical axis as y, the distance R to the coordinates (x_1, y_1) can be given by the following equation:

$$R = \sqrt{(x_1 - \bar{x})^2 + (y_1 - \bar{y})^2} \tag{4}$$

Furthermore, the angle between a line connecting the origin to point (80, 20) and a line running through other points is designated as θ. Here, the correction index r can be derived as follows:

$$r = \frac{90^\circ - \theta}{90^\circ} \tag{5}$$

Therefore, the improvement level can ultimately be derived as

$$\text{Improvement level} = \text{ Distance } \times \text{Correction index} \tag{6}$$

Using the above equations, the "distance," "angle," "correction index," and "improvement level" for each evaluation item were calculated to obtain numerical guidelines for determining the actual degree to which improvements should be made.

Using the methodology described above, the next chapter will introduce a case study of detailed sign improvement tests that were conducted at actual business sites.

3 Testing Methodology

The following is a discussion of the results of the tests conducted at sign-makers' sites using the method described in 2. The first set of tests is comprised of Test 1 and Test 2.

3.1 Test 1

Purpose: To determine items for evaluating signs.

3.1.1 Test Methodology

In the present study, "purposive sampling" [7], which is well known in the fields of qualitative research, was carried out to identify items for evaluating signs. This was designed to undertake sampling that was in line with the objectives of the study to efficiently collect useful data from "informants" who were commensurate with the purposes of the present study. Therefore, the study had to be commenced after the entire design of the present study was sufficiently examined, and clear standards were set for the informants providing the data. For that purpose, 48 changes in sign contents that could help to attract more customers were provided to 10 sign specialists (people who had at least 2-year experience in work directly related to the design or planning of signs), who were asked the questions listed below. The changes in sign contents were excerpted by the testers from references [5, 6] that presented ways for making sign improvements to attract more customers.

Contents of questions: Among the elements related to attracting customers (Response Sheet 1), which of the items below do you, who are working at a company that is trying to develop better signs to attract more customers to shops, think are important? Please rate them on a scale of 1–5, as follows:

5 Extremely important
4 Somewhat important
3 No opinion
2 Not too important
1 Not at all important.

Please write your rating score in the "Evaluation Column" of Response Sheet 1. (Although there may be differences in store conditions, targets, locations, etc.,

please evaluate each of the items from the perspective of whether it is important to all stores). In addition, please select from among these items, the 5 items that you consider to be most important and denote them with a ○ in the "Important" column.

3.2 Test 2: Examples of Improvements

Purpose: Use the 9 sign evaluation items derived in Test 1 to have evaluations made of actual signs, in order to derive points for improvement. Due to space limitations, here we will present specific improvements made to the signs of a ramen shop, "K".

3.2.1 Test Methodology

1. Photographs of the shop with signs were presented to the following groups of men and women who had no direct connection with the sign industry: 43 people age 20–30; 6 people age 31–40; and 4 people age 41–50. These test subjects were asked the following questions regarding the 9 evaluation items derived in Test 1. Eight types of photos of the shop were shown, of before and after improvements were made. The test subjects were not told whether the photos were taken before or after the improvements.
2. From the results obtained in (1), a satisfaction graph was created based on scores of 4 or 5 as "Good," 3 as "Average," and 1 or 2 as "Bad."
3. In order to determine the level of improvement of the evaluation items, a simple correlation coefficient for "looking at it from an overall perspective, would you want to enter the shop?" was derived for each of these items, then a CS graph was created based on the satisfaction graph created in (2).

Contents of questions: Test subjects were then asked to look at the photographs and rate them on the following scale of 1–5 and write the number in the "Evaluation" column.

Response Sheet 1

Score	Important	Item
		Thick letters
		The sign itself is bright
		The sign conveys friendliness
		The sign itself is large
		The letters are in bright colors
		The letters are large
		The content is interesting
		The letter font matches the shop's business
		Beauty of the sign

Score	Important	Item
		The sign imparts a sense of excitement
		The sign imparts a sense of being
		The sign has an elaborate design
		The sign is easy to find
		The sign is light
		The type of business is easily understood
		The impression is strong
		The attractiveness can be felt
		The colors of the signs are coordinated
		Colors “jump out” at the eyes
		The sign seems to be new (new goods, freshness)
		There is a modern appearance
		Vivid, bright colors are used
		The sign is trendy
		Special services are posted
		There is a sense of innovation
		The sign has a distinguishing shape
		The letters are easy to read
		Lighted signs are used
		Originality
		Names of products/services not offered by surrounding shops are listed
		Sharp design
		Names of products/services are listed
		There is novelty
		There is character
		Photos of services offered are posted
		Curves are used in the design
		The shop name is recognized.
		The sign extends to the full width of the front of the shop
		The shop’s floor in the building is shown
		Prices of merchandise are displayed
		The sign’s shape is well-proportioned
		The sign makes the shop brighter
		The sign adds warmth
		The sign is accurate
		The sign conveys the sense of a thriving business
		The sign is matched with its target
		Simple design

Response Sheet 2

Evaluation	Item
	Looking at the overall appearance, I want to enter this shop
	The content is interesting
	The letter font matches the shop’s business
	The sign is easy to find

Evaluation	Item
	The type of business is easily understood
	The attractiveness can be felt
	The colors of the signs are coordinated
	The signs make the shop brighter
	The sign conveys the sense of a thriving business

Fig. 1 Ramen shop K before and after sign improvements. **a** Before improvements. **b** After improvements

3.2.2 Before Improvements

Before the "renewal" of the signs, the shop in this example had an old-fashioned image. The matching of sign colors, the letter fonts, etc., made it seem like a chain restaurant, and as such failed to motivate potential customers to enter the shop. Because it did not have signs that expressed its goodness and sense of pride as an independent restaurant, the signs likely had little effect in "selling" the shop to passersby (Fig. 1a).

3.2.3 After Improvements

The signs were revamped to completely "push" the shop's eye-catching specialty dish, "flavorful roasted miso ramen." The shop was given storefront banners (the tops and bottoms of banners were attached to vertical poles, and hooks were attached to the ceiling and walls) to show large pictures of the shop's products, which acted to vigorously stimulate the five senses of passersby. The colors and designs of the signs evoked a consciousness of wood grain and gave the shop an image of a "cabin on the plains of Hokkaido."

As seen with this example, even if it is not clearly decorated as such, this is a method for giving a subtly dramatic feeling to the people seeing such signs. Such dramatic effects of the signs could give the shop the appearance of an independent restaurant. After the old signs were replaced, the number of customers was 120 % of what it had been in the previous year (Fig. 1b).

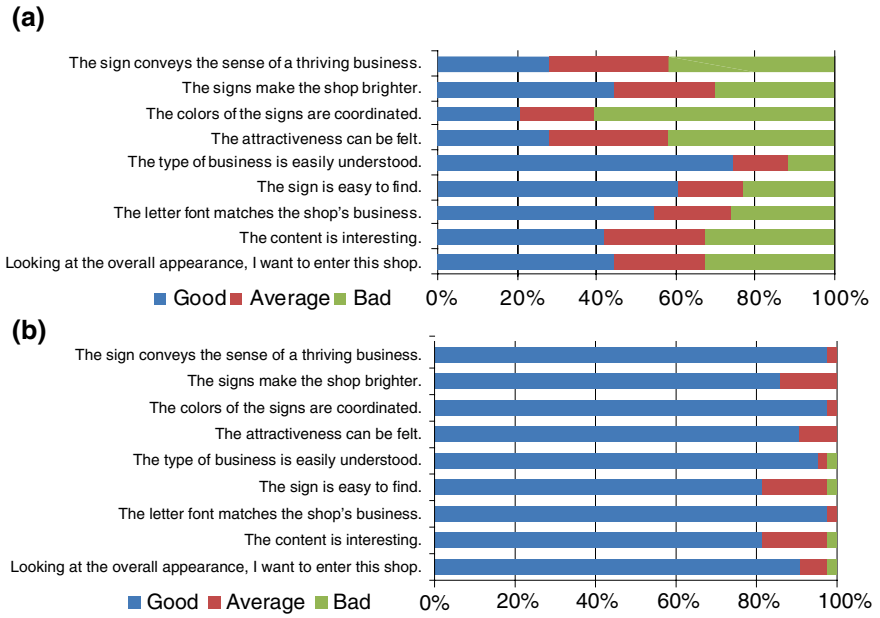

Fig. 2 Satisfaction graphs of ramen shop "K." **a** Tabulated questionnaire results of before improvements. **b** Tabulated questionnaire results of after improvements

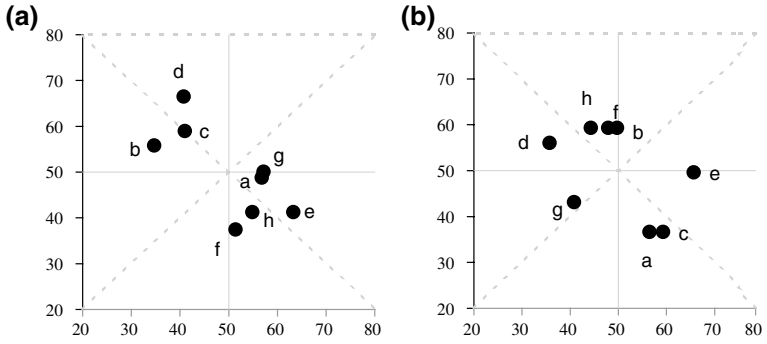

Fig. 3 Significant deviation and satisfaction deviation before (**a**) and after (**b**) sign improvements at ramen shop "K." ***a*** The content is interesting. ***b*** The letter font matches the shop's business. ***c*** The sign is easy to find. ***d*** The type of business is easily understood. ***e*** The attractiveness can be felt. ***f*** The colors of the signs are coordinated. ***g*** The signs make the shop brighter. ***h*** The sign conveys the sense of a thriving business

Next, 43 test subjects were shown the photos in Fig. 1 (without being told which was the "before" and which was the "after" picture) and rated the 9 evaluation items on a scale of 1–5. The results were compiled into the satisfaction graphs shown in Fig. 2. The two graphs show that there was a clear increase in the "Good" (blue) ratings.

Figure 3 shows graphs of the results in Table 1 that were created by plotting the significance deviation on the *x*-axis and the satisfaction deviation on the *y*-axis. As we can clearly see from these graphs, the evaluation items in the fourth quadrant after improvements became less than what they had been before improvements.

Next, as has already been mentioned, the high values for level of improvement were items that had to be improved. By taking the sum of the level of improvement before and after, the state of substantive improvements can be confirmed (Fig. 4). In other words, with the exceptions of b, "the letter font matches the shop's business," which had a negative improvement value, and c, "the sign is easy to find," all items showed lower improvement levels, indicating that improvements had occurred.

4 Discussion of Test Results and Future Topics

As has been shown above, the present study, by applying the concept of deviation values to signs, was able to show the rankings of sign evaluations from the perspective of CS. In addition, in order to verify the effectiveness of this method, analyses and evaluations were made of 3 case studies where detailed evaluations had been made of signs [6]. As a result, the results of the present method and the on-site evaluations could confirm that the evaluations of the signs after improvements were better than those of before improvements.

In the present study, there were 9 items that were selected for evaluating signs, but because they have interrelationships with one another, it will remain for future study to determine whether or not it was appropriate to evaluate everything quantitatively. Actually, as can be seen in the graph of deviation values for significance and level of improvement, positive values for level of improvement indicate that improvement is needed, but negative values indicate that no improvement is needed. Therefore, by looking at changes in the sum of the positive and negative values in the significance/satisfaction graph (Fig. 4), we can see the overall level of improvement. In other words, the size of the values of level of improvement before and after are sometimes positive and sometimes negative, so by adding them together as in Fig. 4, we can get a good understanding of the overall trend in improvement level which can verify the appropriateness of the improvements.

The following is a list of several items that should be considered as topics for future research.

4.1 Generalization of the Interpretation of Sign Deviation Values

By further generalizing the interpretation of the concepts of "deviation values of signs" proposed in the present chapter, the methodology for sign deviation values will become easier to understand. Originally, deviation values were a concept that was introduced to indicate the level of academic ability of test takers within the

Table 1 **a** Deviation value before improvements. **b** Deviation value after improvements

Evaluation item: from the overall appearance, I want to enter the shop	Simple correlation coefficient	Significance	Proportion of "Good" scores	Level of satisfaction	Distance	α (deg)	θ (deg)	*r* (correction index)	Level of improvement
(*a*)									
The content is interesting	0.33	56.79	0.42	48.81	6.89	80.03	35.03	0.61	4.21
The letter font matches the shop's business	−0.03	34.70	0.55	55.82	16.37	69.16	155.84	−0.73	−11.97
The sign is easy to find	0.07	41.00	0.60	58.92	12.68	45.26	179.74	−1.00	−12.64
The type of business is easily understood	0.07	40.77	0.74	66.51	18.92	29.21	164.21	−0.82	−15.60
The attractiveness can be felt	0.44	63.28	0.28	41.22	15.92	56.53	11.53	0.87	13.88
The colors of the signs are coordinated	0.24	51.42	0.21	37.42	12.65	6.43	38.57	0.57	7.23
The signs make the shop brighter	0.34	57.15	0.44	50.07	7.15	89.43	45.57	0.49	3.53
The sign conveys the sense of a thriving business	0.30	54.90	0.28	41.22	10.05	29.14	15.86	0.82	8.28
(*b*)									
The content is interesting	0.55	56.50	0.81	36.65	14.85	25.98	19.02	0.79	11.71
The letter font matches the shop's business	0.43	49.78	0.98	59.30	9.30	1.35	136.35	−0.52	−4.79
The sign is easy to find	0.59	59.30	0.81	36.65	16.27	34.87	10.13	0.89	14.44
The type of business is easily understood	0.19	35.71	0.95	56.07	15.52	66.99	113.01	−0.26	−3.97
The attractiveness can be felt	0.71	65.69	0.91	49.60	15.69	88.52	43.52	0.52	8.10
The colors of the signs are coordinated	0.40	47.89	0.98	59.30	9.54	12.77	147.77	−0.64	−6.12
The signs make the shop brighter	0.28	40.84	0.86	43.12	11.46	53.12	98.12	−0.09	−1.03
The sign conveys the sense of a thriving business	0.33	44.29	0.98	59.30	10.91	31.55	166.55	−0.85	−9.28

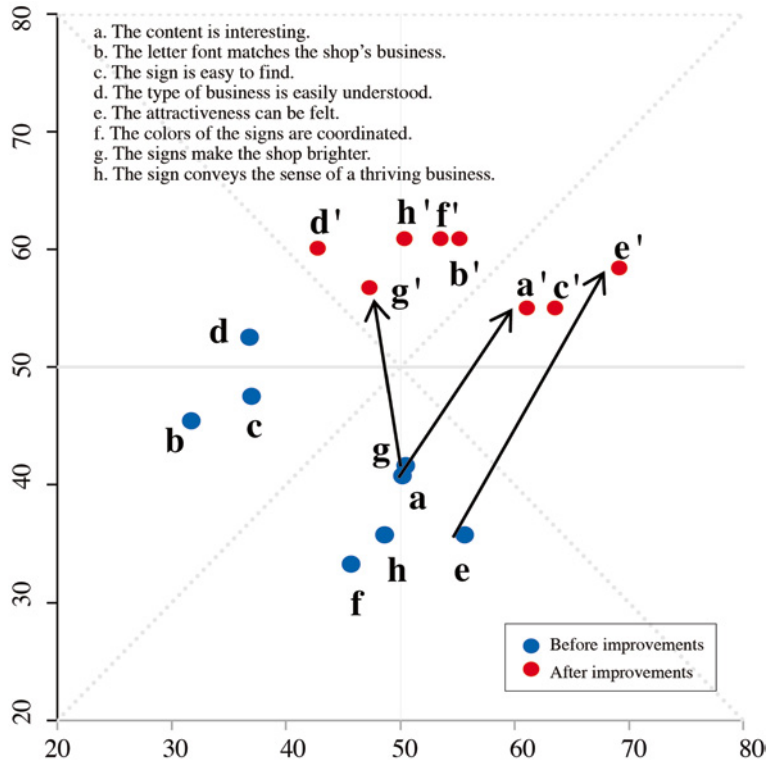

Fig. 4 Changes in the significance/satisfaction graphs before and after sign improvements at ramen shop "K"

entire group. Therefore, applying this to signs can mean that the signs correspond to "test takers" and the various evaluation items correspond to "subjects on the test." Therefore, the problem here is the necessity of developing a unique methodology for sign deviation values that considers the differences between signs and test takers. For this purpose, it will also be necessary to generalize the interpretation of sign deviation values.

4.2 Treating Signs as One System

It is important to clarify the interrelationships among the 9 evaluation items that were selected for the present study. This means treating signs as one system. For that purpose, "systems' thinking" [9] was used to identify cause-and-effect interrelationships among the evaluation items. By clarifying the behavior of the overall system as a so-called open system, the properties of a sign as a dynamic system can be revealed.

4.3 Are There Independent Evaluation Items?

The respective relationships of the sign evaluation items were reported in Sect. 4.1, but the problem is that if truly independent evaluation items exist, they must also be identified at the same time. In other words, what are called independent elements here, when seen from a linear algebraic perspective, refer to combinations of essentially independent elements (evaluation items) which, if they can express other elements, can help to resolve problems by focusing on only the smallest independent elements.

4.4 Statistical Properties Before and After Improvements

Because the evaluations of the items rated by the evaluators showed a normal distribution before improvements, we found that it was possible to apply the deviation value method. While we also confirmed that the distribution of ratings shifted to the right (=good distribution) after improvements, it is important in the quantitative investigation of the nature of signs to understand the relationship between the statistical properties of the two cases and the evaluations of the signs. In other word, the possibility remains for identifying feature values of signs from the properties of the statistical distributions.

4.5 Relation with Visual Communication

It may also be interesting to confirm the utility of this method when evaluating signs from the perspective of visual communication [4].

4.6 Sign Evaluation that Incorporates Qualitative Studies

The evaluation method proposed in the present chapter involves quantitative analysis, but naturally, considerations must also be made from a qualitative perspective. The two perspectives are not in conflict with one another; rather, they can complement the parts that the other is lacking. It would be optimal to incorporate the best aspects of each. This means that another interesting topic might be to develop a method for evaluating signs that takes qualitative studies into account [8].

5 Concluding Remarks

This chapter has introduced the concept of using deviation values to evaluate signs and has proposed a method for improving signs by raising the level of CS. The usefulness of this method was indicated by detailed tests conducted at business

sites. The authors would like to improve this method by further applying its practical aspects by including the items mentioned in this chapter

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Defining Design Subjects According to the Context in Which Problems Occur

Masami Maekawa and Toshiki Yamaoka

Abstract It is necessary to define adequate design subjects to develop attractive and useful products. Not only functional elements but also the ease of use and good affective design are desirable. To bring new values to products, design subjects must be defined without depending on heuristics. However, a problem tends to be the starting point in developing a new product. Problems are relative to the context in which they occur and are typically composed of many causes. Therefore, the study focuses on the context in which problems occur. To make the context easy to be grasped and analyzed, context items were provided. State-keywords were extracted from the descriptions of the context as data for analysis. They were classified into clusters and consequently interpreted to design subjects without heuristics. This chapter shows the process of this method. The results of the experiments used to verify the effect of this method are described and discussed.

Keywords Design subject • Process-state table • Affective engineering • User experience • Context of use • Human-centered design • Task analysis

1 Introduction

Developing a product for solving explicit functional problems is nothing new. In recent years, however, consumers have demanded additional functions, ease of use, and attractiveness. Developers have become confused with planning and

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_5,

designing a product, because the design subjects are not as clear as simply solving functional problems. Consumers, meanwhile, complain that there are few products that they want to use.

User's potential needs are paid attention now. However, it is difficult to find them. Marketing activities were useful in meeting the user's existing needs up to now. The existence of need is the key assumption of past and present marketing activities. However, if customers' existing needs or voices are recognized, attractive products cannot be created because they are likely to be designed with neither originality nor attractiveness. Christensen et al. [1] insisted the necessity of paying attention to the user's jobs. He suggested that the potential needs were found by paying attention to the user's jobs. The importance of finding the potential needs of user's jobs has increased.

Computers cannot be excluded from the discussion about attractive modern products. Unfortunately, many computer products have been invented that are difficult to use and embarrass users because the quality of human–computer interaction (HCI) was disregarded for the expansion of functions and performance [2]. Therefore, in last several decades, finding actual usability problems and the solving them were valued in designing HCI field. However, at this time, the improvement in the attractiveness of HCI has become an aim of design. A high quality of user experience naturally creates a user's favorable impression. In other words, a current requested design activity improves the user's experience.

The basic purpose of design activities is to bring a better experience to the user not only for the HCI field but also for the industrial products and services that are used by all of us. However, when defining design subjects, the design activity tends to be conducted through personal skills or the designer's heuristics.

The improvement in the user experience occurs when the design activity pays attention to the user's activity. Gay and Hembrooke [3] identified the activity-centered design as an effective approach to develop adequate usable systems. This includes paying attention to the user's jobs, as mentioned by Christensen. The design activity focused on the user's activity has the possibility of meeting potential needs that were not acquired in past marketing techniques. However, it is obscure to define an appropriate design subject that differs from the achieving functions. The quality of the result depends on the designer's ability, which is naturally variable because the design subject tends to be provided according to the designer's heuristics [4]. The weight of the survey data particularly tends to be biased by the heuristics [5]. As the heuristics are normally derived from past experience, the design subjects tend to follow the current or past paradigm. A design subject that does not depend on heuristics may become a starting point for new paradigms. Therefore, the method of finding an adequate design subject without someone else's heuristics is worthwhile.

Problems do not tend to occur constantly but only in a certain specific context [6]. For instance, an older person may not be able to easily use the product that a young person can use. Mistakes tend to be made when someone is in hurry. Therefore, it can be thought that the problems are relative to the context in which they occur. The relativity of the context to the problem is focused on in this study. This approach is rarely researched. In this chapter, the method of deriving design subjects from the context is described, and the results of the experiments used to verify the effect are discussed.

2 Existing Techniques

One of the general design processes of improving user experience is the process of human-centered design. For instance, ISO9241-part210 shows a representative of the process. Design subjects are defined in the process.

The conventional techniques for defining design subjects are Jiro Kawakita's KJ method and the card sorting method. They are used to classify problems or events and to make affinity diagrams. In addition, users may be interviewed the reasons of the problems or the details of events. These are attempts to clarify the matters hidden behind the problems or the events. However, these techniques depend on personal sensibility, heuristics etc. Therefore, the quality of the results tends to be different according to the person. Additionally, objective validation of the results is difficult.

The evaluation grid method that Sanui et al. [7] developed can draw out the structure of a person's affective needs. This method is an application of Kelly's personal construct theory. The structure of affection is made by reasons of preference when a participant compares the two presented samples. This method is known as a useful tool to obtain potential affective needs. However, there are some notes. At first, the results tend to be different according to the samples, because the difference that the participants are aware of between the samples becomes the elements of the structure of affection. Moreover, the results do not necessarily show accurate reality because they are just experimental results. The quality of the experimental plan relates whether a proper result can be made or not. Main factors are the samples and the participants. Therefore, the result might be insufficient if the experiment was conducted before these factors are set appropriately.

3 Method

This method is based on the real context of use and problems. As mentioned above, there is a relation between the problems and the context of use. There is a fact that the causes of problems or other events in use tend to be contained in the context [6]. This is the method of specifying design subjects based on this fact. The procedure of this method is described here.

3.1 Problem Findings and Context Descriptions

There are several techniques to find problems. For instance, task analysis [8], the three points task analysis [9], observation, and protocol analysis are used to find problems. These are already popular in product developments and take some parts of this in proposed method. The feature of this method is acquiring not only problems but also the context of the problems. Context is described by the content of each context item (see Fig. 1). With paying attention to the context items, it

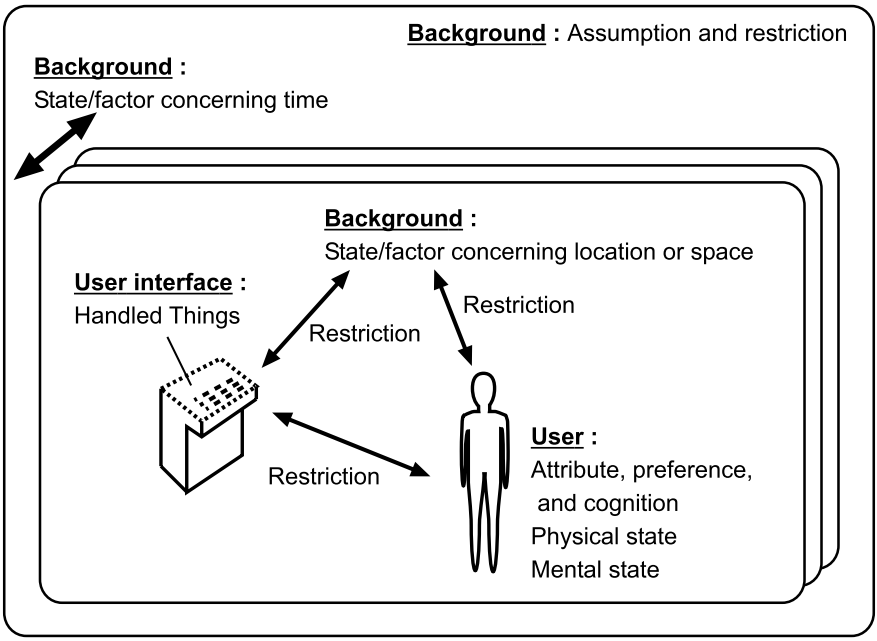


Fig. 1 Context items

becomes easy to search and understand the whole context of the problems. In this method, the data of the context in which the problems occur are more important than the problems themselves.

1. Context items concerning user
   - Attribute, preference, and cognition
   - Physical state
   - Mental state
2. Context items concerning background
   - State/factor concerning time
   - State/factor concerning location or space
   - Assumption and restriction
3. Context item concerning user interface
   - Handled things

These context items were chosen from the elements of several techniques [10]. Some items are contained in persona [11] or scenario, because these techniques are used to show some parts of the context in which products are used. Therefore, the context items have been extracted from actual examples of these techniques. For instance, “Attribute, preference, and cognition” was chosen from the element of persona that Cooper et al. advocated. As Carroll described that scenarios make the context clear [12], “physical state,” “mental state,” “state/factor concerning

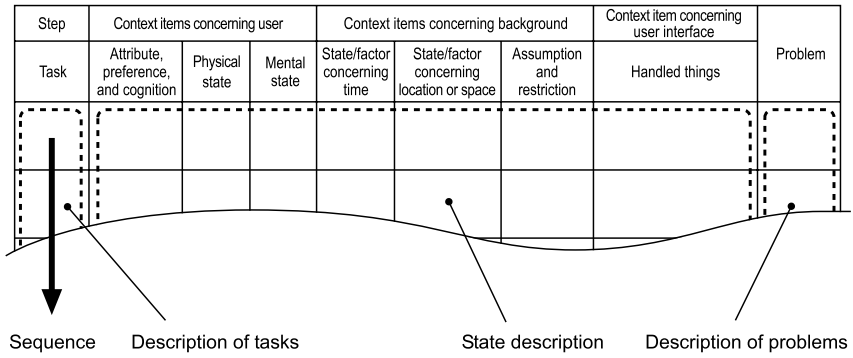


Fig. 2 Form of the process-state table

time," "state/factor concerning location or space," "assumption and restriction," and "handled things" were derived from several scenarios.

The activities are as follows: The contents of the notes and the pictures recorded in surveys are put together and described on the form that is named "process-state table" (see Fig. 2). This is a method that is not only for finding problems in user's activities but also for describing the context according to each of tasks and the context items. The description of each context item in each task is named "state-description." This activity might be seen as a part of a kind of task analysis.

3.2 Extraction of State-Keywords

State-keywords that simply show the state of each context item are extracted from each state-description. Several keywords might be extracted from one state-description. Occasionally, a state-keyword might be state-description itself.

A same matter should be described by same state-keyword, because the keywords are used as category data in the next analysis step. In addition, the state-keywords should be described simple as much as possible like as "borrow the books" or "the map of library."

3.3 Analysis

A categorical data sheet that is composed of the row of state-keywords and the column of problems is made. For a start, the state-keywords are used as category data in the correspondence analysis. Subsequently, the hierarchical cluster analysis is executed with the category score of each state-keyword of some dimensions that is resulted from the correspondence analysis. As the results of the cluster analysis, some clusters are made according to the affinity among the state-keywords.

Descriptions of the problems are used as references to interpret the contents of the clusters. If a concept has been settled before the analysis, state-keywords that do not meet the concept can be excluded from the analysis.

3.4 Interpretation

The state-keywords are classified into some clusters. They are shown in the structure of dendrogram derived from the cluster analysis. The form of the dendrogram is a clue to define clusters, as there is no standard rule to decide the number of clusters. The dendrogram shows the strength of an affinity among state-keywords. The contents of the clusters help us to image the contexts that ought to be concerned in design subjects. If there is a specific problem, it might be easier to image the context. In this case, the descriptions of the problem might be referenced to make design subjects. Finally, the content of each cluster is interpreted to design subjects.

4 Experiments

To determine the effect of this method, two experiments were conducted. And, the results of two experiments were compared. The proposed method was used in Experiment 1, and another existing technique was used in Experiment 2.

4.1 Experiment 1

Three kinds of WEB system that are used to search and reserve to borrow the books of libraries were chosen as objects. Six participants, aged from 22 to 45, who underwent task analysis were designers or students learning design. They were familiar to WEB systems through using various kinds of them daily. The signs of A to F were put to the each participant.

To clarify the differences in the number of state-keywords obtained by between two ways of finding problems, the participants were divided into two groups. Three participants were ordered to find problems, respectively, from another one system. The other three participants were ordered to find problems, respectively, from all of the three systems.

After they found problems from the WEB systems, they described the problems and the context in which the problems occurred according to the context items separately. Some context items were excluded from the description, because the contents of them were judged to have little differences. Three context items of "state/factor concerning time," "assumption and restriction," and "handled things" were applied to this experiment.

Table 1 Number of found problems and extracted state-keywords

	WEB system 1		WEB system 2		WEB system 3		Total	
Participant	Problem	State-keyword	Problem	State-keyword	Problem	State-keyword	Problem	State-keyword
A	12	17	–	–	–	–	–	–
B	–	–	12	22	–	–	–	–
C	–	–	–	–	17	29	–	–
D	13	32	7	16	24	29	44	**50**
E	16	30	14	22	24	29	45	**35**
F	22	34	23	28	14	25	59	**49**
A, B, C Total							42	44
D, E, F Total							148	63
All Total							190	68

Bold indicates average value of 44.67

State-keywords were extracted from the state-descriptions. In this experiment, one experimenter extracted all state-keywords, because a same matter should be described by a same keyword. Therefore, a categorical data sheet that showed the relation between the state-keywords and the problems was made.

Next, the correspondence analysis was executed with the categorical data sheet, and five dimensions of the state-keywords were adopted. Subsequently, the hierarchical cluster analysis on the category score of each dimension was executed. Ward's method was chosen to join neighbor data in the analysis.

A total of 190 problems including repetition were found by the participants, and 68 kinds of state-keywords were extracted. There were 13 kinds of "state/factor concerning time," 26 kinds of "assumption and restriction," and 29 kinds of "handled things." The detailed results of the number of state-keywords and the problems that each participant found in each system are shown in Table 1. As for the total number of state-keywords, repetition was excluded.

The number of state-keywords when the participants found problems, respectively, from one object was shown as follows: The total number of the state-keywords extracted from the results of participants A, B, and C was 44. On the other hand, the numbers of extracted state-keywords were 17, 22, and 29 in each object, respectively.

The number of state-keywords when the participants found problems, respectively, from all systems was shown as follows: The average of each number of state-keywords extracted from the problems that were found by participants D, E, and F was about 44.67. On the other hand, the total number of state-keywords extracted from all problems that were found by participants D, E, and F was 63.

All problems and state-keywords were applied to a categorical data sheet, and the correspondence analysis was executed. Then, state-keywords with five dimensions resulted from the correspondence analysis were put into the cluster analysis. As a result, a dendrogram was made (see Fig. 3). There is no standard rule to decide the number of clusters. In this case, six clusters were adopted according to

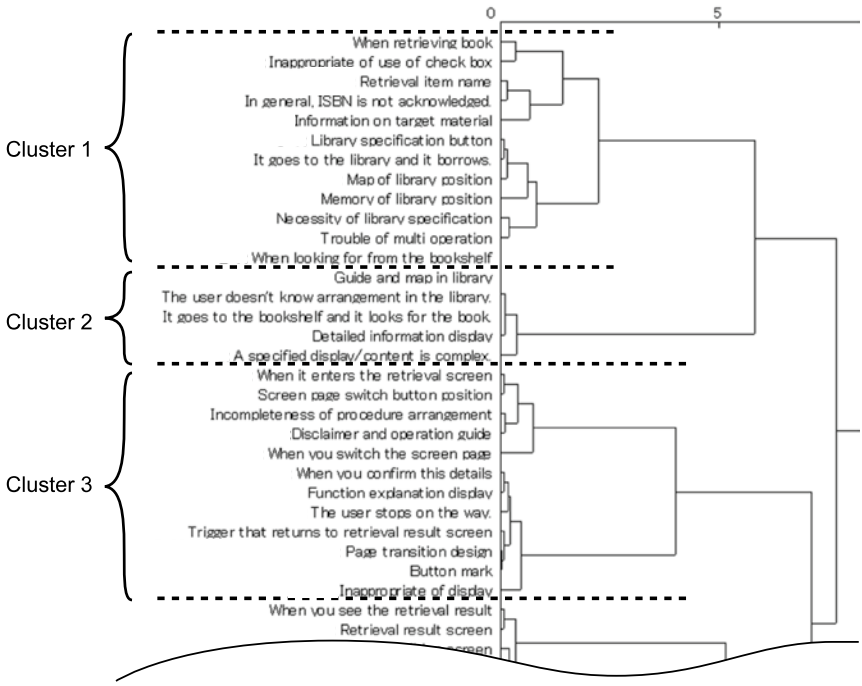


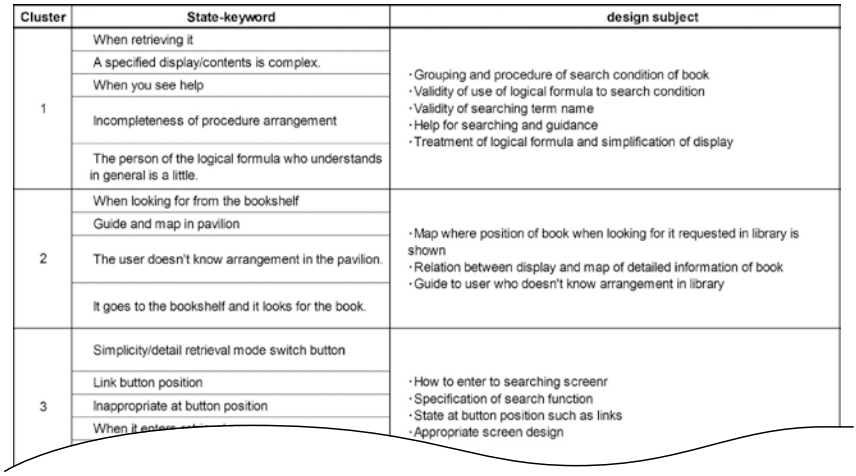
Fig. 3 Dendrogram

the form of the dendrogram. Examples of state-keywords and interpreted design subjects were shown in Fig. 2.

4.2 Experiment 2

An experiment to define design subjects according to heuristics was executed for the comparison with the results of Experiment 1. Using heuristics is a common and convenient technique on the site of design activities. Four participants, aged from 22 to 46 who did not relate to the Experiment 1, were chosen. The descriptions of the 190 problems that were found in the Experiment 1 were used as the data of problems in the Experiment 2. However, neither the state-descriptions nor the state-keywords of the Experiment 1 were used in the Experiment 2. After roughly checking the WEB systems, the participants began to classify the problems to define design subjects.

Some aspects of the problems, for example, external/internal, procedure, and functional/non-functional etc. were tried to classify the problems. Four participants discussed together about the problems with writing some words and drawing figures on a white board. Consequentially, the problems were classified by the



Cluster	State-keyword	design subject
1	When retrieving it A specified display/contents is complex. When you see help Incompleteness of procedure arrangement The person of the logical formula who understands in general is a little.	·Grouping and procedure of search condition of book ·Validity of use of logical formula to search condition ·Validity of searching term name ·Help for searching and guidance ·Treatment of logical formula and simplification of display
2	When looking for from the bookshelf Guide and map in pavilion The user doesn't know arrangement in the pavilion. It goes to the bookshelf and it looks for the book.	·Map where position of book when looking for it requested in library is shown ·Relation between display and map of detailed information of book ·Guide to user who doesn't know arrangement in library
3	Simplicity/detail retrieval mode switch button Link button position Inappropriate at button position When it enters	·How to enter to searching screenr ·Specification of search function ·State at button position such as links ·Appropriate screen design

Fig. 4 Classified state-keywords and defined design subjects

seven classification items. They were "searching books," "visual representation," "transferability of meanings," "layout in the screen," "procedure," "map," and "help."

Design subjects were defined by focusing on functional buttons or indications that related to the problems directly. For instance, design subject was defined as adding sufficient functions for the problems of deficient functions. For the problems of usability, design subject was defined as making existing functions easy. On the other hand, there was no subject aiming to delete or validate existing functions. The design subjects tended to be derived from very narrow classification of the problems based on affinity according to heuristics overall. Eventually, most of them were not the design subjects but the ideas to solve the problems.

5 Discussions

Most of clusters that were derived from the Experiment 1 contained several classification items of the Experiment 2. For instance, cluster 1 that was defined in the Experiment 1 contained the state-keywords concerning "searching books," "procedure," and "help" of the Experiment 2. Similarly, cluster 3 contained the state-keyword concerning "searching books," "visual representation," and "layout in the screen." Therefore, the proposed method was assumed to make design subjects extensive, while heuristics made narrow groups of ideas to solve the problems directly.

In the Experiment 1, it was assumed that the problems were understood in detail by using the context items as the viewpoints. Understanding the problems deeply with the contexts was expected to make design subjects efficient.

In the Experiment 1, the design subjects were derived from 68 state-keywords of three context items. However, it was suggested that the state-keywords could be few when an extremely narrow context was supposed, and this method could have little benefit. The limitations of this method like this ought to be clear by next experiments and investigations.

The state-keywords become elements of design subjects. As a matter of course, the state-keywords that are not extracted are not included in the contents of the clusters. Therefore, it is important to record enough problems and the contexts in which the problems occur, and to extract state-keywords appropriately.

About the number of state-keywords of each context item, the reason of the result that there were few state-keywords of "state/factor concerning time" was thought that the book search systems had a simple procedure. On the other hand, many kinds of state-keywords of "assumption and restriction" were extracted, because the participants could image many reasons in the background of problem occurrences. Additionally, because "handled things" were the operational objects for the most part of WEB systems, many state-keywords of this item were extracted.

About the relation among the number of persons who found problems, the number of objects, and the number of extracted state-keywords, the following results came out in the Experiment 1. The number of state-keywords extracted from one object tends to be less than the number of them from several objects. The reasons were thought as follows: Since the each object was designed with supposing each unique context and restriction, each of them had unique weak points and strong points, respectively. Therefore, the context in which the problems occurred was different between the objects. As a result, more various state-keywords were extracted from three objects than from one.

About the number of state-keywords that were extracted from three objects between by one person and by three, there was a significant difference. The reason was surmised that each person found problems from their unique viewpoints. Therefore, collecting problems by several persons was suggested to be better to obtain various kinds of state-keywords.

Intention was necessary to classify the state-keyword even if the dendrogram was resulted from cluster analysis objectively. And, creative ideas were necessary to interpret state-keywords. Therefore, the design subject could not be defined by numerical data analysis only. However, it was confirmed that the matters that were recognized to make design subjects were more extensive by concerning the context than by paying attention to the problems only. The data of state-keywords were expected to be effective materials in defining design subjects.

Moreover, obtaining materials of design subjects by numerical data analysis was expected to be suitable for in the situation of developments that objective criteria were requested. This feature was seen to be an advantage of this method.

6 Conclusions

The aim of this study was to develop a method that defined design subjects for creating attractive products and improved user experience without depending on a designer's heuristics. This chapter showed the process of determining problems, extracting state-keywords and analyzing, interpreting, and defining design subjects. The results of the experiments were shown and discussed.

Consequently, the following matters were confirmed: More various state-keywords could be extracted by finding problems from plural objects or plural persons. Design subjects could be obtained by interpreting the state-keywords classified on the basis of the dendrogram that was the result of a hierarchical cluster analysis.

The following effects were expected: The design subjects obtained by this method have a possibility of bringing a new value to the product because they are different from the understanding of problems through heuristics based on someone's past experience. Though affective elements have tended to be excluded from the paradigm by solving only the functional aspects of problems, they can now be included in the new value. In this method, the design subjects are considered in the product use. When a person uses the products, the person's affection influences the occurrence of problems [13]. It is natural that the matter that relates to user affection is included in the problems and contexts in use. Therefore, it is expected that the design subjects that implying elements that relates to user affection will be defined when the mental state of the user is included in the state-keywords. In addition, the design subjects can be explained with evidences because they were derived from numerical analyses. Therefore, this method is an effective technique that can be used in the early stage of product development. This method is expected to be useful and effective for designing almost all artificial objects that have user interfaces. This method will be applicable in the design of most industrial products, software, and services.

However, it is too early to assume that the conclusions obtained in this study have general applications. It is necessary to conduct more product developments with this method and advance additional research on its applicable conditions and limitations in the future.

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Design Management Strategy: A Case Study of an Affective Product

Kana Sugimoto and Shin'ya Nagasawa

Abstract Emerging technologies have facilitated the imitation of external design features such as shapes and colors, thus making it a more common practice. As a result of the proliferation of counterfeit goods, both the originality and value of product designs have decreased. Given these activities, a question emerges: How can companies differentiate their products in a market that is trending toward product homogenization? We assume that design strategies that attract consumer loyalty and passion can enable such differentiation. This study focuses on Chanel as a model for design management. Its findings demonstrate that Chanel's unique approaches to strategic product development and icon management have enabled the company to maintain its position as a top luxury brand over the course of several decades.

Keywords Design management strategy • Icon management • Affective product

1 Introduction

This chapter examines the design management strategy of affective products with the goal of identifying practical implications that companies can utilize to develop competitive advantages in a market populated by experienced consumers and a large number of competitors. In today's business world, the mere creation of unique product designs is no longer sufficient for attracting mature consumers.

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_6,

Changes in consumer values and the evolution of technology have forced companies to alter their design management methods. As such, it has become increasingly important for companies to create product concepts that strongly align with their accompanying brands or images, appeal to consumers' emotions, and attract consumers by emphasizing factors other than the external aspects of a product's design (e.g., colors, shapes, new and convenient functions). If a company can effectively design the entire product experience—including its purchase and use—it can enrich the user's experience with that product. Designing the entire product experience can also generate new, consumer-oriented value that competitors cannot replicate as easily as the external product features. Despite the clear benefits offered by creating this customer-centered value, many companies struggle to identify and utilize their inherent assets. Affective products can serve as one solution to this problem.

In this chapter, we define affective products as those that meet a number of criteria. First, affective products are related to consumers' inherent appetites and desires (i.e., those products that relate to consumers' affections). Second, affective products are not directly connected to their physical properties. In addition, we define a comprehensive process of "design management" that includes idea generation, product planning, product design, emotional design, and manufacturing. Activities related to the operation and management of the company, including marketing, logistics, and sales, can also be regarded as part of the "design management" process. Moreover, we define "design management strategy" as a company's direction with respect to the aforementioned design management activities.

Since its inception, luxury brand Chanel has employed a unique design management method referred to as an "icon strategy" that has brought the company continued success. Although the characteristics of the market have largely changed, the company's design management techniques have remained consistent. Given this insight, it would be useful to explore the potential sources of the company's competitiveness in today's market (Nagasawa and Sugimoto [1]).

In an icon strategy, all company characteristics, both tangible and intangible, are considered part of a company's brand identity and thus communicate the uniqueness of the brand. In other words, companies that employ an icon strategy seek to visualize brand identity to evoke their brand images, even in the absence of a brand name or logo. Because companies can benefit from emphasizing design management methods in accordance with market changes, an icon strategy can be an effective means for ensuring the continued success of a manufacturing company. For example, Corbellini and Saviolo [2] demonstrated that people purchase luxury goods because they elicit sensations and emotions from the products' buyers. Given consumers' motivations for purchasing luxury products, they can be considered affective products.

Esslinger [3], an industrial designer and inventor who is best known for his work with Apple Computers in the 1980s, argued for the importance of applying the affective product method to design management. He indicated that product design appeals to a spirit at the core of human beings, particularly if that product design is a brand symbol that expresses their values. Given humans' attraction

to symbols that reflect their values, Esslinger [3] further argued that companies should create designs that merge a product's physical aspects with their target consumers' values. Given his considerable achievements in innovative design at companies such as Apple, Sony, and Louis Vuitton, his claim is certainly convincing.

Related to Esslinger's [3] claim, this chapter examines the representative iconic products of Chanel, which are widely known on the basis of their various internal and external features (e.g., color and shape, brand history, philosophy, and technology). Chanel's focus on icon management has ensured its long-term success. An analysis of icon management strategy in general and an evaluation of Chanel's design management strategy will reveal implications of the strategy to which other manufacturing companies can refer.

2 Definitions and Values of an "Icon" and "Icon Strategy"

Before discussing Chanel's specific strategy, it is important to define and explicate the terms "icon" and "icon strategy." Oxford Dictionary [4] defined an "icon" as a pictorial representation, object of uncritical devotion, sign, or graphic symbol. Using this definition in the context of companies and brands, an icon can be defined as something that communicates the essence of a company and its brand. Alternatively, an icon can be defined as a product function or characteristic that evokes images, emotions, or cognitions related to the company, its brands, or the products/services it provides. In other words, an icon should facilitate company or brand recognition, even in the absence of a brand name or logo.

In this study, a product's external features (e.g., colors, materials, and shapes), a product creator's underpinning philosophies and principles, and company histories are considered "iconic." In addition, this study demonstrates the value that an "icon" adds to a brand. An icon's value can be understood from two perspectives: value for consumers and value for companies. Because they are individual human entities, consumers attempt to differentiate their identities from the identities of others, principally by behaving in ways that differ from those around them. In this vein, purchasing a product known for its brand prestige can be considered a form of self-expression intended to differentiate one consumer from another.

Because a product's iconicity is inherently connected to its perceived value, consumers can satisfy their desire for "conspicuous consumption" by purchasing prestigious and iconic products. Takahashi [5] insisted that the brand should have universality (perenniality). For customers, perenniality is associated with heritage and culture, which evokes images and perceptions of stability. In addition, the length of time for which brand value and status endure contributes to the brand's prestige. Takahashi [5] further asserted that heritage, culture, and company history bring greater value to a brand and the profits it generates. Given this, if companies can effectively create iconic products, opportunities for sales would substantially increase in number and value. In this way, an iconic product can be of considerable value to consumers (for identity differentiation) and companies (for sales) alike.

Fig. 1 The merry-go-round set from Chanel's Fall-Winter 2008 show in Paris featuring Chanel icons. *Source* Nagasawa [1, p. 123], *photographs* (AFP = Jiji)

Given the above, the degree to which a company can be seen as an "icon" can serve as an important tool for enhancing brand value and recognition, increasing sales opportunities, and stimulating consumers' motivations to purchase the company's products. Therefore, we define brand or design management strategies that focus on the development and strategic utilization "icons" as "icon strategies."

3 Case Study Particulars

Although a number of companies have employed icon strategies, this study focuses on Chanel for two reasons. First, the company has long demonstrated the implications of its design management methods through its famous icons. Chanel has produced several famous icons that are widely recognized as parts of the ultimate luxury brand on the market. Yamamuro [6], editor-in-chief of women's wear daily (WWD) Japan, identified several of Chanel's icons, including suits, the camellia motif, imitation pearls, quilting, bicolor shoes, the CC logo, chain straps, Fig. 5 (associated with the company's signature perfume), the lion motif, and others. He indicated that these (and other) icons clearly indicate that a certain product is a Chanel product, even in the absence of a company logo or brand name. This icon strategy has proven effective in winning consumer loyalty over more than 100 years since the company's inception (see Fig. 1).

In addition to communicating the company's brands through its iconicity, it is critical for luxury-brand businesses to add value to their products by appealing to consumers' emotions and developing useful product functions and attractive product qualities. The source of a product's differentiation derives not only from the allure of the product itself, but also from the characteristics of the product that directly appeal to consumers' affections. Given their continued success in the luxury goods market, it is clear that Chanel has developed its icon management skills in parallel with industry trends and characteristics.

The second reason we chose Chanel as the specific focus of this study relates to the nature of the business scenarios to which it has been exposed. Since its inception, Chanel has faced the maturation of consumer demands, an increase in counterfeit goods (spurned by continuous technological advancements), the assimilation of products, and price competition. In spite of these issues and ongoing challenges from common businesses, Chanel has maintained its position as a high-price, high-added-value company through effective management practices. An evaluation of Chanel's approach for addressing these issues may identify actions that other companies must undertake to overcome similar difficulties.

4 Literature Review

Using a systematic, empirical research approach, Holt [7] analyzed brands that are commonly referred to as "iconic." He argued that "icons have an extraordinary value because they carry a heavy symbolic load for their most enthusiastic consumers" (p. 2). He further insisted that myths performed by a brand lead the audience to perceive those myths to be reflected in the brand's markers such as its name, logo, and design elements, and as a result, "the brand becomes a symbol, a material embodiment of the myth" [7, p. 8].

Kapferer and Bastien [8] described both tangible and intangible aspects of brands and icons. According to the authors, products (icons) associated with luxury brands are endowed with a sacred history that creates an aura of a holy image. In addition, they defined icons as a collection of symbols, including logos, numbers, and signs. They described the intangible features of icons by arguing that "the more the products have a symbolic, social and cultural function, the more importance attaches to the non-verbal imaginary" (p. 123). More importantly, with respect to the physical features of icons, they emphasized the importance of a luxury brand's possession of a real collection of symbols for expressing itself in a variety of ways. They stated that a luxury brand carries on its past and "it draws from it its strength, its serenity and its confidence in the durability of its values" (p. 132). They further added, "a luxury brand has one or two iconic products that symbolize, and prefigure its values" [8, p. 130]. Finally, the authors described the venerability of icons and claimed that those icons may not necessarily represent the brand's best-selling product. However, venerability is a defining feature of Chanel's No. 5 perfume.

The points outlined above highlight the importance of icons and iconic products for long-term maintenance of value for luxury brands. Kapferer and Bastien [8] reiterated these points by discussing icons/iconic products that have qualities lent themselves to durability and longevity.

Holt [7] focused on the definition of iconic brands, their intangible aspects, and methods for creating them. He also briefly discussed the tangible facets of product brands. Rather than looking at individual facets of product brands, Kapferer and Bastien [8] provided a comprehensive description of luxury brands and business strategies associated with them. They also demonstrated the importance of icons and iconic products, but neglected to analyze individual iconic products.

Taken together, past research in this domain has defined and demonstrated the value of icons. Most extant research has focused primarily on the intangible aspects of icons, such as brand history, culture, and heritage. Despite the existence of extensive research on these intangible aspects, a systematic value analysis of luxury brand icons and iconic products as tangible assets has yet to be performed. Because icons have both tangible and intangible values, such an analysis is imperative. Therefore, our study aims to determine those features that enable a brand to sustain its value for an extended period of time. Specifically, we conducted a systematic, empirical analysis of Chanel products. We analyzed the physical aspects of the brand's identity and the value of those products that we refer to as icons.

5 Methodology

As outlined above, this study seeks to identify design management implications by examining the case of Chanel. It is clear that companies must differentiate their products from those produced by competitors, not only in terms of design, but also in terms of unique added value. Intangible elements such as the product creator's philosophy, the history of the product, brand heritage, brand myth, and the origin of the product's creation can supplement a product's tangible elements (i.e., colors, materials, shapes) to create value for the product, brand, and company. It is these intangible elements that motivate loyal consumers to buy a company's products, regardless of price. Given this, we examine Chanel products on the basis of their implications for branding. Borja de Mozota [9] used the term "brand" to describe the following:

1. The sum of all the characteristics, tangible or intangible, that makes an offer unique and
2. The elements of brand identification (e.g., name, symbol, and color) by which an offer can be identified.

Borja de Mozota [9] argued that a brand could infuse products with added value and differentiate them from products offered by competitors. Moreover, she asserted that effective brands can create an identity for a company that transcends time and place. If a product's uniqueness is defined by certain intangible elements

(e.g., brand principles, episodes, and histories) in addition to colors, shapes, and functions, strategic branding is an effective method for attracting consumers and inciting them to purchase the company's products. This represents the true value of an effective brand.

Therefore, it is worthwhile to examine a design management case that incorporates both tangible and intangible elements to determine how its design management method attracts today's mature consumers.

6 Case Studies

In this section, we examine four iconic Chanel products: Chanel suits, the "little black dress," the shoulder bag, and bicolor shoes.

6.1 Chanel Suits

Although the "Chanel suit" incorporates a variety of characteristics, it has maintained continuity in style since its introduction in the 1920s. Introduced in 1928, the Chanel suit is widely recognized as iconic [10]; consumers can identify a Chanel suit upon seeing its design, textiles, and details of its composition, even in the absence of the double-C brand logo (see Fig. 2).

Specifically, certain characteristics of the suit, such as the fabrics used for the outer layer and lining, stitching, cuffs and pockets, jewel-like buttons, and gilt chain stitched around the inside hem, are instantly recognizable and thus iconic identity elements of Chanel. Although these physical attributes of Chanel suits are relatively easy to imitate, there exist several symbolic features of Chanel suits that contribute to brand identity.

The symbolic tenets of Chanel suits are based on their intangible features, such as brand philosophies, technologies, and histories. Coco Chanel, founder of the brand, insisted that it is necessary for women's clothes to be both practical. On the basis of this philosophy, she argued that a skirt and jacket facilitate and encourage the movements required in a modern life, such as walking, running, and suddenly sitting down or standing up. Her design ideology focused on creating styles that bring together beauty and function [11].

For example, the pockets on Chanel suits are intended to be used functionally rather than serve an aesthetic purpose. Chanel used a form of tweed that was specifically invented for use in the Chanel suit, as it stretches and allows the wearer to move freely. The gilt chain stitched around the inside hem of the cardigan-style suit jacket is weighted and allows the jacket to retain its shape, even after being worn for a long period of time (see Fig. 3).

Particular episodes related to Chanel's focus on marrying fashion and functionality during the development of the Chanel suit exist as a form of brand identity.

Fig. 2 Chanel suits: the day ensemble. *Source* Nagasawa [1, p. 152], *photographs* (The Kyoto Costume Institute)

Although these episodes and experiences are not tangible aspects of the product, they are nonetheless recognized as integral features of the brand. These intangible elements that comprise Chanel's icons are difficult for competitors to copy. Moreover, the added value of the suit's iconic features provides the consumer with a reason to purchase a "Chanel suit" rather than a "Chanel-like suit."

Coco Chanel was once quoted as saying that "Chanel—above all else, is a style. Fashion, you see, goes out of fashion. Style, never" [11]. In accordance with this philosophy, Chanel products possess the characteristic continuity. Although Chanel products have largely retained the same basic tangible features, consumers loyal to the brand are drawn to its identity—the "spirit" of Coco Chanel. This allowed Karl Lagerfeld, a successor to Coco Chanel, to innovate the features of the brand in his own way. Accordingly, he has never copied a design or models created by Coco. Instead, he has sought to innovate the company's products without hesitation [10]. As such, he has produced the classic Chanel suit in a variety of models. Despite changes to the suit made by Lagerfeld, consumers have remained loyal to the Chanel brand, as they are able to sense the continued existence of the Chanel spirit in its products through the company's icons.

The Chanel suit encapsulates all characteristics, both tangible and intangible, that make Chanel's products unique to consumers. Its elements, including fabric,

Fig. 3 The gilt chain stitched around the inside hem of the suit jacket. *Source* author's possession, *photographs* (author)

shape, functions, and purchase motivations, make that product uniquely identifiable and branded as being of "added value."

6.2 Little Black Dress

Chanel introduced its ever-popular "little black dress" in the 1920s (see Fig. 4). According to its description on Chanel's official Web site, the product was a black dress with a perfectly simple design meant to relieve women from the constrictions of a corset. Moreover, the introduction of the little black dress signaled a preliminary use of jersey (which was originally used in men's undergarments) as a fabric in the design of a woman's dress. In addition, Chanel incorporated crepe de chine and lace into the design of the "little black dress," to provide a close-fitting sheath.

Originally, black was meant to be used in dresses meant for mourning; it was never used as a color for daily wear or evening dresses. The "little black dress," however, popularized the use of black in women's fashion.

In line with the brand philosophy that beauty should be created in conjunction with comfort, the design of the little black dress was meant to emphasize functionality. Still, as a result of the product's aforementioned features—its color, fabric, and simplicity—the little black dress immediately became one of Chanel's iconic products. Consumers who had grown weary of overly decorative women's clothes embraced Chanel's distinguished fashion style.

Fig. 4 Little black dress in 1927. *Source* Nagasawa [1, p. 36], *photographs* (The Kyoto Costume Institute)

In 1926, the American edition of the fashion magazine *Vogue* published an article on the little black dress, claiming the product to be a "Ford signed 'Chanel.'" With this statement, *Vogue* was comparing the little black dress with the Ford automobile, implying that Ford's strategy to mass-produce automobiles had been applied to the production of Chanel's little black dress. According to Yamada [12], the perceived relationship between Chanel's little black dress and haute couture dress for the privileged class was comparable to the association between Ford's automobiles "for the masses" and European high-end automobiles. This comparison became a widely disseminated part of the Chanel story and thus expresses a critical part of Chanel's brand identity.

Given the above, we can see the sum of all tangible and intangible characteristics that render the offering of Chanel's little black dress unique to consumers. In addition, the features of this iconic product are clearly identified by consumers as adding value to the Chanel brand.

6.3 Shoulder Bag

Chanel began developing its shoulder bag in 1929, but it did not go into actual production until 26 years later, in February of 1955. In honor of the month and

Fig. 5 Classic version of Chanel's "2.55" *Source* Chanel homepage [16]

year of its introduction to consumers, Chanel's first shoulder bag was named "2.55." Like the little black dress, Chanel's shoulder bag has become an iconic product for the company (see Fig. 5).

The bag was originally launched in 1929 in the shape of a quilted pouch, but adjustments to the bag have altered its design up to the present day. For example, the 2.55 bag is available in a variety of materials, colors, and shapes. The first improvements to the original version of the bag were made by Coco Chanel herself; she added an adjustable-length chain that allowed the 2.55 bag to be carried over the shoulder. According to Yamaguchi [13], the shoulder bag was originally designed to resemble a haversack that soldiers would use on the battlefield, as a bag without a shoulder chain limits the use of one arm, making it impossible to use both simultaneously. Chanel provided women with the ability to use both arms simply by adding a chain on the traditional, though somewhat inconvenient bag. Perhaps more importantly, Chanel applied a technical innovation in design by producing a strap that would not break while carrying heavy items (i.e., a chain entwined with a leather strap). Although this chain was originally meant to be a purely functional design alteration, it is now widely recognized as a popular Chanel icon. In this way, Chanel's goal of bringing together function and beauty in her shoulder bags perpetuated the degree to which aspects of the bag were perceived as icons of the company.

Although the shoulder bag is ultimately designed to be both elegant and functional, it incorporates other technological elements that facilitate its use. These technologies include a turnover flap to prevent the bag from opening unexpectedly, a wide gusset to increase the bag's storage capacity, an inside pocket for lipstick,

Fig. 6 Interior of the Chanel shoulder bag. *Source* author's possession, *photographs* (author)

and the use of a quilting process that allows the bag to retain its shape more easily (see Fig. 6).

Chanel currently offers several bag sizes and designs, all of which are derived from the classic version of the shoulder bag and feature the company's widely recognized double-C brand logo.

By examining Chanel shoulder bags, we can see that they effectively incorporate the sum of the company's brand identity elements. On the basis of the iconic features that are incorporated into Chanel shoulder bags (e.g., the leather strap with the chain, quilting), consumers can easily identify a Chanel bag, even in the absence of the brand logo. This serves as a testament to the fact that the Chanel brand has been disseminated among consumers in the form of an easily identified image. It is also noteworthy that the bag's production is not exclusively based on external design. In accordance with Chanel's history and ideology, each element of the bag exists for specific reasons, thus rendering the final product uniquely "Chanel."

Taken together, the external elements of Chanel's shoulder bags and the underlying philosophy and technological innovations that contribute to its design are difficult to imitate. As such, both tangible and intangible factors provide value to consumers and serve as a precious asset to Chanel.

6.4 Bicolor Shoes

Chanel first made bicolor shoes (i.e., two-tone flat shoes with a bar across and a slightly square black toe to shorten the foot) in 1957. The contrast of the beige

Fig. 7 Chanel's bicolor T-strap with cap toe, from the 2011 collection. *Source* Chanel homepage [16]

part of the shoe, which is harmonized with skin color, and black toe elongate the foot. Moreover, black toe makes any collection of dirt or dust less pronounced. The design of the bicolor shoe is sufficiently simple that it matches any ensemble a woman may choose to wear (see Fig. 7).

Coco Chanel designed the bicolor shoe for personal reasons. She wished to do what she enjoyed (playing sports and going on trips) without visibly dirtying her shoes, as she believed that a woman with good shoes was never ugly. To Chanel, good shoes were a final touch of elegance.

Originally, there were four variations of the bicolor shoe: beige and black, beige and gold, beige and navy, and beige and dark brown. Lagerfeld, however, extended this iconic product by offering more than 1,000 variations, featuring various combinations of colors, materials, and models [14]. We assume that because the core element of this iconic product, its style, could be infinitely varied in terms of color and shape, the decision to innovate its classic design was an easy one to implement.

Owing to the popularity of Chanel's bicolor shoe, a variety of counterfeit and imitation bicolors have emerged on the market. A bicolor design and some combination of beige and black give these counterfeit shoes a "Chanel flavor," thus evoking images of Chanel's bicolor shoes, even in the obvious absence of a brand logo. The degree to which the Chanel bicolor shoes are imitated suggests that the shoe's style is a valuable portion of the brand identity. If the brand identity was not recognized as indicative of high added value, the shoe would not be imitated. As with the shoulder bag, Chanel's bicolor shoe encapsulates all of the company's brand characteristics, both tangible and intangible. In addition, the elements of the shoe that contribute to brand identity work in concert to differentiate Chanel shoes from imitators.

7 Conclusion

This chapter makes the case for the effectiveness of a specific design management method referred to as icon strategy. The results of the Chanel case study analysis suggest that Chanel efficiently and effectively offers its tangible and intangible brand features to consumers. If consumers accept a particular product offering, that product (or its features) can become iconic, thus giving a company a means for long-term sustainability and competitive superiority.

In summary, we have identified three major characteristics of an icon:

1. Its power has accumulated over decades.
2. It is difficult to imitate.
3. It is versatile and can easily innovate.

Given these characteristics, we conclude that manufacturing companies must apply efficient design management strategies to succeed in today's market for a number of reasons. Most notably, efficient design management strategies can mitigate the effects of the proliferation of counterfeit goods and price competition, both of which have been exacerbated by recent developments in IT and manufacturing technology. Opposition within the market has intensified as a result of price competition and the maturation of consumer demands. As such, the role of design in differentiating a company's products from those produced by competitors seems to be diminishing. Therefore, a company can more effectively differentiate its products from others by implementing a design strategy that cultivates and attracts consumer desire and loyalty. By emphasizing product features that are impervious to imitation (e.g., brand history, product stories, and product technology), a company can effectively establish a differentiated brand image.

Iwatani [15] argued that a consumer's assessment of a product as being excellent (in terms of external design features and functions) depends on the consumer rather than the product. He further stated that for this reason, external product features are ineffective sources of product differentiation. Iwatani's [15] assertions reiterated the importance of icon development in cultivating brand differentiation. However, the development of a company's history and technological capacity takes time. It is therefore challenging to craft a compelling and distinctive story for consumers based on these elements. As a result, if companies wish to differentiate themselves from their competitors on the basis of intangible features, an icon strategy may prove most effective, particularly when executed in conjunction with certain external design features. This type of product design/development strategy facilitates a company's differentiation from its competitors and promotes consumer loyalty and passion. The lessons learned from this study will surely help manufacturing companies that are seeking to identify ways to establish sustainable brand value and position in today's fiercely competitive market.

Despite the contributions it provides, this study also suffers from a key limitation: We examined only one brand with a basic empirical approach. The examination of other brands through objective methodologies will validate the claims we

have made in this study. Other luxury brand products, including the Gucci bamboo bag, Burberry trench coat, or Hermes Birkin bag, can help to triangulate our findings related to manufacturing companies with long histories, distinguished heritage, and advanced technologies.

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Kansei as a Function of Aesthetic Experience in Product Design

Oluwafemi S. Adelabu and Toshimasa Yamanaka

Abstract Following the current trend of modern product designs and developments, *kansei* and aesthetics are becoming inescapable concepts that must be considered in a user-centred design process. In this chapter, we make the assumption that aesthetic emotion is part of *kansei* feeling based on the cognition of sensori-emotional values evoked in interactions between humans and artefacts within situated contexts, either through immediate sensory perception or bodily interaction. Therefore, we construe aesthetic experience as a *kansei* element and an emotive cognition process in the construction of product values, and then propose that this phenomenon traverses all layers of product experience in both intrinsic and extrinsic ways, depending on the context, culture and environment. We project that the understanding of *kansei* as a denominator for aesthetic experience in design will foster value-based approach to the development of products that truly resonate and satisfy the users' cognitive and emotional sensibilities.

Keywords Aesthetic experience • Affect • Product design • *Kansei* • Kansei research

1 Introduction

> Kansei is an advanced function of the brain that can be a source of emotion, inspiration, intuition, pleasure/displeasure, taste, curiosity, aesthetics and creation. [1]

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_7,

Aesthetics fills an important role in the evolutionary trend of design, as the design of objects has taken a key position in shaping culture, and impacting lives in far-reaching ways. As designers become more aware of the emotive powers of design than ever before, the aesthetic quality of products increasingly becomes a pervasive factor in the design process centred towards the users' satisfaction. With today's maximation of product's function(s) and ergonomics, aesthetic quality is recognized as a pleasure-eliciting design attribute [2] which impress on the users' *kansei* (affective sensibility) through sensorial experience or interaction; forming an essence that strongly promotes products' value in a global culture. In this chapter, we hold the view that aesthetic perception is a fundamental part of the users' *kansei*, and this can be anchored on the cognition of sensori-emotional values evoked in interactions between humans and artefacts within situated contexts either through immediate sensory perception or bodily interaction. We elaborated on this by presenting various definitions of both concepts towards establishing a meaningful relationship.

Kansei has strong Japanese origins, with its foremost application in the engineering. Today, the field of *kansei* research is growing as a consilience of disciplines concerned with the understanding and interpretation of the state of the human mind and behaviour as an interactive function of the brain, neural system, artefacts and the environment. *Kansei*/affective engineering, *kansei* (information) science and *kansei* design research areas connect diverse fields in arts, design, engineering, neurosciences, psychology and so on, to create products, systems and environments that afford rich, meaningful experiences, thus enhancing the quality of life. *Kansei*/affective engineering evolved as an advanced industrial design method and a user-based product development process for fulfilling consumers' psychological feelings and product demands [3–5]. *Kansei* has been formally introduced as a Japanese approach to industrial design—the implication of *kansei* on *kansei* design [6]. In recent times, *kansei* studies have adopted cross-cultural approaches, while the frontier of the *kansei* research continues to expand to the international communities, as now seen in Europe. The research output from *kansei*-related studies has gained significant attention; Japan's national strategy noted the leading example of the practical research as "*Kansei* value creation" [7].

In the domain of product design and design experience, design aesthetics has been widely accepted and discussed as a crucial factor for eliciting pleasurable experience with designed objects or systems [e.g. 2, 8–12]. Until now, the subject of aesthetics as a cognitive and emotional-oriented phenomenon is allusively portrayed in previous product design-based *kansei* studies. Though *kansei*, in a broad sense cannot be limited to aesthetics, the aesthetic experiences with design objects within situated contexts have been adopted as an approach for understanding the nature of users' *kansei* [e.g. 13, 14]. Because the concept of design aesthetics stands as a more familiar construct to the international design communities, that most represents the emotive or appealing elements in design, interpreting this concept within the *kansei* study will provide more insight towards grasping the complex nature of the *kansei* itself. This is the primary goal of this chapter. Moreover, we draw inspiration from the foregoing studies of both concepts, sharing views from relevant fields of theories in order to flesh out an integrated perspective of aesthetics in product design and *kansei* which has emerged as an essential value in Japanese designs and research approach.

2 Aesthetics: A Contextual Definition

In the field of theories, aesthetic(s) is an elusive phenomenon which seems to lack a defined disciplinary border or unified definition. The meaning is multilayered, subjective, culturally dependent and fluidic among fields of discipline [15–17]. In a diverse sense, the term "aesthetic" has been applied to designate a branch of philosophy, a feeling of pleasure, an experience, classicism in art, a judgment of taste, the capacity of perception, a value, an attitude, the theory of art, the doctrine of beauty, a state of the spirit, contemplative receptivity, an emotion, an intention, a way of life, the faculty of sensibility, a type of subjectivity, the merit of certain forms, the quality of an object or an act of expression [15, 17].

Today, the term "aesthetics" may broadly cover (1) the study of all the aesthetic phenomena, and (2) the study of art or what is considered to be artistically worthwhile or notable or "good", as a specific expression of what is perceived as being aesthetic [18]. While it appears that there are several theories on aesthetics with multifarious subjective interpretations, the subject was classified into two parts: the philosophy of art and the philosophy of the aesthetic experience and character of objects (non-art phenomena) [19]. The recurrent theme addresses on the standard and theory of beauty, taste, pleasurable values appreciable through sensory, emotional or intellectual perception. From a neuro-psychological perspective, aesthetic experience touches on cognition and emotion; inciting our sense of judgment and influencing our behaviour. Nevertheless, a relevant definition that has been drawn to support this chapter defines aesthetics or the aesthetic *as a cognitive mode in which you are aware of, and think about, the sensory and emotive qualities of phenomena and things* [20].

2.1 Aesthetics as a Perceptual Experience in Design Artefacts

It is said that humans have an innate, sometimes sub-conscious, ability to perceive a wide range of qualities in objects [21]. This covers many specific cognitive adaptations for quickly assessing attractive and repulsive properties of the physical world and some of these adaptations are considered to be likely relevant to aesthetic judgments of artefacts [22]. See Fig. 1 for an adapted illustration on sensory and cognitive experience of an object of aesthetic interest [23].

This had been in part explained through the evolutionary theory [11, 22, 24]. The evolutionary perspective is that in the process of human adaptation, aesthetic responses must have provided a reproductive advantage or means to survive. It is formally presented: "Beauty is the moving experience associated with information processing by aesthetic judgment adaptations when they perceive information of evolutionary historical promise of high reproductive success" [25]. Whereas there are notions of a universal sensitivity to objects' beauty or aesthetic cognition of design [11, 22, 26], the range of perception and degree of responsive behaviour might vary based on context, cultural formation or value system [11, 27]. Eighteenth-century philosophers such as David Hume

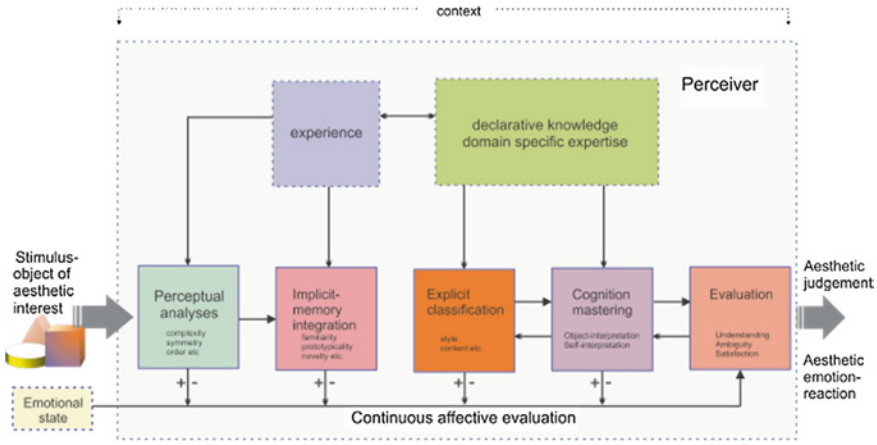

Fig. 1 A schematic representation of aesthetic experience (adapted from [23])

and Immanuel Kant engaged the fundamental question of the extent to which aesthetic quality is absolute and universal or dependent on context [18, 22]. Some principles have been asserted in an attempt to describe a general cause underpinning aesthetic pleasure in design. For instance, the Vitruvian design principles described in [12]; and the four principles of pleasure in design presented in [24], such as: maximum effect for minimum means, unity in variety, most advanced, yet acceptable and optimal match.

Aesthetics is one of the important fields of theories concerned with interactions involving human(s), artefact(s) and contexts. To fully appreciate the role of aesthetics in the product development process, the notion that design is only concerned with mere styling or empty beauty was refuted through the idea of "aesthetics of interaction": "Beauty, and thus beauty in interaction, is an experiential and social given. It is not just a quality of an object. It is the way an object speaks to us, calls us, affords us, puts us into contact with others, is meaningful to us, shares its inner horizon with us. Thus considered, beauty emanates from our unity with the world. It is pre-reflective" [28].

From the cognitivist point of view, it has been commonly established that product aesthetics positively affects usability in a significant way. Following critical observation supported by experimental case studies [10, 26], it has been shown that beauty (aesthetics) promotes usability and fulfils an emotional role that product function alone cannot. Norman [26] illustrated this using the experiments carried out by two Japanese researchers, Kurosu and Kashimura [29]. Following Tractinsky's [30] further research using the same experiment under more methodological controls but with other cultural subject—the Israelis; not only did he replicated the Japanese findings, but the results were even stronger in Israel than in Japan, contrary to his belief that beauty and function "were not expected to correlate". The aesthetic experience model proposed for this study resonates with the Norman's three-dimensional

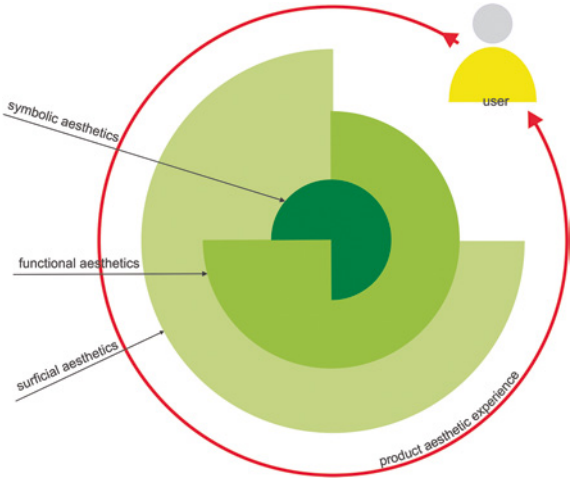

Fig. 2 Layer of aesthetic experience in product design

theory of emotional design (namely *visceral*, *behavioural* and *reflective*) and the analytical/pragmatic constructs of aesthetics [10, 31].

2.1.1 Reinterpreting Aesthetic Experience in Product Design

In our previous study [32], we proposed a holistic view of aesthetics using the three levels of experience as interconnected dimensions (cf. Fig. 2).

- *Surficial aesthetics*—In first contact, the appearance of product unconsciously intrudes upon the senses of a user. However, the sensation of the image only transpires as far as the observer is interested in sustaining his/her attention on the object. The external parts of a product which is the platform that exhibit tangible design elements such as shape, form, colour, texture, smell, sound and other physical quantities that can be detected and received via the sensory interfaces. Also the representation of the intangible design elements such as style, contrast, symmetry, harmony, rhythm is also received from the product appearance. The ease of processing all these sensed elements based on factors such as complexity, prototypicality and familiarity could influence the level of attention or shift beyond the receptive field for further mental processing.
- *Functional (interactive) aesthetics*—When the use of products engages the user in a pleasurable way, aesthetics becomes a function. Likewise when the operation of a product or system evokes pleasurable experience which makes to improve the use and performance of a product, this could be relayed to as the functional dimension of aesthetics.
- *Symbolic aesthetics*—Pleasure evolves in reflecting meaningful association with the product. This is a level of aesthetic experience where consciousness, emotion and other cognitive functions are fully engaged. This aspect of products

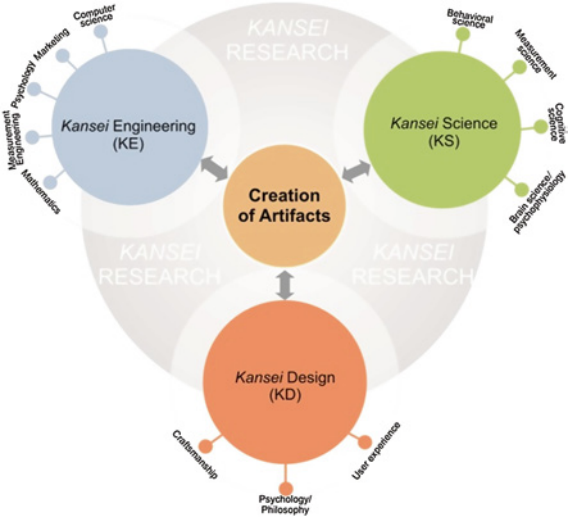

Fig. 3 Main disciplines in the field of *kansei* research (namely *kansei* engineering, kansei science and *kansei* design) related with the design of artefact

possesses intangible qualities that touch on users' self-image, taste, preference, memory and so on. This aspect is highly subjective, personal and susceptible to variability through experience, culture, education and personality.

In product design, aesthetics is a strong factor for product development in a highly competitive market. Also, there is a need for cultural understanding in product development in order to promote wider acceptance in aesthetic appreciation.

3 Kansei: Definitions Based on Previous Studies

The ambiguous nature of *kansei* is owed to the diverse definitions proposed through previous studies. Some of the definitions relevant to this study will be presented to basically describe *kansei*, *kansei* science, *kansei* design and the *kansei*/ affective engineering (cf. Fig. 3).

Mitsuo Nagamachi, founder of the concept of *kansei* engineering, defines *kansei* as "a mental state where knowledge, emotion and sentiment are harmonized" [33]. As defined by Harada [34], *kansei* is "a terminology which unifies concepts such as sensitivity, sense, sensibility, feeling, aesthetics, emotion, affection and intuition." *Kansei* thus describes a fundamental tacit process of the human mind which involves several emotional feeling such as sensation, perception and cognition [35]. In [36] and [37], *kansei* was buttressed as a mental function, and more precisely as being a higher function of the brain. Three aspects of *kansei* were proposed as follows:

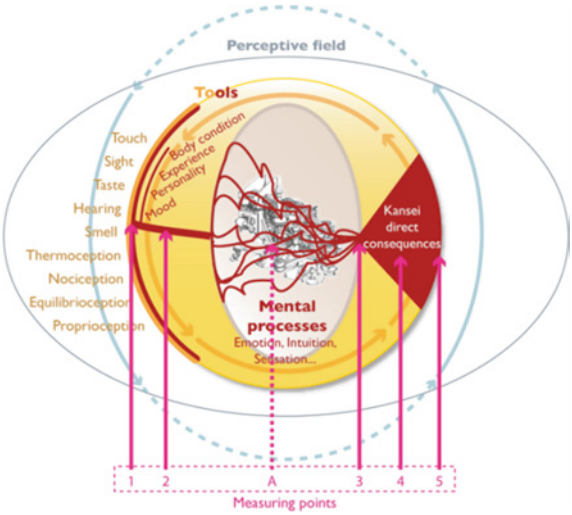

Fig. 4 A comprehensive view on *kansei* as proposed by Lévy and Yamanaka [36]

Kansei process that gathers mental functions related to emotions, sensitivity, feelings, experience, memory, and intuition, i.e. sensory-quality-related functions including interactions between them.
Kansei means are all the senses and probably other internal factors (such as personality, mood, experience…and so on)
Kansei as the *fruit of kansei process* (i.e. of these function processes and of their interactions). It appears to be a unified perception providing a qualitative meaning and values of one direct environment. *Kansei* result is a synthesis of sensory qualities (cf. Fig. 4).

A recent definition of *kansei* by Yamanaka et al. [38] suggested that the term *kansei* consists of two compounds: (1) a "situation of astonishment and mind" and (2) "mind and life" (which they also describe as "sensibility and the German term Sinnlichkeit"). They pointed out that the concept of *kansei* in the view of "the sensing ability" incorporates the "process of understanding". *Kansei*, they suggest, shifts the direction of understanding into the description of perception (悟性-gosei in Japanese or Verstand in German) that leads to decision.

4 Reconciling Aesthetics with Kansei

As established in [37], the term *kansei* evolved in Japanese literature as early as the seventeenth century when it was reflected in the written poetic work of Yoshida (Nanshoku masukagami) in 1687. Later during the Meiji era (1868–1912), the

term became characterized as an academic term through the study of Amane Nishi in philosophy and psychology at Leiden University (1962–1875) in the Netherlands. In this period, Nishi studied Baumgarten's work on Aesthetics, from which he acquired some key terms into Japanese linguistic interpretation. Among these were the following words coupled with their interpretations: know (知-shi), act (行-gyuo), feel (感-kan), intellect (智-chi), will (意-i), sensibility (思-shi), true (真-shin), good (善-zen) and beauty (美-bi). Remarkably, the word *kansei* (感性) which was lexicographically coined from the kanjusei (感受性) to denote "sensitivity", "sensibility" or "the faculty of feeling" (感-kan denoting "feeling" and 性-sei denoting human "faculty"). Subsequently, the term *kansei* was further buttressed in the Japanese translation of Kant's Critique of the pure reason done by Teiyu Amano (1930). In this work, the German term "Sinnlichkeit" (defined by Kant as the faculty of intuitions, perception and mental imagery) was translated into "Kansei". Other notable works contributing to the understanding of *kansei* was said to be done by Kitaro Nishida, known as one of the most influential philosophers in modern Japan.

The modern renaissance of *kansei* eventually led to the development of a productive research discipline and an industrial technique based on *kansei*: the *kansei/*affective engineering [5]. However, the current trend suggests that *kansei* has become matured enough to be considered as an important concept in Japan and hence the applicability to design as a Japanese approach of industrial design. Following striking innovations and market successes claimed through the application of *kansei* in engineering, *kansei* was considered a key element in the Japanese modern design culture and beyond. Since the 1970s, the impact of *kansei* in Japan has persisted through the promotion of *kansei* value in design products, marking a paradigm shift from an industrial age of mass production to mass customization.

As the importance of the sensorial content of objects continues to grow, the pervasiveness and significance of aesthetics as a factor in human-product experience cannot be underestimated in attempt to understand the nature of human *kansei*. *Kansei*, described as a holistic and contextual sensory-mental model for human being, shapes aesthetic experience as it relates to the physiological and psychological aspects of product design. Senses, perception, mental processes and behaviours are all considered in the model to encounter (understand) human being in the perceptive field [5, 8].

Even though the phenomenology of "aesthetics" still appears elusive in the field of art and design theories, its interrelatedness with *kansei* can be established. Aesthetic perception in design artefacts is anchored by an individual *kansei* (i.e. subjective sense of value for a certain artefact, environment or situation through various sensory modalities such as sight, hearing, touch, smell, taste, balance including the intuitive perception and reaction to external stimuli) [39] (cf. Fig. 5).

Since *kansei* study is becoming more relevant to design applications today, design artefacts are considered to evoke feelings which can be characterized to understand the human mind processes. Significantly, the aesthetic qualities of products have been used in *kansei* studies which seek to quantify the people's

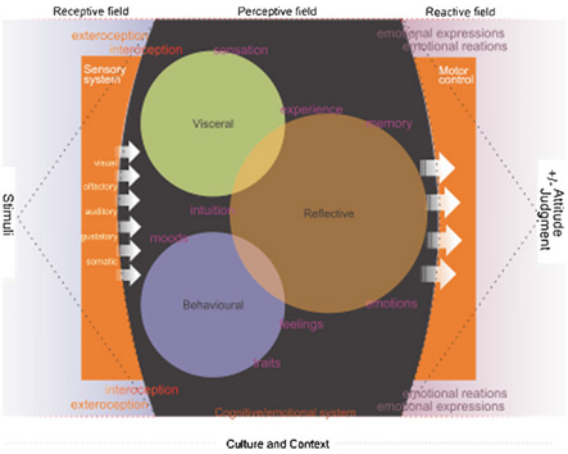

Fig. 5 Aesthetic experience incorporating *kansei* process, means and result (psycho-physiological space)

perceptions of artefacts. The perceptions of aesthetics in these products are evaluated as subjective response which covers *kansei* means, its process and result.

Though, aesthetics in design can evoke human affect, the cultural influences can make it unexplainable in a broad sense. According to Salem et al. [40], *kansei* nature within the context idea of aesthetics has been defined, explained and explored in many ways. Usually, aesthetics is associated with the concept of beauty, the canon of beauty or its experience. In one sense, it is the measurement of beauty which is associated with pleasure. Beauty needs not and should not, within this context, be limited to visual beauty. It is an attribute that could be sensed and perceived. That is why aesthetics is also defined as subjective assessment of the beauty of an experience.

4.1 Implications for Aesthetic Design Through Kansei Study

Kansei and aesthetics pervade a major role in the modern trend of design and inspirational source for creativity [14, 41]. Both concepts thrive in the fields of design and possess qualities that can be multi-dimensionally described and measured with respect to emotion, perception, cognition, subjective response and appreciation. In recent times, the theme of aesthetics has been indirectly reinforced by a growing number of *kansei* studies. Coupled with an adoption of cross-cultural approach, a new vista for understanding the multifaceted nature of *kansei* is being opened up. Attempts to study *kansei* have been done by stimulating the sensory modalities to evoke emotional (perceptual and behavioural) interaction between artefacts and human within a contextual space. Design researchers also tend to be aware of the issue of cultural diversity towards understanding the *kansei* process. This is reflected by the myriad of studies targeted at exploring cultural

distinctions in the designers'/users' creativity, perception and interaction with design products or systems (e.g., [32, 42–45]).

Kansei information and design science laboratory at the University of Tsukuba aimed towards understanding mind functions through experimental work and *kansei* design practices. A wide range of interacting disciplines including design, psychology, cognitive science, brain and neurological sciences conjoin not only about understanding *kansei* as brain and neural functions but also on how to measure the state of mind and the sensory qualities of entities. The study of aesthetic responses to a product stimuli in pre-conditioned settings has been adopted as psycho-physiological means in *kansei* research. Aesthetic perception through *kansei* study can also be a source of inspiration for creativity even though this was not the target in the research carried out by and reported in [1].

Indeed, *kansei* design has an interdisciplinary nature, which evolves progressively towards a trans-disciplinary domain, becoming a field of application related to *kansei* science and aesthetics psychology as both are important dimensions in the field of human factors research and practice. In the development of user products, the knowledge of inclination in perception can be utilized effectively in considering the design process. Sensitivity to design qualities will be a way to understand the process of designing for the senses as a means of providing products with new values. Also, the understanding of product cognition beyond cultural borders will spur a new way of understanding *kansei* and approach in the design process. An exploration of this area could open up more design potentials for the developed and developing world.

5 Conclusions

In today's field of product design, *kansei* and aesthetics have served as an inspirational source for creativity and promoting the differentiation of products in the global marketplace. Numerous product design studies have concerned themselves with the subject of aesthetic-based and emotion-related design factors. Moreover, the findings from on-going experimental studies on these phenomena reflect on how perception, influenced by culture, can determine the user valuations of design products and environments.

Products thrive only when they align with the user values, attitudes and behaviours, even if they result in changes to those values and behaviours. As designers become more aware of the responsibility that design must bear in the twenty-first century, the form and content of user-centred products or systems now demand an integration of the perceptions and wishes of the prospective users of the product (i.e. the consumers' *kansei*). Part of this expectation is the awareness of not only users' satisfaction but also an elicitation of values that promotes a sustainable consumption. This is reflected in the Japanese aesthetics. Not only are technical and objective demands important, but aesthetic, emotional and other experiential factors are highly desired, some of which are hard or impossible to express objectively [14]. The task of

design practice now lies in the need to balance objective and subjective properties, functional technology and emotional expressiveness, and information and inspiration.

As the study of *kansei* takes on a cross-cultural approach, there is new insight into the dynamic nature of aesthetic perception in product design. Culture-driven *kansei* research can provide a platform for new knowledge and ways of thinking that will help to address emerging design issues and inspire more creative steps towards product innovation. The onset of new issues can be a considerable factor to design for a real world through a culturally sensitive *kansei* design approach.

Acknowledgments This study was supported by the Japanese Government through the Monbukagakusho (MEXT) Scholarship.

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Kawaii Rules: Increasing Affective Value of Industrial Products

Michiko Ohkura, Tsuyoshi Komatsu and Tetsuro Aoto

Abstract The Japanese word "Kawaii," which represents a kansei/affective value, has such positive meanings as cute, lovable, and small. In the 21st century, the kansei/affective values of industrial products are becoming very important. However, since few studies have focused on kawaii attributes, we systematically analyze kawaii products themselves: the kawaii feelings caused by shapes, colors, sizes, and texture and tactile sensation caused by materials of those products. In this chapter, we introduce our experimental results for abstract objects in virtual environments and describe interesting tendencies for the visual attributes of kawaii, including thier shapes, colors, and sizes. We present these tendencies as kawaii rules.

Keywords Kawaii • Kansei/affective value • Product design • Shape • Color

1 Introduction

In Japan, the cute aesthetic is exploited by many organizations and for many purposes including police mascots, and warning signs for dangerous areas. Although using cute to motivate and inform might seem strange, cute does offer potential. Dr. Cheok et al. [1] argued that Japanese "kawaii" embodies a special kind of cute design, which reduces fear and makes dreary information more acceptable and appealing. Such Japanese kawaii characters as Hello Kitty and Pokemon have become popular all over the world. However, since few studies have focused on kawaii attributes, we systematically analyze the kawaii interfaces themselves: kawaii feelings caused by such attributes as shapes, colors, and materials. Our aim is to clarify a method for constructing a kawaii interface from our research results.

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_8,

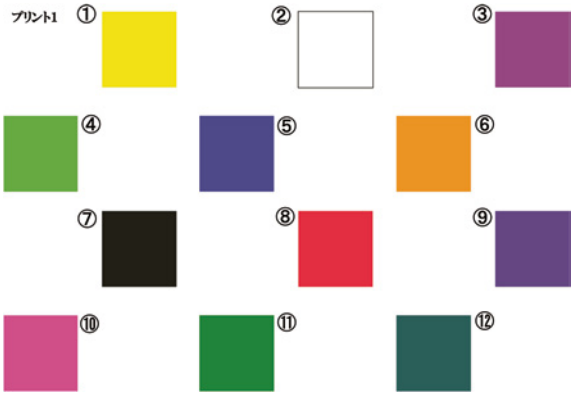


Fig. 1 Color sheet

Kawaii might be one important affective (kansei) value for future interactive systems and industrial products of Asian industries. Therefore, we performed experiments and obtained interesting tendencies about such kawaii attributes as shapes, colors, and sizes. In this paper, we describe the experimental results and categorize them as kawaii rules.

2 Background of Kawaii

The first description of the value of kawaii appeared in *The Pillow Book of Sei Shonagon*, a famous, 11th century female Japanese essayist [2]. Her examples of kawaii objects included the behavior of a chirping sparrow, a small hollyhock leaf, and a sky-blue jar.

Recent works on kawaii include *Kawaii Ron* by Inuhiko Yomota, a middle-aged Japanese male researcher [3], *Hello Kitty: The Remarkable Story of Sanrio and the Billion Dollar Feline Phenomenon* by two American male journalists [4], and *Cuties in Japan* by a female researcher in Britain [5]. These works recognize the following as common attributes of kawaii:

- affective value of Japanese origin
- Such positive meanings as cute, loveable, and small.

3 Experiments with Kawaii Shapes and Colors

After a preliminary experiment to confirm the affective value of kawaii [6], we performed another experiment to confirm its colors and shapes [7]. Ten basic hues from the Munsell color system (MCS) with the addition of white and black samples were presented to twenty female and twenty male student volunteers in their 20s. They chose the most kawaii color from 12 candidates on a sheet shown in Fig. 1

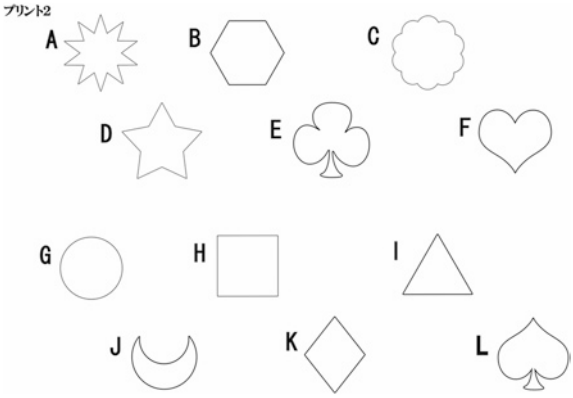


Fig. 2 Shape sheet

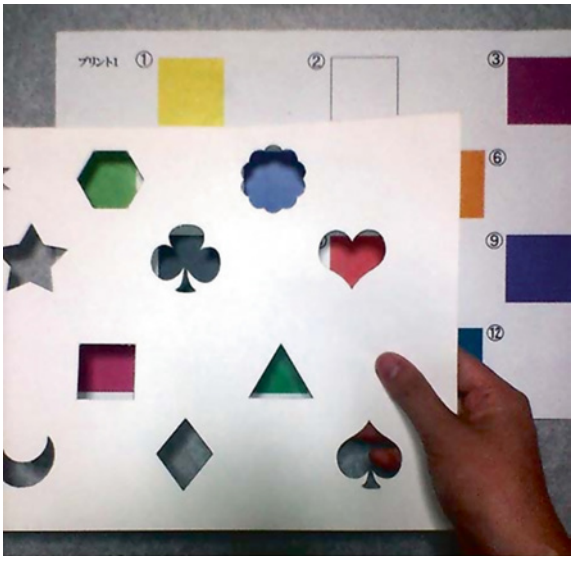


Fig. 3 Sheets to be combined

(yellow, white, purple, yellow-green, blue, yellow-red, black, red, purple-blue, purple-red, green, and blue-green). If they could not choose, the answer was "no color." Then, they chose the most kawaii shape from 12 candidates (Fig. 2). If they could not choose, the answer was "no shape." We employed the 12 basic shapes of the Adobe Photoshop.

Finally, they combined a color and a shape for the most kawaii example using the same color sheet shown in Fig. 1 and a sheet with cutout shapes shown in Fig. 3. If they could not choose, the answer was "no combination."

Figures 4 and 5 show the experimental results for the first and second questions. In both figures, the vertical axes show the number of participants who chose the color or the shape in the horizontal axes.

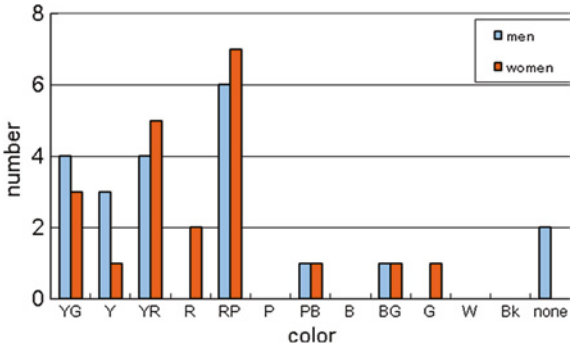


Fig. 4 Histogram of most kawaii color

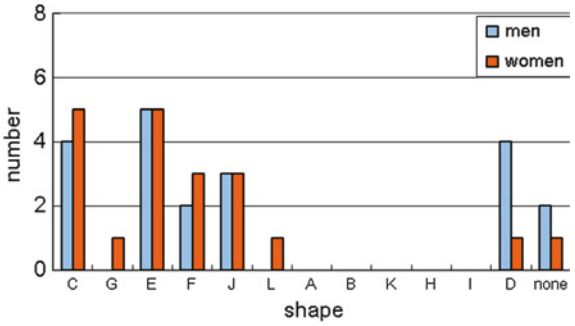


Fig. 5 Histogram of most kawaii shape

We obtained the following from Fig. 4:

- All participants (except two) chose a kawaii color.
- Warmer colors tended to be chosen as the most kawaii more than colder colors.

We obtained the following from Fig. 5:

- All participants (except three) chose a kawaii shape.
- Curved shapes tended to be chosen as the most kawaii more than shapes with straight lines.

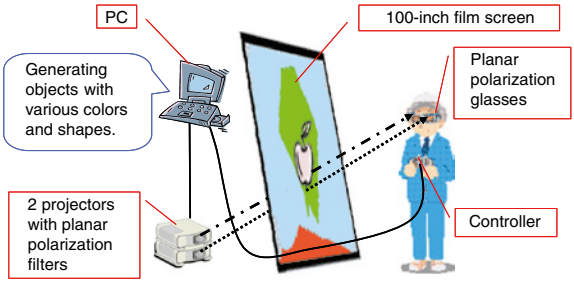
For the final question, each number shows the number of participants who chose that *color* and *shape* combination (Fig. 6).

The combination chosen as the most kawaii was not necessarily the same as the results of the most kawaii color and shape. However, the tendencies to choose warmer colors and curved shapes as the most kawaii did not change. Thus, we believe these tendencies are consistent. This simple experiment reconfirmed that the kawaii values for artificial objects is acceptable to Japanese men and women in their 20s.

Fig. 6 Numbers of combination of most kawaii shape and color

	3	1	2		2					1	
	1		4		2						
		1			3		1		1		
	1	2			1						
				2	1		2				
					1						
									1		
	1	4	1						1		

Fig. 7 Experimental setup



4 Experiment on Kawaii Shapes and Colors in Virtual Space

Since the final goal of our research is to construct kawaii products for our 3-dimensional living space, we extended our previous study on 2-dimensional environments to a new experiment employing a 3-dimensional environment [8].

We employed the virtual environmental system constructed for our previous researches [9] (Fig. 7). Six basic objects from 3ds Max, a modeling software by Autodesk Inc., were chosen as 3-D object candidates: a box, a pyramid, a cube, a cylinder, a tube, and a torus. Five basic objects were chosen as 2-D object candidates: a square, a triangle, a circle, a rectangle, and a torus. Red, blue, and green were chosen as the basic colors. The numbers of these shape and color candidates were smaller

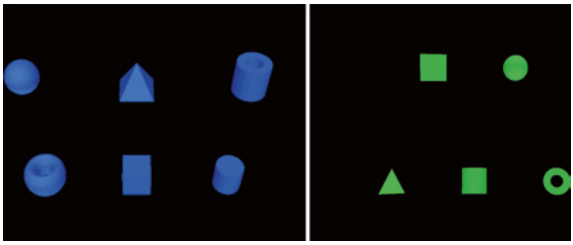


Fig. 8 Examples of 3-D objects (*left*) and 2-D objects (*right*)

Table 1 Results of most kawaii shape

3-D	Men	Women	2-D	Men	Women
Green pyramid	0	1	Green triangle	0	2
Green cube	3	0	Green circle	2	2
Green torus	3	3	Green rectangle	2	1
Blue cube	1	3	Green torus	1	1
Blue torus	4	2	Blue triangle	0	1
Red cube	1	5	Blue circle	4	1
Red cylinder	0	1	Blue rectangle	0	1
Red torus	2	0	Blue torus	0	3
			Red circle	0	1
			Red rectangle	1	1
			Red torus	2	1

than the previous study in the previous section because we wanted to keep this experiment's design as simple as possible for clearer results. Participants were presented a set of six 3-D objects of the same color from various viewpoints and asked to choose the most kawaii object and to explain their choice. This procedure was repeated three times for three colors. Examples of the presented sets of objects are shown in Fig. 8. Finally, we presented the participants with their three chosen objects for different colors and asked them again to choose the most kawaii 3-D object and to explain their choice. Similar procedures were performed for 2-D objects (Fig. 8). The presentation orders of the three colors were set randomly, and the orders of the 3-D and 2-D objects were counter-balanced.

Experiments were performed with six female and six male students in their 20s. Table 1 shows the results for each color and the number of participants who chose the shape as the most kawaii. Table 2 shows the final results. We obtained the following conclusions:

- Such round objects as cubes, cylinders, tori, and circles were chosen as the most kawaii.
- Most participants judged blue or green objects as more kawaii than red objects.

These experimental results confirmed the kawaii values for artificial objects to Japanese men and women in their 20s. In addition, we conclude that such curved shapes as a torus and a sphere tend to be evaluated as more kawaii than straight-lined shapes. However, differences about kawaii colors exist between these results and our previous study described above.

Table 2 Results of most kawaii colors and shapes

3-D	Men	Women	2-D	Men	Women
Blue cube	1	2	Blue triangle	0	1
Red ball	0	2	Green triangle	0	1
Green ball	2	0	Blue circle	3	0
Blue torus	1	1	Red circle	0	1
Green torus	2	1	Blue rectangle	0	1
			Green rectangle	2	0
			Blue torus	0	2
			Red torus	1	0

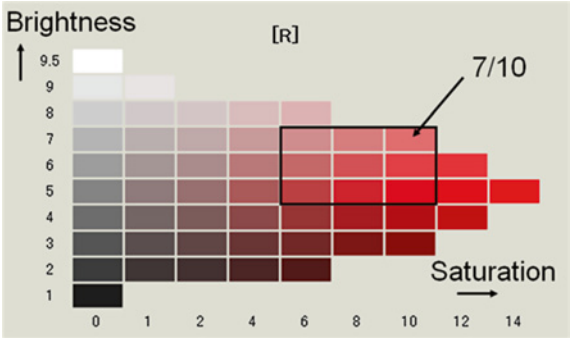


Fig. 9 Example of selected color: *red*

5 Experiment on Kawaii Colors in Virtual Space

A discrepancy exists in kawaii colors between the experimental results of the previous sections. Warmer colors tended to be chosen as the most kawaii in one experiment, yet most male participants chose blue objects as the most kawaii in another experiment. To solve this discrepancy, we performed a new experiment [10].

We showed virtual objects on a 22-inch 2-D/3-D compatible Zalman LCD monitor. Participants wore polarized glasses to stereoscopically observe them.

For the kawaii shape of objects, a torus was employed based on the results of our previous studies. To select the candidates of kawaii colors, we used MCS. A color had three elements: hue, saturation, and brightness. For hues, we employed five basic hues (red, yellow, green, blue, and purple) based on MCS. For each hue, we selected three connected values of saturation and three connected values of brightness (Fig. 9). The total number of kawaii color candidates was 45. The background color was set to gray with a saturation level of five.

Participants were presented three objects out of nine of the same hue and asked to choose the most kawaii. After this procedure was repeated three times to present one of the five basic hues to all candidates, the selected objects were shown again for the final determination of the most kawaii object by hue. After the above procedures were repeated five times for all basic hues, the five selected objects were

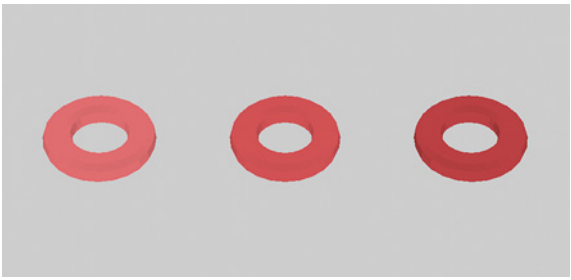


Fig. 10 Example of set of objects on screen

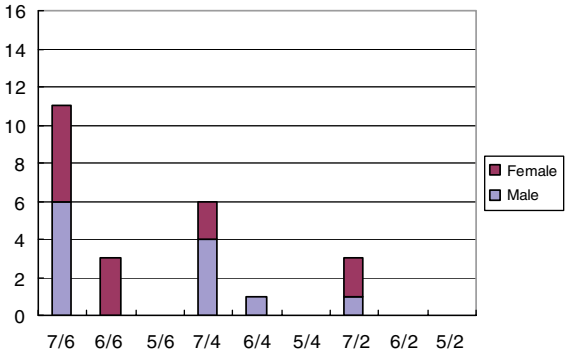


Fig. 11 Example of results: *blue*

shown again for the final determination of the most kawaii object. The orders of showing the three objects out of nine for each hue and the five hues were both set randomly. Examples of the presented sets of objects are shown in Fig. 10.

The experiments were performed with twelve female and twelve male students in their 20s with normal or normally corrected eyesight. Figure 11 shows an example of the results for each hue, where the vertical axis shows the number of participants who chose the object as the most kawaii; the brightness and the saturation are shown on the horizontal axis. The following is the results of an analysis of variance with three elements for each hue: brightness, saturation, and gender:

- Brightness is significantly effective in red, blue, and purple.
- Saturation is significantly effective in purple.
- Gender is not significant for any hues.

Figure 12 shows the final result of the most kawaii color, where the horizontal axis is a combination of hue, brightness, and saturation.

From Figs. 11 and 12, we obtained the following:

- When an object has greater brightness, more participants chose it as most kawaii for every hue.
- When an object has greater saturation, more participants chose it as most kawaii for every hue. However, the differences were smaller than those for brightness except for yellow.

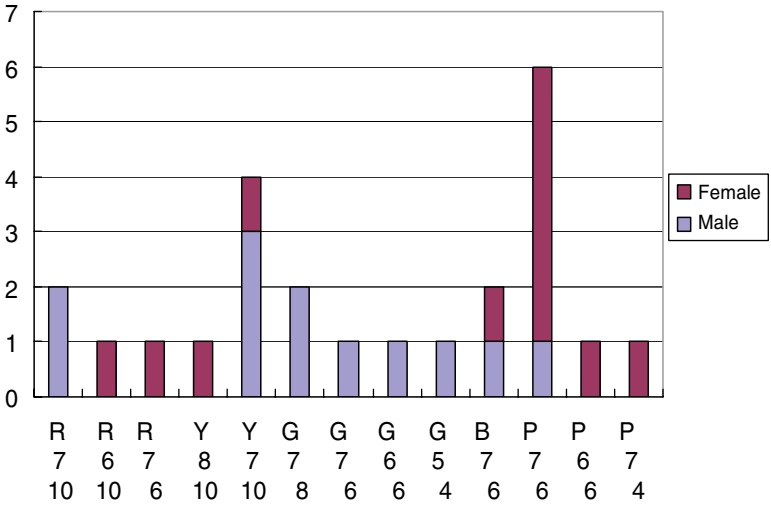


Fig. 12 Final results of most kawaii

- All hues were chosen as most kawaii by at least one participant. The most frequently chosen hue was purple, and the next was yellow. Most participants who chose purple were female, and most participants who chose green or blue were male.

These results show the importance of purple and yellow as candidates for kawaii hues. The discrepancy between the results of our previous experiments may reflect that in some of them, only red, blue, and green were hue candidates.

The comparison results between pure colors and the brightest and most saturated candidates for each hue in the experiment are different depending on the hues.

6 Experiment on Kawaii Colors Using Visual Analog Scale

Although we performed experiments on kawaii colors, we did not employ intermediate hues based on MCS in previous work. So we performed additional experiments employing intermediate hues.

We employed five basic hues (R: red, Y: yellow, G: green, B: blue, and P: purple) and five intermediate hues (YR, GY, BG, PB, and RP) based on MCS. For each hue, the following four colors were selected:

- #1 is white, which has the highest brightness and the lowest saturation.
- #2 has higher brightness and lower saturation than the base color.
- #3 is a base color with high brightness and high saturation.
- #4 is pure color, which has lower brightness than the base color and the highest saturation.

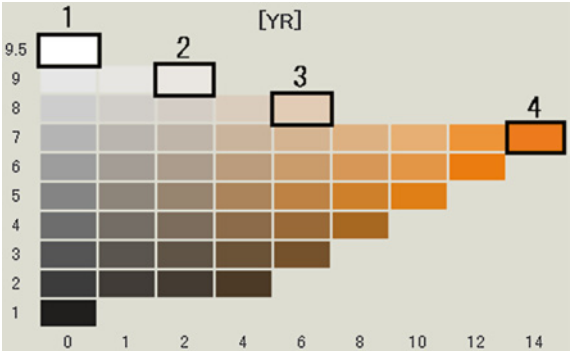


Fig. 13 Selected colors for hue YR

Fig. 14 Example of set of objects

We selected these colors for each hue. Figure 13 shows an example for hue YR. Because #1 for each hue is the same color, the total number of kawaii color candidates was 31. The background color was gray.

To evaluate the kawaii degrees, we used the visual analog scale (VAS), which is commonly used to evaluate pain severity and relief [11]. Participants arbitrarily marked in 200-mm segments, where they believed the left side line does not seem kawaii, but the right side line does. The length from the left side to the mark put on the segments by participants is converted into scores ranging from 0 to 100.

First, we tested the color blindness of the participants with the Ishihara color test [12]. Next, they were shown four colors of the same hue, and we simultaneously evaluated their kawaii degrees with VAS. This evaluation was repeated for each hue. The ten hues were shown randomly. An example of the presented set of objects is shown in Fig. 14.

The experiments were performed with ten female and ten male students in their 20s with normal or normally corrected eyesight.

The scores of the kawaii degrees were normalized based on the score of white.

Figure 15 shows an example of the results by gender. The vertical axis shows the averages of the scores of kawaii degrees with brightness and saturation shown in the horizontal axis. The error bars indicate the standard deviations.

We obtained the following:

- Colors BG#4, YR#4, and G#3 were evaluated high by males.
- Colors YR#4, RP#3, GY#3, and BG#4 were evaluated high by females.
- Color #2 of each hue was evaluated low by both genders.

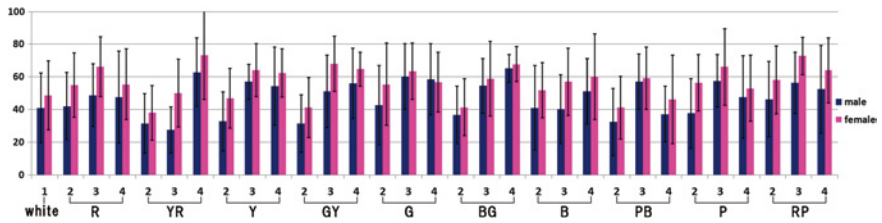


Fig. 15 Averages of kawaii degrees for each color

We obtained the following from the results of the analysis of variance with three elements: hue, brightness/saturation, and gender:

- The main effects of gender, hue, and brightness/saturation are significant.
- The interaction effect between hue and brightness/saturation is significant.

The analysis of variance results show that the scores of the kawaii degrees for colors differ by gender, hue, and brightness/saturation. The interaction effect between hue and brightness/saturation is significant, and the combinations of hue and brightness/saturation are important for evaluations of the kawaii degrees of colors.

We also obtained these findings:

- The scores of the kawaii degrees for colors differ by gender, hue, and brightness.
- The combinations of hue and brightness/saturation are important for evaluations of the kawaii degrees of colors.
- Pure yellow-red and pure blue-green were evaluated highly by both genders and were considered kawaii.

7 Experiment on Kawaii Size Using Biological Signals

We previously performed experiments on such kawaii attributes as shapes and colors, as mentioned above. However, we only employed questionnaires to evaluate kawaii feelings in those experiments. Although questionnaires are the most common form of evaluation for emotion, they suffer from the following demerits:

- Linguistic ambiguity
- Possibility of mixing the intensions of experimenters and/or participants into the results
- Interruption of the system's stream of information input/output

Thus, to compensate for these questionnaire demerits, we examined the possibility of using biological signals because they offer the following merits [13–15]:

- Can be measured by physical quantities.
- Difficult to be influenced by intensions of experimenters and participants.
- Can be measured continuously without interruption.

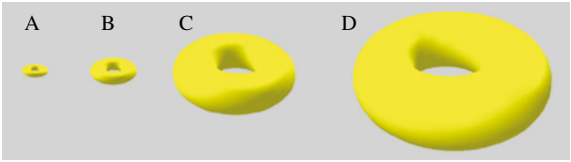


Fig. 16 Objects employed for experiment

Table 3 Visual angle of each object in Fig. 16

Object	A	B	C	D
Size	1	2	6	10
Vertical degree	3.7	7.5	22.0	35.4
Horizontal degree	5.0	10.2	29.5	47.3

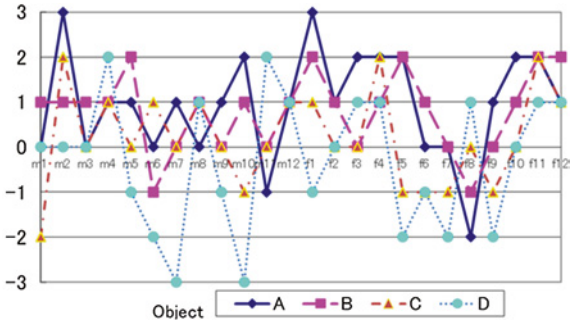


Fig. 17 Questionnaire results for kawaii sizes

Our first experiment, which is not described in this paper, addressed kawaii colors.

Our second experiment addressed the kawaii sizes of objects. The experimental setup was almost the same as in Fig. 7. Participants stereoscopically watched an object on a large screen and evaluated its kawaii degree. The shape and color of each object were set as torus and yellow, 5Y8/14 in MCS (Fig. 16), based on the results of our previous experiment described above. The size, which means the visual angle of each object, was set as one of the four sizes shown in Table 3 based on our preliminary experiment, which is not described in this paper.

Our experiments were performed with twelve female and twelve male student volunteers in their 20s. Figure 17 shows the questionnaire results, where the horizontal axis shows the participants (males: $m1$–$m12$, females: $f1$–$f12$) and the vertical axis shows the kawaii degree for each object size. The results of a 2-factor analysis of variance show that the main effect of size is significant at the 1 % level, but the main effect of gender is not significant. The averaged biological signal data were divided into the following two groups: the "kawaii" group with kawaii scores above 0 and the "non-kawaii" group with kawaii scores below 0. The data with 0 score were omitted from analysis. From the unpaired t test results of the difference of the mean value of the two groups, the heart rates showed a significant difference. Since a higher heart rate shows an unrelaxed state, the mental state when

feeling kawaii is considered more exciting than not feeling kawaii. In addition, the results of the similar difference test of the heart rate for object C showed a significant difference at a 5 % level, and the results of the similar difference test of the heart rate for object D showed a significant difference at a 1 % level. These results show that a mental state when feeling kawaii is probably more exciting than not feeling kawaii even if the size of the object being watched is the same.

8 Conclusions

In the 21st century, the affective values of industrial products are becoming very important. In this study, we focused on kawaii as one important affective value for future industrial products.

We introduced our studies on a systematic approach for kawaii feeling affected by such attributes as the shapes and colors of artificial products. We also introduced new trials to clarify the relation between kawaii feelings and biological signals.

Based on these experimental results, we propose the following kawaii rules:

- Such round objects as cubes, cylinders, tori, and circles are more kawaii than shapes with straight lines.
- Brightness and saturation are effective for kawaii colors.
- All hues can be chosen as the most kawaii. Although the kawaii scores for each hue sometimes differ between male and female, pure yellow-red and pure blue-green are evaluated highly by both genders.
- Small is generally more kawaii than large.
- The heart rate increases when experiencing kawaii feeling.

Acknowledgments This research was partly supported by Grant-in-Aid for Scientific Research (C) (No. 09017360), Japan Society for the Promotion of Science and by SIT Research Promotion Funds. We thank to the students of Shibaura Institute of Technology who contributed to this research and were served as volunteers.

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Modeling Emotional Evaluation of Traditional Vietnamese Aodai Clothes Based on Computer Vision and Machine Learning

Thang Cao, Hung T. Nguyen, Hien M. Nguyen and Yukinobu Hoshino

Abstract The more that human society develops, the greater the human need for well-mannered and elegant clothes, especially traditional costumes. Selecting fine clothes for a specific occasion is always an interesting individual question. Based on computer vision and machine learning, this research proposes a Kansei (emotional) evaluation for Aodai, which is traditional and well-known Vietnamese clothes for women. Features of an Aodai image are described by color coherence vectors. Self-organizing maps (SOMs) and multilayer neural networks (NNs) are used to learn the relationships between the image features and the Kansei words. Once learned, the system can recommend which Aodai is suitable for a woman through her desired feelings. She can use this recommendation when purchasing an Aodai at online stores or selecting one from her own collection for an outing. Topics for future research include investigating other image representation methods, such as combinations of color buckets in different parts of the Aodai, using more detailed descriptions in decorative patterns, and integrating conspicuity factors such as color harmony, discriminability and visibility.

Keywords Kansei • Vietnamese Aodai • Fashion design • Traditional costume • Color coherence vector

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_9,

1 Introduction

One important aspect that highlights the beauty of Vietnamese women is their Aodai costume. Early versions of the Vietnamese Aodai appeared in the 17th century in the Nguyen Dynasty. Throughout the country's history, the Aodai has changed little in design, decorative pattern, and color [1]. Currently, the most popular Aodai style is a long dress that fits tightly around the women's upper torso and splits into two flaps from the waist down, covering wide pants. This style emphasizes a woman's bust and curves while making it easy to move, as shown in Fig. 1.

Each Aodai is customized to fit a specific body. Color and decorative patterns, together with the wearer's emotions, normally depend on her age and outgoing environment. Young girls often dress in pure white, office women in delicate pastels with slight decoration, and middle-aged women in strong, rich colors and decorations, as illustrated in Fig. 2. A woman's Aodai also embodies her personality and social position.

Using computer vision and machine learning, this paper presents a Kansei evaluation system for the Aodai. Based on Aodai images and emotional evaluations gathered from a survey, the system estimates whether an Aodai image fits the feelings of a woman. Section 2 describes the selection of an Aodai for different occasions. Section 3 introduces Kansei engineering in fashion design. Sections 4 and 5 present the selection of Kansei words, image features, and data preparation in our experiments. Section 6 presents the modeling of the Kansei evaluation for Aodai images featured by CCV histograms with self-organizing map (SOM) and neural network (NN)s. Our conclusions and future works are discussed in Section 7.

2 Selecting an Aodai for an Occasion

For every dressing, the more elegant clothes we wear, the more respect we have from surrounding people. Clothes and fashion of a person may bring a relaxing and interesting atmosphere to other people. We often ask ourselves how to choose suitable clothes for a specific occasion so that we could become distinguished or the same as others.

In Vietnam, a woman often has a collection of Aodai with a variety of colors and decorations, and for each outgoing, she chooses one that fits her own emotions. Here are some questions she may ask herself when choosing clothes:

- Meeting place: university campus, office, hotel, or park?
- Emotions she wants others to feel about her: vivid, sweet, or gentle?
- Activity purpose: conference, outing, showing, or ceremony?
- Who she will meet: students, office staff, or businessmen?
- How about surrounding people: young, middle-aged, old, or all of them?

From such questions, the woman chooses an Aodai with the color and decoration which she thinks the most suitable and she hopes that the others also feel in a similar way.

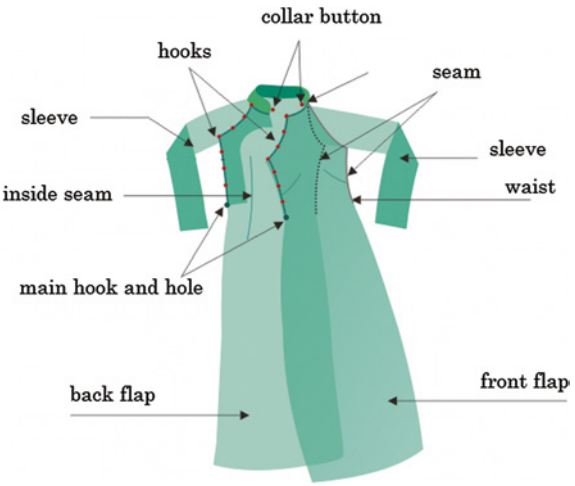

Fig. 1 Design of Aodai (*Source* Wikipedia)

Fig. 2 Examples of Aodai for girls (*left*), office women (*middle*), and middle-aged women (*right*)

However, sometimes things chosen by the emotion of an individual do not fit the others', and the wearer may need an advice, especially when going to a special event. She also needs a recommendation when looking for an appropriate Aodai on online stores.

3 Kansei Engineering in Fashion Design

Kansei or Affective Engineering translates human emotions and feelings into specific parameters that can be used for product development, design, and evaluation [2]. So far there have been few Kansei researches on fashion such as clothing, fabric design [3–5], and fashion [6–8].

Ogata and Onisawa [3] proposed a system which presents several clothing design patterns to the user. Based on the user's evaluation, the system runs the genetic algorithm to search through clothing patterns until a satisfied pattern is found.

Kim and Cho [4] also used an interactive genetic algorithm to develop a fashion design support system. They classified the design of dresses for women into three parts which are represented in separate 3-D models and then created different designs from a combination of these models. The system suggests a preferable design through an interactive session with the user.

Using the rough set theory, Santos and Rebelo [5] constructed a semantic database describing relations between the function and context use of clothes. The proposed system provides clothing designers and producers with relevant information such as users' clothing preferences for a certain task and therefore can help in the beginning of the clothing design process.

Using principal component analysis, Anitawati et al. investigated relations of e-commerce web site designs and emotional responses of consumers to the web site. The relations are analyzed based on predefined rules on colors, design elements, layouts, page orientations, and typography [6].

By survey with fashion experts, from a variety of fashions collected from fashions magazines and documents worldwide, Yi-Ching Chang et al. used cluster and multidimensional scale analysis to identify some distinct fashion style images and to define a suitable design language for each style image. The survey also used to find out differences in sensing fashion style image between designers and consumers [7].

S. Ishihara et al. presented an automatic semantic structure analyzer and Kansei expert systems (ES) builder using self-organizing NNs. The system automatically analyzes semantic structure of Kansei words by using two SOMs. Via graphical user interface, users can browse and explore Kansei structures generated by the ES [8].

Eric and Kamei used a multilayer NN to produce a color conspicuity value from RGB values of two figures and a potential ground. The output value, which is ideal relative area of the two figures, is applied to visualization designs by weighting each conspicuity value with a ground coefficient and the relative size of every color in a design [9].

This research deals with emotional evaluation for Vietnamese Aodai images. Image features and Kansei words are learned by SOM and multilayer NNs. Having learned, the system can recommend which Aodai is suitable for a woman through her desired feelings and can be used in purchasing an Aodai at online stores or selecting one from her own fashion collection.

4 Selecting Kansei Words for Aodai

From common adjectives that are used by Vietnamese people to express their emotions and feelings about clothes, we collected 34 Kansei words categorized into three groups: Elegant, Active, and Inactive. After conducting an initial survey, we

Table 1 Kansei words for Aodai

Elegant group		Active group		Inactive group	
English	Vietnamese	English	Vietnamese	English	Vietnamese
Sober	Đúng mực, chín chắn	Showy	Bóng bảy, phô trương"	Casual	Bình thường
Elegant	Thanh lịch, tao nhã	Attractive	Hấp dẫn, lôi cuốn	Debilitating	Yếu ớt, u ám
Cute	Duyên dáng, đáng yêu	Gorgeous	Rực rỡ, lộng lẫy	Restful	Nhẹ nhàng, yên lặng

Fig. 3 An interface of the survey program

selected only nine words for the three groups, as illustrated on Table 1. Then, we used the semantic differential scale method with five levels from one to five in a survey for emotions of different Aodai clothes. Figure 3 shows an interface of the survey program in Vietnamese.

5 Image Features and Training Data

To give a reasonable emotional advice for selecting clothes, the system should be able to model relations between clothing characteristics such as color, size, type, and Kansei words. A popular method for representing the clothes images is histogram, as described below.

5.1 Color Intensity Histogram

A color intensity histogram represents the number of occurrences of color intensities in an image. For an image $I{:}(x, y) \rightarrow [0, 255]$ where (x, y) is a pixel in row x and column y of the image, the color intensity histogram is given as follows:

$$h_i = \text{card}\{(x, y)|I(x, y) = i\} \tag{1}$$

That means h_i is the number of pixels having a color intensity value of i. Color histograms are often used to compare images because different objects usually have distinctive histograms, and histograms are easy to calculate. However, a color histogram only shows overall pixel intensity information and does not represent correlations between color objects on the images. Two different images may have the same color intensity histogram.

5.2 Color Coherence Vector

Color coherence vectors (CCVs) is a histogram-based method for comparing images that incorporates spatial information [10]. A color's coherence is defined as the degree to which pixels of that color are members of large similarly colored regions. The significant regions are called coherent regions. Coherent pixels are part of some sizeable contiguous region while incoherent pixels are not. A CCV stores the numbers of coherent and incoherent pixels for each color. CCVs prevent coherent pixels in one image from matching incoherent pixels in another. This allows a fine distinction that cannot be made with color intensity histograms.

To compute a CCV, an image is slightly blurred first, and then, the color space is discretized into n color buckets. Next, connected components that have the same discretized color buckets are calculated. A pixel is coherent if the size of its connected component exceeds a fixed value τ, and the pixel is incoherent otherwise.

The CCV of an image is the vector $\langle(\alpha_i, \beta_i)\rangle$, where α_i is the number of coherent pixels and β_i is the number of incoherent pixels of the i-th discretized color. It has been reported that CCV is better than color histograms in image comparison [10]. Figure 4 illustrates CCV regions on an Aodai image.

5.3 Training Data

Training data for building the system consist of 110 images of Aodai clothes and corresponding Kansei words collected from a survey with 41 Vietnamese people in a variety of ages and social positions. After the survey, we have $110 \times 41 = 4{,}510$ training instances with detailed numbers for each Kansei words shown on Table 2.

Fig. 4 An illustration of CCV regions

Table 2 The number of training instances for each Kansei word

Kansei words	Training instances	Percentage
Sober	415	09.20
Elegant	734	16.27
Cute	551	12.22
Showy	448	09.93
Attractive	489	10.84
Gorgeous	520	11.53
Casual	784	17.38
Debilitating	218	04.83
Restful	351	07.78

From the Aodai images, normalized CCV histograms are created and clarified after performing appropriate image preprocessing steps, such as histogram equalization and noise removal.

Fig. 5 Modeling Aodai images and Kansei words by SOM

6 Modeling Relations Between Aodai Clothes and Kansei Words

6.1 Modeling by SOM

SOM is a kind of unsupervised learning. It is often used to discover structures or relationships in data. SOM automatically finds a mapping from the space of input vectors to a one- or two-dimensional space. The mapping preserves the closeness between the vectors; two input vectors close to each other would be mapped to points on the output map that still keep the spatial relationship in the input space [11].

The advantage of SOM is that it is simple, easy to understand, and good for visualization. One can easily train the network and then intuitively evaluate how well the training is performed and how similar the objects are. The limitation of SOM is accuracy of distances among output neurons. It is easy to see the distribution of input vectors on the output map, but it is difficult to accurately evaluate distances and similarities between them. Moreover, if the output dimension and learning algorithms are chosen improperly, similar input vectors may not be always close to each other and the network may converge into some local optimal points [12].

SOM has so far been used in many practical applications, including Kansei modeling [8, 13]. In this research, inputs to the SOM are CCV histograms and its output is a map showing locations of Aodai images. Aodai images with similarities in CCV histograms would be arranged in the vicinity each other. The modeling Kansei words described for the similar Aodai would also be in the vicinity each other. The modeling of Aodai images and Kansei words by SOM is illustrated in Fig. 5.

On a winner neuron on the output map, modeling emotional degrees are estimated from training instances fallen on the neuron and its neighbors described below.

Let the winner neuron be B, its neighbor neuron be $B_n (n = 1, \ldots, N)$, degrees of emotional words modeled by the winner be A^j ($j = 1, \ldots, 9$ for the nine emotional words.) and A^j is computed as follows:

$$A^j = A^j_B + \sum_{n=1}^{N} A^j_{B_n} \times d_{B_n \to B} \tag{2}$$

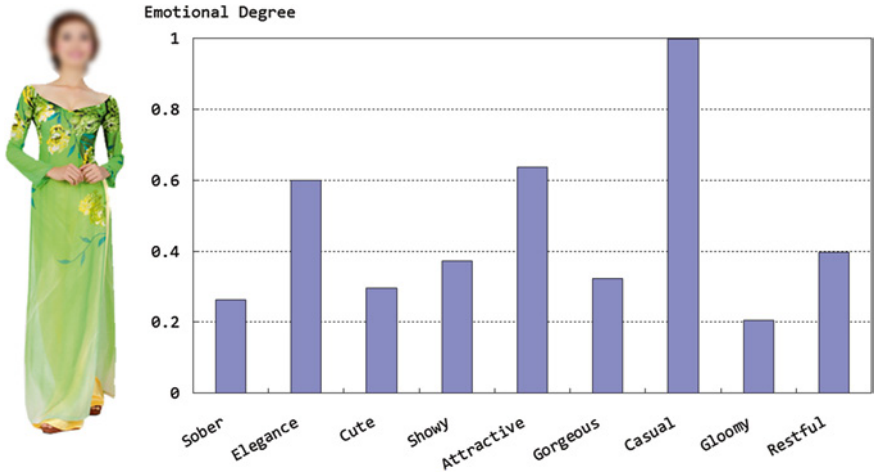

Fig. 6 Normalized emotional degrees (*right*) for an Aodai image (*left*) using similar images on SOM's output map that is shown in Fig. 7

where A^j_B and $A^j_{B_n}$ are degrees of the word A^j on the neurons B and B_n, respectively, $d_{B_n \to B}$ is the distance of the neighbor neuron B_n to the winner neuron B, $d_{B_n \to B}$ is close to one when B_n is near B and it is close to zero otherwise.

When a woman chooses an Aodai, its image will be put into the SOM inputs and a winner neuron will be identified on the output map. By Eq. (2), the system estimates degrees of Kansei words associated with the winner neuron as emotional evaluations for the Aodai. Figure 6 shows an example of emotional evaluations for an Aodai image by SOM. An output map is illustrated on Fig. 7.

6.2 Modeling by MultiLayer Neural Networks

As a kind of supervised learning, multilayer NNs is an effective technique to analyze, model, and make sense of complex data across a broad range of applications. It enables intelligent systems to learn from experience and examples, improving performance of the system over time [9, 14–16]. To train a NN, a set of training instances with corresponding outputs need to be provided. A trained NN can be used to predict outputs for unknown input data.

In modeling emotional evaluations of Aodai clothes, inputs to the NN are the features of Aodai images, and outputs are Kansei words with their degrees. After training, relations of the image features and emotional words are generalized, and the trained NN can give a proper emotional word to a new Aodai image. When a woman looks for an Aodai, the system can help her identify how people feel about the Aodai that she likes. The modeling by NNs is shown in Fig. 8.

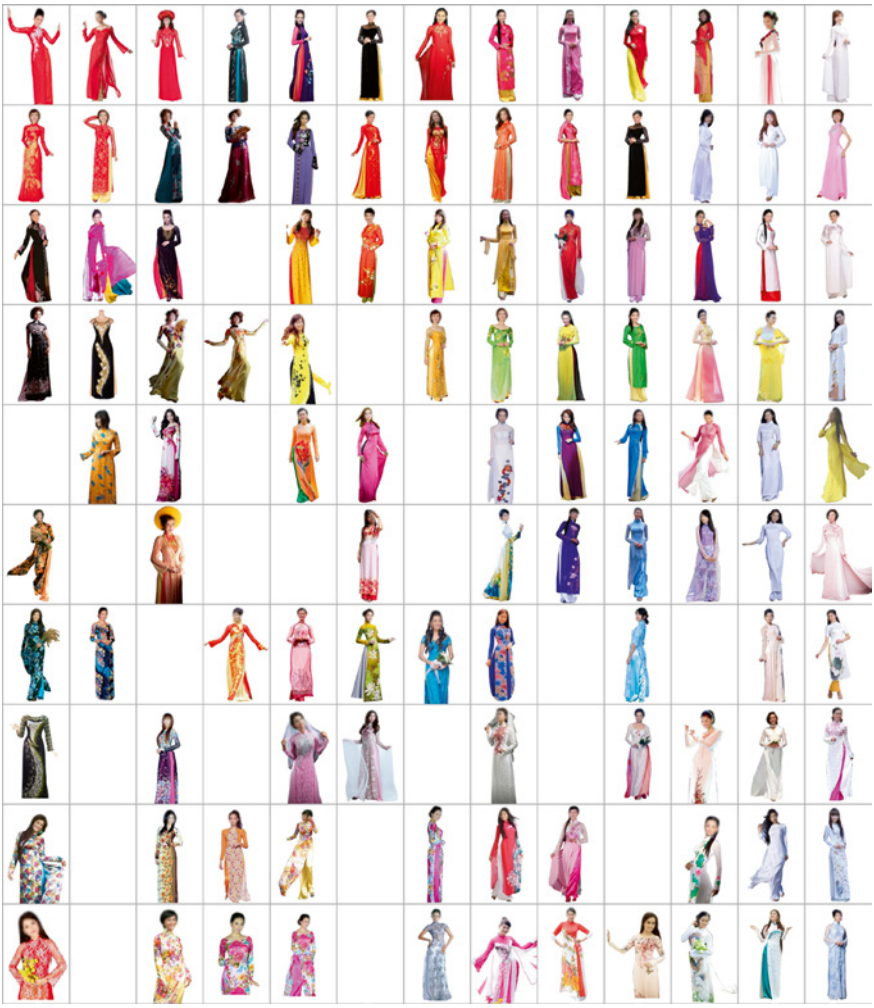

Fig. 7 A SOM for Aodai images after learning with CCV histograms

Fig. 8 Modeling emotions on Aodai images by neural network

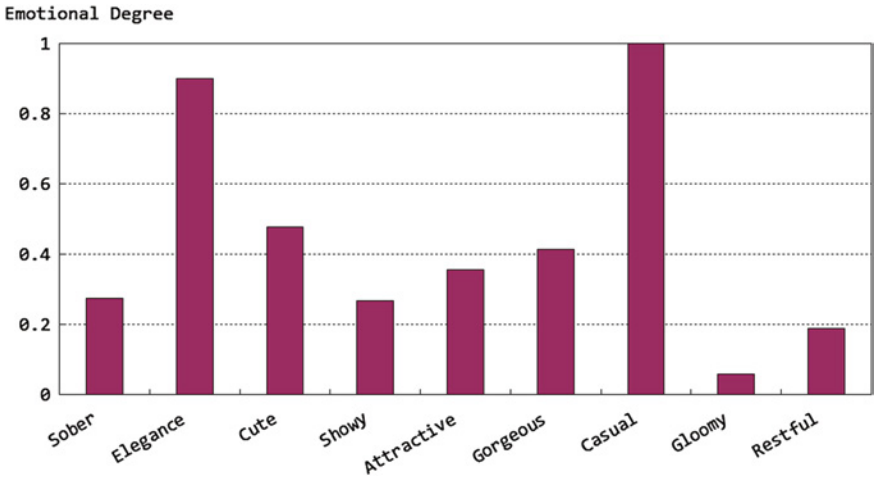

Fig. 9 Normalized emotional degrees from neural network for the input image shown on the *left* of Fig. 6

In our experiment, inputs to the NN are CCV histograms and outputs are nine Kansei words. The NN adopts the sine function on the hidden layer and the identity function on the output layer. Figure 9 shows a normalized emotional evaluation by the NN for the input image shown on the left of Fig. 6. As illustrated on Figs. 6 and 9, dominant degree adjectives are almost the same in using both SOM and NN to modeling emotions of the Aodai image.

7 Conclusions

This paper presents a modeling of emotional evaluations for traditional Vietnamese Aodai clothes based on computer vision and machine learning. Based on the image data and the emotional Kansei words collected from surveys, the system can recommend which emotional words are suitable for a given Aodai. Experimental results show that SOM and NNs are suitable tools for modeling emotional evaluations of Aodai images described by CCV histograms.

Our future research includes investigating other image representation methods, such as combinations of color buckets in different parts of the Aodai, using more detailed descriptions in decorative patterns, integrating conspicuity factors such as color harmony, discriminability, and visibility. We plan to conduct a survey with more people and extend our research for Aodai images with outgoing scene backgrounds.

Acknowledgments The authors would like to thank Mr. Dang Tuan Linh at Ritsumeikan University and other people for their valuable help on the Aodai evaluation survey.

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Near-Infrared Spectroscopy (NIRS) Analysis of Emotion When Reading e-Books with Sound Effects

Akira Nagai, Eric W. Cooper and Katsuari Kamei

Abstract The e-book market has been experiencing a boom recently, as more books are available in a number of different e-book reader formats, including tablets, smartphones, and dedicated e-book devices. Although there have been studies to improve the performance and speed of e-book software and hardware, there has been little research on the content of e-books, despite the fact that they offer more features than their printed counterparts. This chapter focuses on the emotive use of sound effects in e-book reader software by analyzing near-infrared spectroscopy (NIRS) of the user. NIRS is used as a physiological method for measurement of the reading emotion. The results show that the oxygenated hemoglobin (*oxyHb*) in blood of the reader's brain increases when reading a portion of an e-book with sound effects suitable for the contents of that portion of the book. These results suggest that e-book reader contents made available with suitable sound effects may concentrate emotions and lead to more intensity in the experience of reading selection of such e-books.

Keywords Near-infrared spectroscopy • E-book audio content • Emotional response • Multimedia reading

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_10,

1 Introduction

Recent advances in handheld device technologies, in addition to the tremendous expansion of their use, have resulted in a boom in the electronic book market. Online booksellers have reported that their sales of these e-books have now outpaced printed books [1]. However, the resolution of the electronic viewer is still lower than that of the printing press so the character clarity is also inferior to paper. Small screen sizes pose additional constraints for the use of handheld devices as electronic book readers. So it was once thought that the use of handheld devices for reading digital documents would be limited [2]. With the release of popular dedicated devices such as Amazon's Kindle, as well as the increasing popularity of other handheld devices, the market expanded greatly and many companies began developing e-book viewers.

Although the market size of e-books was one billion JPY in 2002 in Japan, by 2010, the market had grown to 65 billion JPY, with expectations to reach the 200 billion JPY level in 2016 [3]. The 2010 release of the Apple iPad also invigorated the e-book market greatly [4, 5]. Now, new e-book viewing software is being released every day. Reading books on tablets, smartphones, and dedicated readers has become a normal daily activity for many people who love books.

There have been a number of publications on e-books and reading and various experts' opinions vary on the effects of reading e-books versus print books [6]. There have been a number of studies on "supported eText" which means text with materials to support the meaning of the content, especially for those who have reading difficulties [7]. A general consensus of such research is that multimodal contents such as audio enhancements improve comprehension when they match the contents and may hinder comprehension when not supportive of the content. Since, however, much of this research has focused on reading for comprehension and increasing reading skills, few studies have focused on e-book reading as an emotional experience, nor on how multimodal contents may influence that experience.

This chapter describes near-infrared spectroscopy (NIRS) monitoring of brain activity during e-book reading experiences that are enhanced with audio content versus those that are not, in order to infer differences in emotional experience, and feelings of concentration and devotion. Two popular books in e-book format were downloaded from the Internet and two copies of each were enhanced with sound effects, one copy of each with sound effects thought to be suitable to the content and one copy of each with sound effects thought to be unsuitable. These experimental stimuli are discussed in the following section. Next, the experiments about emotion evaluation of reading by NIRS are conducted using a viewer for the e-books developed based on iPod touch by authors, as described in Sect. 3. Section 4 gives the results of those experiments and discusses what the NIRS monitoring results suggest about how the addition of various sound effects influences the emotions of the e-book readers, such as feelings of concentration or devotion to reading. Finally, Sect. 5 gives the conclusions reached and proposes possible areas of future study.

2 E-Books with Sound Effects

2.1 Original Books

The e-books used in the experiments are "Night Train to the Stars (*Ginga Tetsudo no Yoru* in Japanese)" by Kenji Miyazawa and "Jack and Beanstalk" translated into Japanese by Masao Kusuyama. In popular opinion, the former is said to have "dark" contents and the latter is said to have "bright" contents. These e-books were selected under the following conditions:

- The story is well-known in the socio-cultural group of the subject pool.
- The book is easy to read and comprehend.
- The book is available in the public domain for educational uses.

2.2 Sound Effects

Sound effects from animated video (DVD) productions of the stories were selected as "suitable" sounds. The reading speed of each subject is different so the timing of sound effect playback was set immediately after the reader has turned a page. Therefore, the sentence where the sound effect was considered to be most appropriate was placed at the top of the page. This method of sound effect implementation has been adopted previously for example in Murakami's production of the e-book "A Singing Whale (*Utau Kujira*)" [8, 9].

Experiments were conducted to validate the suitability of the selected sound effects for the book contents. A five-step Likert Scale (1: strongly disagree, ···, 5: strongly agree) were used for the evaluation. Table 1 shows the average of evaluation scores of 10 subjects. The scores 4.67 for "Night Train to the Stars" and 3.08 for "Jack and Beanstalk" were considered high enough to validate their adaptation as suitable sound effects then the adopted sound effects. Various sound effects available for free download from the Internet were used as the "unsuitable" ones. They include various sounds such as noises from daily life, noise of impacts, and various natural sounds. Hundred sounds were collected in total, and these were randomly attached to the e-books in the same manner as the suitable sound effects.

3 Experiments

3.1 Objective

The objective of the experiments is to use NIRS to investigate the hypothesis that the emotions of e-book readers with the suitable sound effects is stronger than that when reading both e-books with unsuitable sound effects and those and e-books

Table 1 Average scores of sound effect suitability for the book contents

E-book title	Average suitability rating
"Night Train to the Stars"	4.67
"Jack and Beanstalk"	3.80

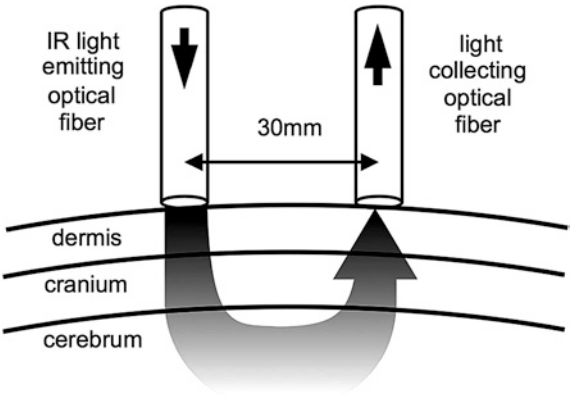

Fig. 1 Light is passed from each emitting optical fiber, through the cranium into the cerebellum, scattering light back into each adjacent receiving optical fiber. Specific changes in the spectrum received indicate changes in the density of oxygenated hemoglobin (*oxyHb*)

without sound. Emotions in this case refer basically to reported feelings of concentration or devotion when reading, in other words, feelings of an emotional attachment to the story. These feelings are thought to be closely related to the brain activity in the prefrontal cortex region [10].

NIRS is a physiological method to measure various changes associated with the spectrum of infrared light passing through the human body and is employed here to measure changes in the density of oxygenated hemoglobin (*oxyHb*) associated with brain activity. The basic principle of NIRS brain activity imaging is shown in Fig. 1. NIRS can be used to monitor the status of oxygen density in these states: oxyhemoglobin (*oxyHb*), deoxyhemoglobin (*deoxyHb*), and total hemoglobin (*totalHb*, the sum of *oxyHb and deoxyHb*). Since the behavior of *deoxyHb* density is complex and the change in *totalHb* is relatively small, this study only considers *oxyHb* density [11].

3.2 Procedure

Subjects read the e-books using a smartphone application viewer developed by the authors fitting with the NIRS head-mounted apparatus and sitting in a chair. Figure 2 shows the procedure of each experimental session.

First, *oxyHb* density of the subject is measured by NIRS in a state of rest, with eyes closed, for 5 min. This is called Rest 1.

Next, the subject reads the e-book "Night Train to the Stars" for 30 min or "Jack and Beanstalk" to the end of book. The average of reading time of "Jack and Beanstalk" was found to be about 11 min in preliminary experiments. During this whole time, the *oxyHb* density of the subject is measured. This measurement is called Task *X*, where *X* is the task number shown in Table 2. Finally, the *oxyHb* density is

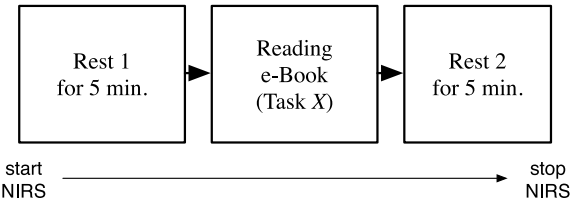

Fig. 2 Each experiment session starts with setting and starting the NIRS equipment, followed by a brief rest, after which the task begins and, after the task is completed, there is another brief rest before the NIRS equipment is removed

Table 2 Tasks to be completed for each experiment session

Task *X*	Sound effects	E-book title
Task 1	Suitable	
Task 2	Unsuitable	"Night Train to the Stars"
Task 3	None	
Task 4	Suitable	
Task 5	Unsuitable	"Jack and Beanstalk"
Task 6	None	

measured again in the same manner as in Rest 1. This is called Rest 2. The experimental results of Rests 1 and 2 are used for a baseline adjustment of the experimental results of Task *X*. The subjects participated in either Tasks 1–3 or Tasks 4–6. The order of tasks is random, and the time interval between tasks was more than 1 week.

3.3 E-Book Viewer

The e-book viewer for the experiments was developed using the iPod touch device, by Apple Inc. The document of the book is arranged in the vertical Japanese form, with up to 21 characters in each column and 8 characters in each row (up to eight columns or lines of text). The e-book viewer imports document and displays it. The page turning of the documents is done by flicking or wiping the display. Each sound effect is played back immediately after the page turn is complete. Figure 3 shows a part of "Night Train to the Stars" displayed on the handheld device.

4 Experimental Results

4.1 Preprocessing of NIRS Data

The following procedure was used to preprocess the *oxyHb* density data:

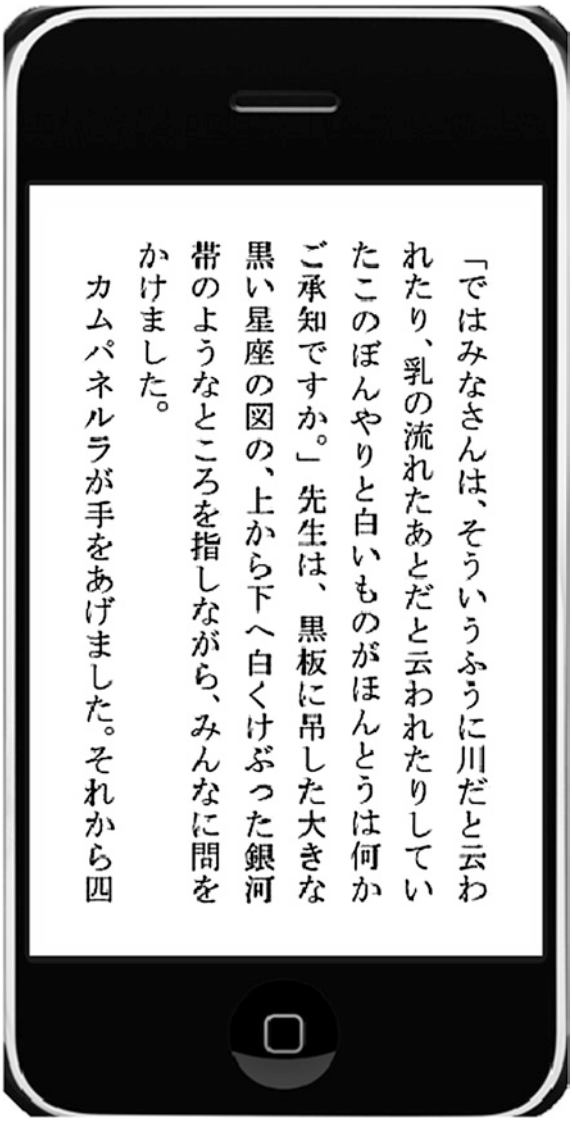

Fig. 3 The reader application screen showing one page of "Night Train to the Stars"

1. A weighted moving average method with a window of 11 data points is applied for smoothing.
2. Baseline adjustment is performed. First, a line connecting the average of *oxyHb* densities in Rest 1 and Rest 2. Next, the difference between the *oxyHb* density in Task *X* and the line is calculated as the adjusted *oxyHb* density.
3. The most clearly indicative *oxyHb* density is selected from all channels of NIRS, as evaluated by lack of noise and other probable outlier indications. Below, this adjusted and selected value is called the *oxyHb density*.

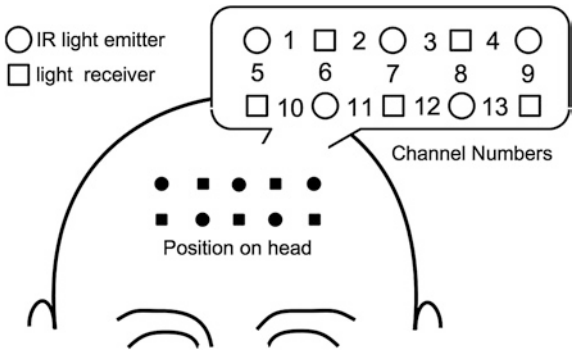

Fig. 4 The locations and position of the channels, where each channel is the path from one emitting optical fiber into one receiving optical fiber

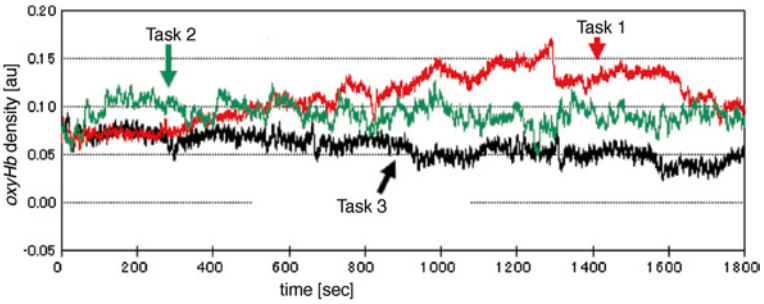

Fig. 5 *oxyHb* density changes at Channel 10 of Subject A in Tasks 1–3

Table 3 Averages of *oxyHb* densities for all subjects reading "Night Train to the Stars" for 30 min

	oxyHb density (au)				
Tasks	Subject A	Subject B	Subject C	Subject D	Subject E
Task 1 (suitable)	0.111	0.0892	0.0985	0.0670	0.1031
Task 2 (unsuitable)	0.093	0.0782	0.0801	0.0637	0.0676
Task 3 (no effects)	0.058	0.0695	0.0626	0.0617	0.0567

4.2 "Night Train to the Stars"

The *oxyHb* density at Channel 10 (as numbered in Fig. 4) of Subject A in Tasks 1–3 is shown in Fig. 5 as a typical result in case of reading "Night Train to the Stars". Table 3 shows the averages of *oxyHb* for all subjects who did Tasks 1–3.

Figure 5 and Table 3 show that the *oxyHb* densities in all tasks increased while Subject A was reading "Night Train to the Stars". In the case of Task 1, in which the sound effect is suitable for the contents of book, the increase in the *oxyHb*

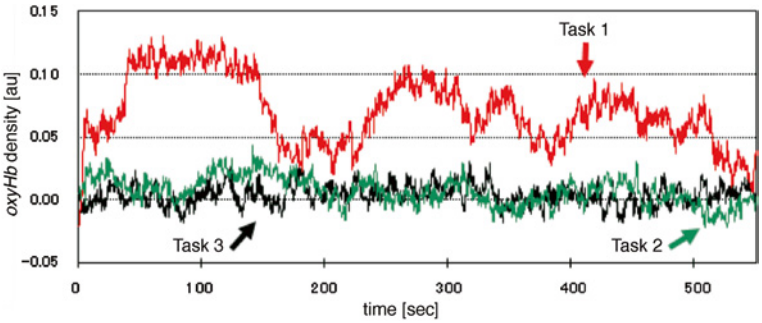

Fig. 6 *oxyHb* density changes at Channel 7 of Subject G in Tasks 4–6

Table 4 Averages of *oxyHb* densities for all subjects reading "Jack and Beanstalk" to the end

	oxyHb density (au)				
Tasks	Subject F	Subject G	Subject H	Subject I	Subject J
Task 4 (suitable)	0.0129	0.0640	0.0506	0.0156	0.0415
Task 5 (unsuitable)	0.0022	0.0068	0.0194	0.0029	0.0083
Task 6 (no effects)	0.0070	0.0038	0.0093	0.0089	0.0155

density is largest. The second largest density is for Task 2, where the sound effects were unsuitable. The lowest density is Task 3, in which there were no sound effects. The results shown in Table 3 were compared using a *t* test, which showed a $P \leq 0.5$ significance level between each of the tasks.

4.3 "Jack and Beanstalk"

The *oxyHb* density at Channel 7 of Subject G in Tasks 4–6 is shown in Fig. 6 as a typical result for subjects reading "Jack and Beanstalk". In these tasks, all subjects had to read the e-book to the end. So they took different times to complete the task. Subject G took 10 min and 44 s (10′44″), 09′05″ and 09′09″ in Task 4, Task 5, and Task 6, respectively. Figure 6 shows the *oxyHb* densities by 09′05″ when the time is shortest. Table 4 shows the averages of *oxyHb* densities at Channel 7 of Subject G while reading the e-book to the end.

Figure 6 and Table 4 show that the *oxyHb* densities in all tasks increased while Subject G was reading the e-book. The *oxyHb* density in Task 4, in which the sound effects are suitable for the contents of the book, is largest as was shown in subjects reading "Night Train to the Stars". Also, the second largest *oxyHb* density is Task 5 that the sound effects are unsuitable and the lowest one is Task 6, in which there were sound effects. These results are similar to those in case of "Night Train to the Stars". The results shown in Table 4 were compared using a *t* test, which showed a $P \leq 0.5$ significance level between each of the tasks.

As shown in Table 4, the averages *oxyHb* densities of all subjects are largest in Task 4 and second largest in Task 6, except for Subject H. Possible explanations for the *oxyHb* density in Task 6 to be the second largest, as opposed to the third as in subjects reading "Night Train to the Stars", include the following:

- The subjects concentrated less on reading because the reading time is shorter.
- The bright (positive) contents and the unsuitable sound effects prevented the subjects from concentration in reading.

4.4 Discussion

Previous studies have reported that the prefrontal cortex is activated when a person concentrates on reading or comprehending a task, such as calculation, which requires concentration [12–14]. Since the activation of the prefrontal cortex activity is observed when the subjects read the e-books with the suitable sound effects for the book contents, the results suggest the subjects concentrate on the reading and felt devotion to the story.

Comparing in terms of the reading time, for "long" reading, the suitable sound effects were best and the unsuitable ones were better than no sound effects. On the other hand, in case of "short" reading, no sound effects had better responses than the unsuitable ones. In addition, comparing in terms of the contents of book, "positive" (bright) or "negative" (dark), the suitable sound effect is best for the e-books in both contents and the unsuitable sound effect is better than no sound effects in case of "negative" contents. On the other hand, no sound effect was better than the unsuitable ones in case of "bright" contents.

5 Conclusions

The results of this study give limited support to the hypothesis that audio effects used appropriately in e-books increase feelings of concentration or devotion. Suitable sound effects evoked responses in e-book readers that were consistent with feelings of concentration in reading or devotion to reading efficiently, according to the results of NIRS. The results of these studies suggest that the intensity of such emotional responses is also related to the contents (bright or dark) and reading time (long or short) in comparisons with unsuitable sound effects versus no sound effects.

This study shows methods and an example of studying brain activity during e-book reading using NIRS. The study described here shows how using NIRS allows tasks such as reading in a natural environment without distractions or special environments required in many other imaging systems, such as functional magnetic resonance imaging (fMRI). The results also show some of the methods and challenges in handling NIRS data for evaluation of emotional response. Understanding the role

of limited multimedia in e-books allows educators, writers, publishers, and other communicators to plan and publish more effective e-books for education and entertainment. Future studies will continue to elaborate more precisely the neurological and psychophysical influence of sound effects in e-book reading with more accurate NIRS methods and other physiological measurements of brain activity.

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The Effects of Culture on Users' Perception of a Webpage: A Comparative Study of the Cognitive Styles of Chinese, Koreans, and Americans

Ying Dong and Kun-Pyo Lee

Abstract This study aims to reveal the relationship between cognitive style and Webpage perception. In particular, Webpage perceptions of people with different cognitive styles are compared. Based on Nisbett's cognitive model on holistic and analytic thought, this study hypothesizes that differences between holistic thought and analytic thought can be reflected in Webpage perception. An experiment was then carried out involving American, Chinese, and Korean participants. The users' eye movements, which can provide specific information about their cognitive processes, were recorded while browsing different language versions of Webpage prototypes. In the end, the hypotheses of this study were supported. Findings from the analysis suggested that the Chinese, Koreans, and American participants employed different viewing patterns on the Webpage, revealing a positive relationship with Nisbett's cognitive theory. Given that cognitive differences exist among holistically minded people and analytically minded people, it is suggested that Webpage design should be carried out according to the target audiences' specific cognitive style to enhance the perception and usage of the Webpage.

Keywords Cross-cultural study • Cognitive style • Webpage perception • Eye tracking

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_11,

1 Introduction

Since its creation, the World Wide Web (WWW) has become the most popular medium of communication around the world. At present, Web sites can potentially be visited by people around the world, and people from different cultures may employ different usage strategies on a Web site. An effective Web site requires consideration of these factors and should be designed to accommodate the needs of people with diverse cultural backgrounds [1]. Many studies have been carried out to shed light on the effects of cultural differences on Web usability. The term "Culturability," emphasizes the importance of the relationship between culture and usability in WWW design. A user interface should be designed to accommodate cultural preferences and bias to increase its usability [2]. The Webpage acts as an interface, allowing people to interact with the Internet. Good interface designs can enhance the user's capacity to process the information on the Webpage. Additionally, a number of cross-cultural Web design studies, which were grounded in Hall [3, 4] and Hofstede's [5, 6] cultural theories were carried out. These studies compared Web sites from different countries by taking cultural dimensions as criteria and derived characteristics of Webpage design in different cultural contexts [7, 8, 9].

Research on cultural differences from various perspectives such as linguistic studies, cultural patterns, cultural models, and cognitive style has contributed to cross-cultural Web design. Cognitive style plays an important role in the design of Web content because a Web design should ultimately accommodate an individual's typical mode of perception, thinking, remembering, and problem solving to promote usability. Differences in cognitive style are magnified when East Asians and Westerners are compared. Nisbett's recent research [10] on cultural cognition provides a theoretical framework for cross-cultural study. Through observations of how people from diverse cultures view images, he defined holistic and analytic cognitive styles. Nisbett combined cultural and cognitive perspectives that enrich the aspects of cultural influence in Web usability research, thus creating a new approach in this field. Research in the field of online communication has focused on the consistency of the cognitive style of people within the same cultural context, such as the influence of cultural context on the cognitive style of Web site designers and users [1, 11]. This research conducted a new approach for connecting cognitive style with the Webpage usability.

2 Cultural Cognitive Style

Cognitive style, as defined by Riding and Rayner [12], is "an individual's preferred and habitual approach to organizing and representing information," or as Ford et al. [13] stated, "A tendency for an individual consistently to adopt a particular type of strategy is known as a cognitive style." Anthropological and psychological studies of general cognitive processes suggest that cognitive styles are connected to culture [12, 14–16].

Nisbett and Masuda [17] revealed the perceptual differences of East Asians and Westerners through an experiment in which underwater scenes were shown to Japanese and American participants. The participants were asked to recall what they had seen. Japanese and Americans made equal numbers of statements about the focal fish which is larger than others, but Japanese made about 70 % more statements about the field and twice the amount on the relationships between the fish and the background than Americans did. This study revealed differences between East Asians and Westerners. That is, East Asians are more focused on the field and relations, while Westerners are more focused on objects and detach objects from the field. These different styles of thoughts were summarized as holistic versus analytic thought.

Nisbett and Norenzayan, in their paper, "Culture and Cognition" [15], proposed that cognitive processes differ according to holistic and analytic perspectives. They stated that cultural differences in cognitive: processes are tied to cultural differences in basic assumptions about the nature of the world (i.e., holistic vs. analytic). Scholars in a number of disciplines maintained that East Asians and Westerners differ greatly in their methods of reasoning. Holistic and analytic reasoning was summarized as follows:

Holistic thought involves:

(1) Orientation to the context or field as a whole, including attention to the relationships between a focal object and the field; (2) a preference for explaining/predicting events on the basis of such relationships; (3) An approach that relies on an experience-based knowledge rather than abstract logic and the dialectical; (4) an emphasis on change, recognition of contradiction, and the need for multiple perspectives.

Analytic thought includes as follows:

(1) A detachment of the object from its context; (2) a tendency to focus on the attributes of the object in order to assign it to categories; (3) a preference for using rules about the categories to explain and predict the object's behavior; (4) inferences that rest in part on the decontextualization of structure from content, use of formal logic, and avoidance of contradiction [15].

3 Eye Tracking in Usability Testing

The process of visual perception is an essential part of a user's interaction with an interface. Modern eye tracking equipment now makes it possible to track and analyze this process. Research in eye movement flourished with major advances in both eye tracking technology and the psychological theory to link eye tracking data and cognitive processes. Eye tracking provides insight into the user's cognitive strategies and allows us to identify patterns that even the users do not consciously see. Cowen et al. [18] claimed that eye movement data can augment data obtained through user testing by providing more specific information about the user's cognitive processes. Most of the work in this area is focused on research in psychology

and physiology and explores how the human eye operates and what this can reveal about perceptual and cognitive processes. Salvucci [19] stated that eye movements provide a rich and informative window into a person's thoughts and intentions. Through eye movement, users' behavior in using an interface can be examined.

4 Hypotheses

Cultural differences between East Asian and Western thought, communication, and interaction serve as an increasing influence in the use of Web. Westerners have an analytic cognitive style, which tends to detach the object from its field and focus on categories. East Asians have a holistic cognitive style, which tends to see the field as whole and focus on the relations. In the operation, viewing a Webpage is similar to viewing an image. East Asians and Westerners may show different viewing patterns and perceptions while browsing Webpages. Thus, this research proposes a new approach to enhance the usability of Webpage design by applying the culturally different cognitive styles of East Asians and Westerners.

The main hypothesis is as follows:

H0: Holistically minded people and analytically minded people show different viewing patterns on the Webpage.

This hypothesis can be examined through several sub-hypotheses:

H1: Holistically minded people show spread fixations over the page, while analytically minded people show concentrated fixations over the page.

H2: Holistically minded people show a nonlinear reading pattern, while analytically minded people show a linear reading pattern.

5 Experiment

5.1 Participants

This research attempts to gain an in-depth understanding of how people's cognitive style influences their behavior when browsing a Webpage. In terms of qualitative research, one study indicates that testing four or five participants will expose the vast majority of usability problems [20]. Rubin [21] claimed that most of the usability problems may be exposed with four participants, but there is still a good chance to overlook a problem that could have severe ramifications. He proposed testing at least eight participants if at all possible.

In this experiment, American, Chinese, and Korean participants were recruited. A total of 41 people were invited to take part in the experiment, including 14 Westerners, 15 Chinese, and 12 Koreans. Due to problems with the device and participants, only nine eye movement data from nine subjects per each group qualified for analysis. (Due to technical problems related to the device, the camera

Fig. 1 Chinese version of the prototype

could not track the participants' eye movement normally if they wore thick glasses or did not open their eyes wide enough or blinked too often.) All participants were between the ages of 24 and 35, with 6 males and 3 females from each culture, and all of them had experience on browsing Webpages.

5.2 Webpage Prototype

The prototype used in this experiment was designed by imitating a popular Web site, Yahoo! The Webpage prototype was designed with the most basic Webpage elements and page layout. The clearly and neatly divided areas were designed to easily allocate eye movements data. Stylization of the design was restrained so as to limit distraction to the participants (see Figs. 1, 2, 3). Prototypes with identical contents and layout, as well as identical page elements, were designed.

Three different language versions of the prototype were provided in English, Chinese, and Korean. It is well known that English text flow is left-to-right. Even though in ancient China and Korea, the text was written starting mostly at the top right corner of the page and proceeding downward to the bottom, nowadays the Chinese and Korean text flow are the same as in English. The prototype was originally created in English. It was then duplicated, and the English text was removed and replaced by Chinese and Korean text. Before the main experiment, the Chinese

Fig. 2 English version of the prototype

Fig. 3 Korean version of the prototype

prototype was tested with Chinese volunteers in order to check for confusing words and content. Based on the volunteers' comments, those prototypes were finalized.

Those prototypes are bitmap images and are designed to fit in one screen. They are not clickable and cannot be scrolled down. In order to imitate the real Web environment, a browser-like interface, including a toolbar and a status line, was added to the final prototype. According to the resolution of the monitor (a part of the Eye Tracking device), all prototypes were set to a resolution of 1,024 × 768 in order to be displayed without interpolation, thereby providing the clearest possible image during the experiment.

5.3 Apparatus

The hardware component, the Eyegaze Development System, used in this experiment was developed by LC Technologies, Inc. The software EMT tracker was used to record users' eye movement data.

Eye tracking metrics are used to measure eye tracking data. The selection of eye tracking metrics varies according to different eye movement studies. The main measurements used in eye tracking research are "fixation" and "saccades."

Fixation: The focusing of the eye on an object is termed fixation. A fixation defined by the eye position stabilizes within some threshold of dispersion (typically ~2°) [22] over a duration lasting from 66 to 416 ms (218 ms on average).

Saccade: A rapid eye movement from one location to another is termed a saccade. It is the movement occurring between fixations, typically lasting for 20–35 ms [23]. During a saccade, no information is obtained.

More eye tracking metrics are also commonly used:

Scan path: A spatial arrangement of a sequence of fixations. It usually consists of a sequence of fixations and interconnecting saccades.

Area of Interest (AOI): Area of a display or visual environment that is of interest to the researcher or design team and is thus designed by them (not by the participant).

Gaze duration: Cumulative duration and average spatial location of a series of consecutive fixations within an area of interest. Gaze duration typically includes several fixations and may include a relatively small amount of time for the short saccades between these fixations.

In addition, software named EyeGo was developed and used to review and analyze the recorded eye tracking data.

5.4 Procedure

Participants were given brief instructions after they arrived to the experiment room. They were told that the purpose of the test was to compare how people from different countries would view a Webpage. They were informed that an eye tracking device would be used in the test and that it would not directly come into contact with them. In the experiment, their eye movement would be recorded, and the

recorded result would be only used for the research and not for evaluating users. They were encouraged to relax during the test.

After being seated in front of monitor and eye tracking device, participants were informed of the details of the experiment including how the eye tracking device would work and what they would be asked to do in the experiment. They were also asked to keep their head motionless during the experiment for better eye tracking. The experiment began with device calibration, which calibrates the participants' eye to the screen of the monitor on which the prototype is to be presented. Once calibrated, participants were asked again to avoid moving their head since the experimental session on data recording was to be followed immediately. The participants were asked to use their left hand to support their head so that their head would remain steady during the test. Participants were exposed to the prototype version in their native language, and they were asked to freely look at the Webpage without clicking on anything since the task was trying to let people show how they actually view a Webpage without a specific searching item so that their natural viewing pattern could be revealed. As soon as the prototype was shown on the display, the eye tracking device was triggered by the experimenter to record the eye movements, and the recording was stopped after 30 s.

6 Analysis Results

6.1 Prototype Webpage Area of Interest (AOI) Division

The prototype page was divided into several AOIs, which are used for allocating eye tracking data and analyzing those data (see Fig. 4).

6.2 Analysis According to Eye Tracking Metrics

6.2.1 Accumulated Number of Areas of Interest (AOIs) the User Visited in the First 25 s

From pilot test, people showed different viewing patterns within 30 s. In this experiment, all participants have qualified eye tracking data within the first 25 s. Thus, 25 s were set as time range for analysis. Original collected data includes the following.

(1) Time: eye movement was recorded from 0 to 25 s; (2) Moves: refer to the number of AOIs the participant visited each second; (3) Areas: indicate which area the participant visited in each second; and (4) Accumulated number of AOIs the user visited: refers to the total number of AOIs the participant visited previously during each second.

Comparison of accumulated area moves in the first several seconds can reveal how often participants moved their eye among the content areas.

Figure 5 shows the results of the accumulated number of AOIs that a participant visited in the first 25 s. The mean of each group of participants' movements among AOIs in each second were used to make the diagram. The blue line with rhombus

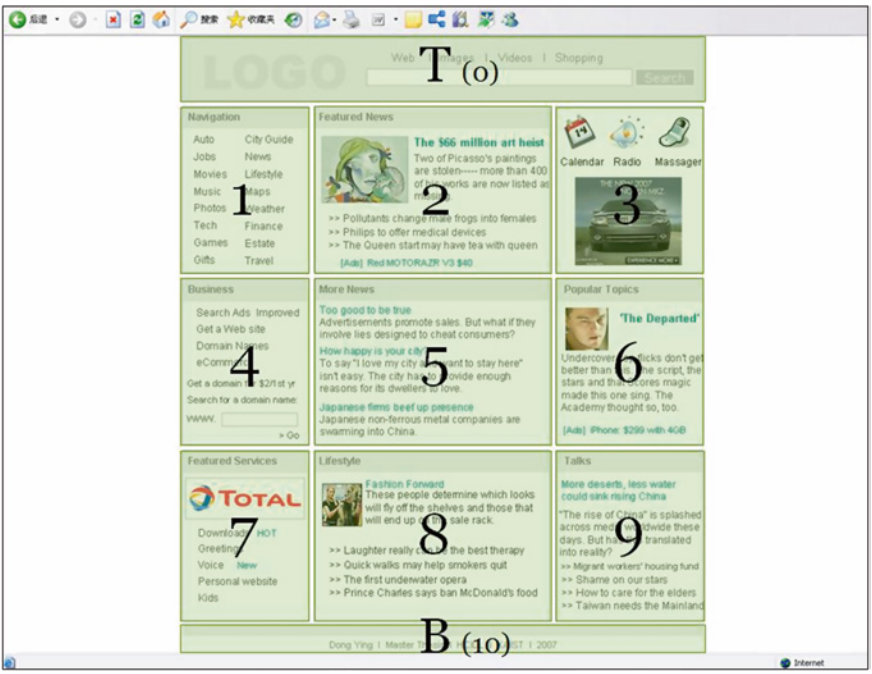

Fig. 4 Prototype Webpage with defined areas of interest

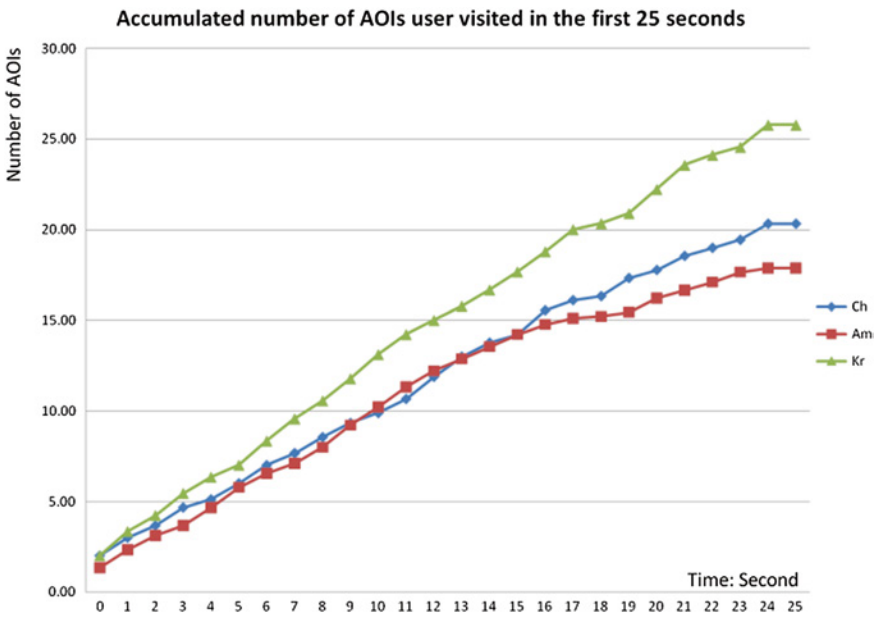

Fig. 5 Accumulated number of AOIs the user visited in the first 25 s

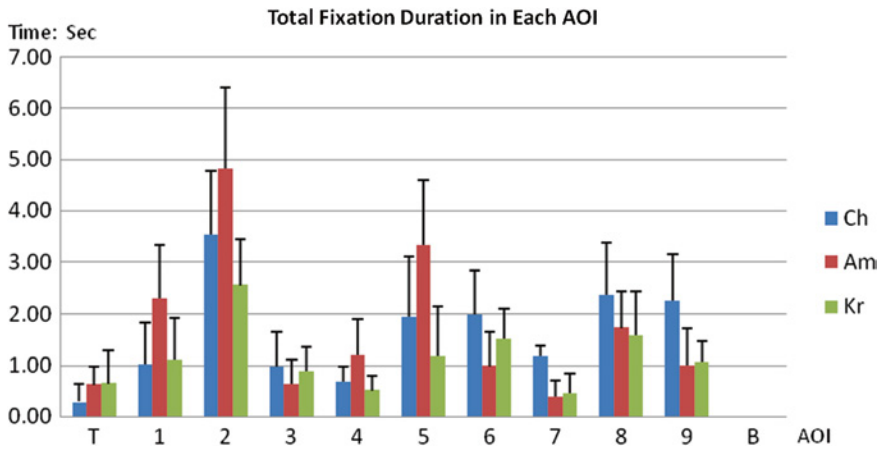

Fig. 6 Total fixation duration in each AOI

dots denotes Chinese participants, the red line with square dots denotes Americans, and the green line with triangle dots denotes Koreans. Figure 5 shows that the green line is always above the other two lines, which indicates that the Korean users moved a great deal on the page starting from the beginning of the session. They moved across more areas in each second than the other two groups. Chinese and Americans showed similar movements before the 15 s, while Chinese AOI movements were slightly more frequent than the Americans' within the first 10 s and exceeded those of the Americans shortly after. After the 15 s, the rate of increase of AOI movements of the American participants was lower than that of the Chinese participants, which reflected that the Americans began to stabilize their eye and focus on something on the page.

6.2.2 Fixation(s) Duration in Each Area of Interest (AOI)

This metric measures how long participants remained in each AOI. The duration of fixations in an area reflects the relative importance of the area to the participant. Area 2, which is located at the top middle area, is especially important. It attracted substantial attention from all three of the groups. Overall, the Americans had longer fixation duration in areas 1, 2, and 5 than the other two groups. The Chinese had longer fixation duration in Areas 6, 7, 8, and 9 than the other two groups (Fig. 6).

A mixed between-within subjects analysis of variance was conducted to explore the impact of nationality and AOIs on the total fixation duration. There was a significant main effect for AOIs (area) [$F(10, 15) = 62.93$, $p = 0$] within the three groups, and the effect size was large (partial $\eta^2 = 0.98$). There was also a significant main effect for nationality [$F(2, 24) = 5.56$, $p = 0.010$] between the groups, and the effect size was also large (partial $\eta^2 = 0.32$).

6.3 Analysis from an Eye Tracking Map

6.3.1 Eye Tracking Data Visualization

Each individual's eye tracking data was visualized for the subject's own language version of the prototype Webpage. Examples are provided in Figs. 7, 8, and 9. The viewing sequence on the prototype is displayed by different colors: green denotes the start of the eye movement and red the end (in a black and white print out, green is printed as a lighter color, while red is darker; thus the lighter color denotes the start, and the darker color represents the end).

6.3.2 Viewing Pattern Defined

The analysis procedure from the eye tracking map is as follows (Fig. 10): by reviewing each individual's eye tracking map, a few keywords of viewing pattern were defined based on each eye tracking map. After reviewing all eye tracking maps from the three groups and defining viewing patterns on each map, all defined viewing patterns were gathered and synthesized into several viewing pattern categories. These viewing pattern categories were used as the analysis criteria for mapping three groups into a chart so that the similarities and differences can be revealed among these three groups.

By reviewing and synthesizing all eye tracking maps, six viewing patterns were defined. They are as follows:

- *Sequential Reading*: The eye moves sequentially from one area to the neighbor area and continuously reads contents within one area.
- *Circular Scan*: The scan path is similar to a circle being drawn on a page.
- *Scan Back and Forth*: The eye moves back and forth among the contents; the participant visits one area repeatedly within a short time.
- *Only Scan*: Participants only scan the page without reading in detail. It shows rapid eye movements on the eye tracking maps.
- *Focus on Title*: Participants pay a comparatively high amount of attention to the title.
- *Read Navigation*: Participants pay attention to the navigation bar and spend some time reading navigation items.

The viewing patterns defined above were classified as "Analysis Criteria 1," which shows whether participants read or scan the page and the way of reading and scanning the page. Also, another analysis method, "Analysis Criteria 2" was defined in order to show how participants would proceed in viewing the page. It shows a visualized image of the viewing pattern. The "Analysis criteria 2" includes the following:

- "0" *Shape*: Eye movement is similar to drawing a "0" on the page
- "5" *Shape*: Eye movement is similar to drawing a "5" on the page. (Typically, the eyes visit areas in the following sequence: area 2, 5, 6, 9, 8, 7.)

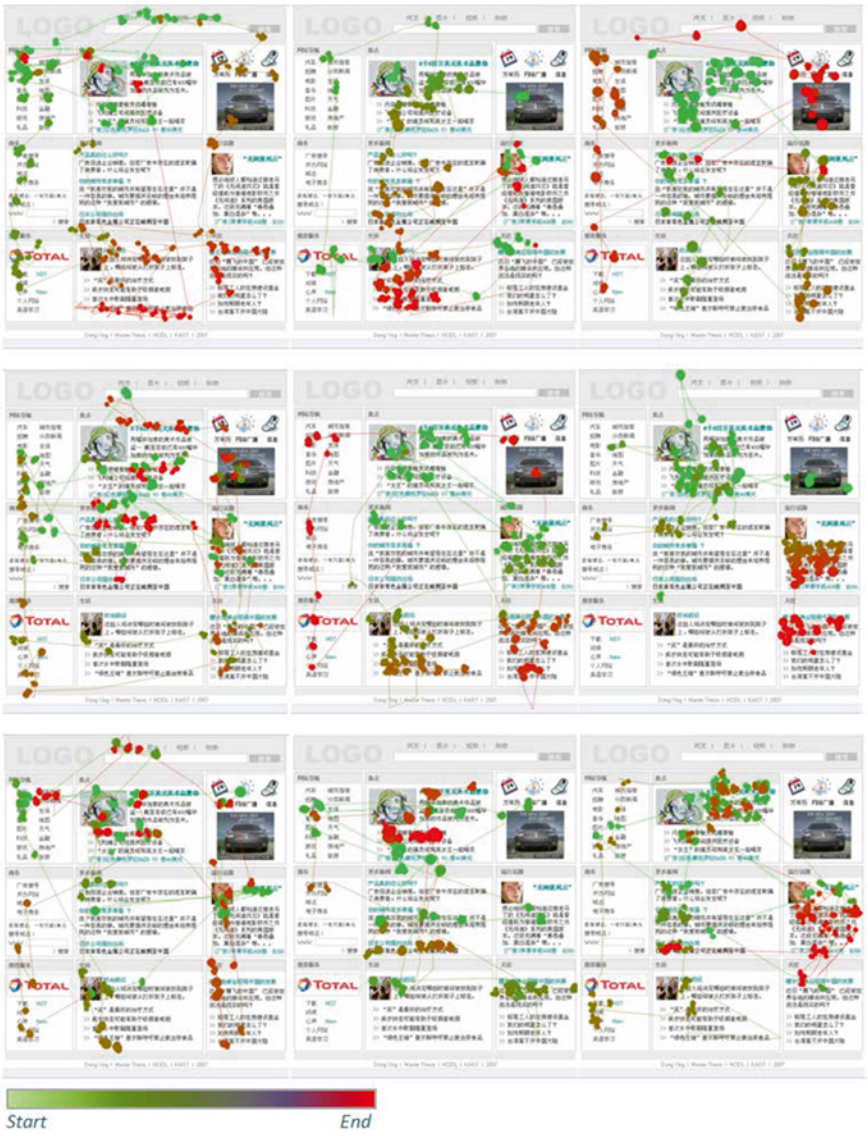

Fig. 7 Chinese eye tracking map

- "N" *Shape*: Eyes move down in one column and then move over to another column.
- "Z" *Shape*: Eyes pass over columns first and then move down the page.
- "X" *Shape*: Eyes move diagonally across the page and scan the page with random jumps.

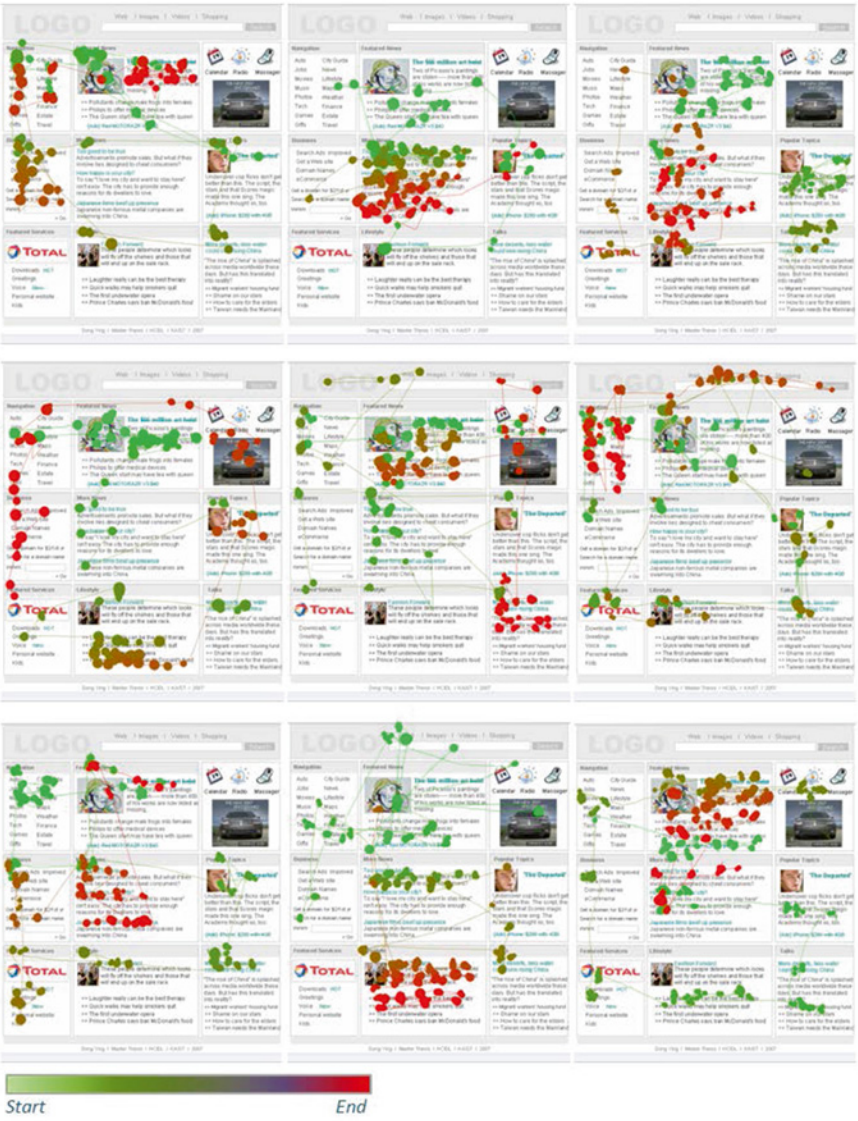

Fig. 8 American eye tracking map

6.4 Analysis Results

With the viewing patterns defined as given above, each eye tracking map from the three different national groups can be marked in a chart according to each analysis criterion. Two radar charts were made according to Analysis Criteria 1 and 2, respectively. For each analysis criterion, the viewing patterns were set as

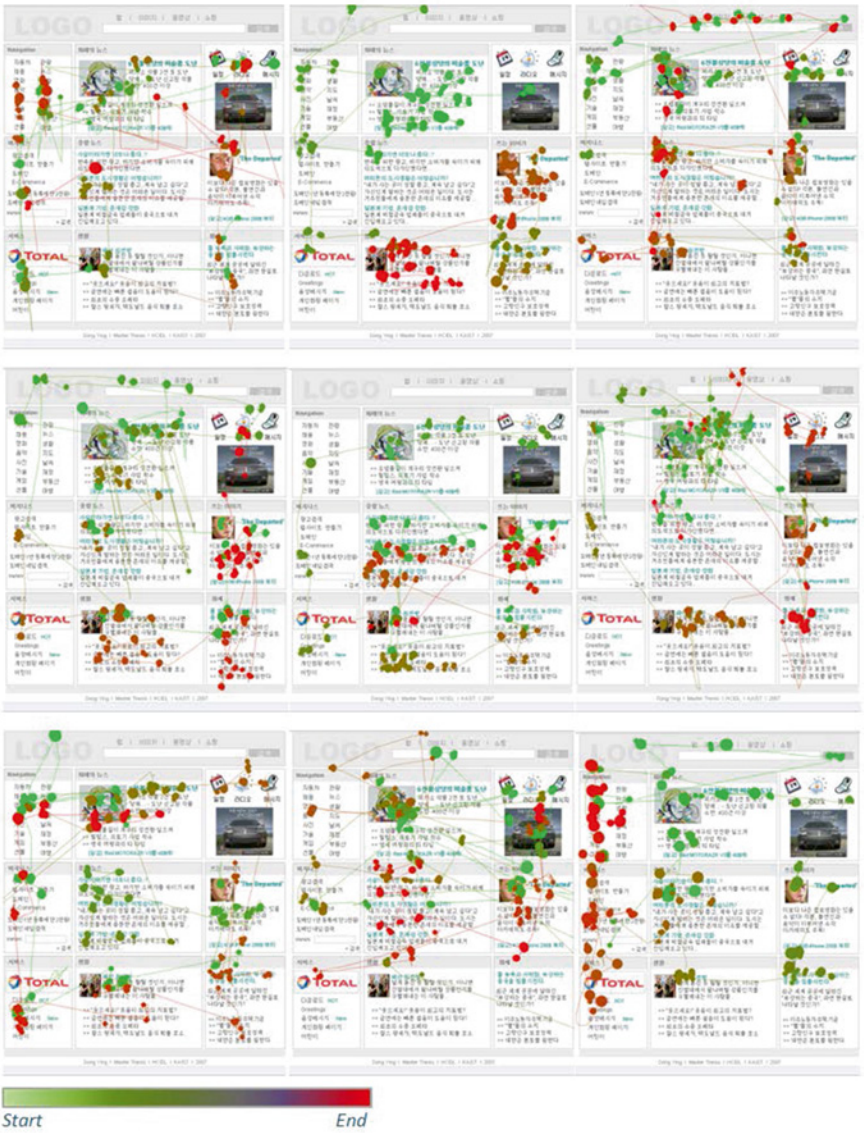

Fig. 9 Korean eye tracking map

an axis, and the axis was divided into several sections according to the number of people. In one national group, the people who showed the same viewing pattern are accumulated and marked in the relevant viewing pattern axis. In this way, the total number of a certain viewing pattern among the three groups can be compared.

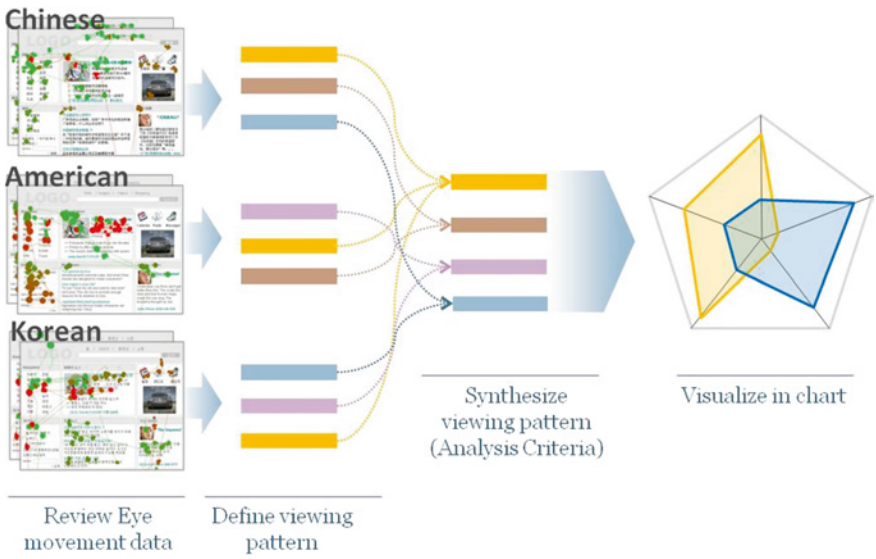

Fig. 10 Eye tracking map analysis procedure

Figure 11 shows viewing patterns mapped in a chart according to Analysis Criteria 1. Each group's results are marked on the viewing pattern axis. The results displayed in Fig. 11 indicate that each group has a moderately different viewing pattern that partially overlaps the others. For example, 7 out of 9 American participants tend to read the prototype page in sequential order, while few Chinese and Korean participants show sequential reading patterns. On the contrary, the Chinese and Korean participants are more likely to scan back and forth between page contents, and they are more likely to scan the page in a circular pattern. When we suppose that a Webpage is perceived as an image, we can imagine that the image is filled up with informative objects such as information items and/or information boxes, and the whole page can be perceived as a field. Holistically minded people have tendency to see the field as a whole, so they employ a strategy to perceive the Webpage by scanning across each information box. Scanning back and forth implies that Chinese and Koreans are not really reading carefully, but just randomly scanning the page. Since analytically minded people tend to detach objects from their background field, those people tend to focus on each piece of information one by one, and this behavior leads to a sequential reading pattern. Americans seldom scan without examining the details and rarely scan back and forth between contents. Americans are likely to focus on the page title and also likely to read the navigation, while few Chinese and Koreans do so. Analytically minded people are inclined to think in categories, so knowing what kind of categories the Web site has would help them to perceive the Web site. The graph below clearly illustrates similarities and differences in the viewing patterns among these three groups.

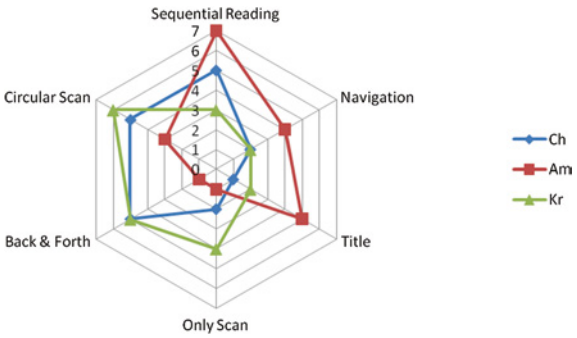

Fig. 11 Mapping viewing patterns according to Analysis Criteria 1

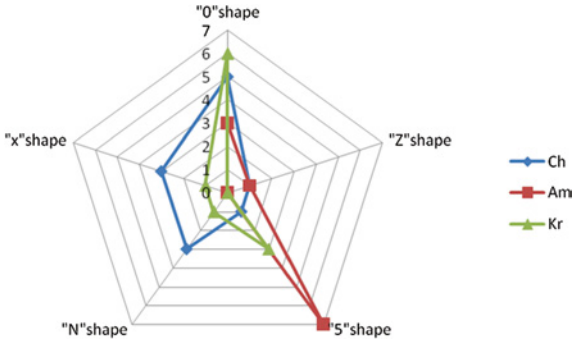

Fig. 12 Mapping viewing patterns according to Analysis Criteria 2

Figure 12 shows viewing patterns mapped in the chart according to Analysis Criteria 2. The chart illustrates that most Chinese and Korean showed a "0" shaped viewing pattern, while Americans showed a more "5" shaped eye movement on the page. "0" shape implies that Chinese and Koreans tend to scan the whole page which is similar to the circular scan above. Most Americans show a tendency to read from the center to the periphery of the page. Other viewing patterns in Analysis Criteria 2 do not seem to be significantly employed by a certain group.

7 Conclusions

Nisbett proposed that the thought patterns of East Asians and Westerners differ greatly and classified these differences as holistic and analytic. Holistically minded people have a tendency to perceive a scene globally; in other words, to perceive the context and field as a whole. They also tend to focus on the relationships between objects and the field, which means that they are more field-dependent. Analytically minded people have a tendency to perceive the object separately from the scene and tend to assign objects into categories. Analytically minded people are more field-independent.

In this study, Chinese, Koreans (holistic thought), and Americans (analytic thought) were recruited for the experiment. Findings from the analysis suggest that the Chinese, Koreans, and Americans employed different viewing patterns on the Webpage. The Chinese and Korean subjects showed more similarities to holistic thought, while Americans showed more similarities to analytic thought.

The present findings indicate that holistically minded people and analytically minded people have unique ways of perceiving the Webpage. The characteristics of perception reflect some aspects of Nisbett's proposition about cognition. It is suggested that the Webpage designer should be aware of the cognitive differences existing among holistically minded people and analytically minded people; accordingly, Webpage design must be carried out according to the target audiences' specific cognitive style to enhance the perception and usage of the Webpage.

7.1 Recommended Design Guidelines from the Study

This study primarily focused on revealing the relationship between Nisbett's cognition theory and Webpage perception. The different viewing patterns of these three groups of people indicate the potential influence on their Webpage usage, thus requiring that the Webpage should be designed to match the users' cognitive style to enhance the Webpage usability. By understanding Nisbett's theory and collecting and synthesizing of all the findings, this study thus proposes several recommendations for Webpage design.

For holistically minded people:

- To cater to a holistically minded approach to browse Webpages, which involves obtaining an overall big picture of the Webpage by scanning the entire page, content design should show the entire context of the Web site.
- Because holistically minded people tend to scan the entire page and show nonlinear scan patterns, the contents can be placed more freely on the page compared to when it is designed for analytically minded people.
- When designing a Webpage for holistically minded people, the harmony between the foreground and background as well as the relationship among all content areas should be taken into account. This guideline is derived directly from Nisbett's theory, although this study does not prove this.

For analytically minded people:

- The Webpage design should be as clear and simple as possible. Major categories and highlighted contents on the Webpage may cater to analytically minded people's usage. The Webpage layout should be clear enough to be read by users who focus on each information group.
- Because analytically minded people tend to employ sequential reading among areas and read from the center to the periphery of the page, the arrangement of all contents areas must be carefully considered.

- Category title and navigation items should be named as clearly as possible because analytically minded people tend to pay more attention to these items and gain an overall picture of the Web site from them.
- When designing Webpages for analytically minded people, efforts must be directed toward designing each content area. Independent content areas should be emphasized. This idea is taken directly from Nisbett's theory, although this study does not prove this.

7.2 Future Work

This study is only an initial step toward defining the relationship between cognitive style and Webpage perception. Most of the effort here was allocated to the eye viewing pattern itself. Consideration of other variables on the Webpage was comparatively weak. For example, different Webpage lengths could result in different viewing patterns. However, this study explored a complete analysis process which can be used or referenced in future studies.

In addition, to make this study more practical, the recommendations proposed herein must be examined. For further study, more specific Webpage design issues should be addressed, such as defining the relationship between cognitive style and Webpage layout design.

Acknowledgments In acknowledging the various kinds of help and support I have received in the process of this research, I would first of all like to mention with deep gratitude Professor Kun-Pyo Lee, who had cared and supervised my work since the beginning of this research. Very special thanks to my senior KiTae Oh, who spent time in developing analysis software for my experiment. I am also very grateful to KAIST (Korea Advanced Institute of Science and Technology), which provides me financial support in studying and conducting researches. Thanks for editor and reviewers' comments on paper revision. I appreciate all above efforts to make this chapter to be published successfully.

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Part II
Application

Backrest Designs in Meeting Chairs

Toshio Matsuoka, Hirokazu Kimura, Hiroyuki Kanai, Fusao Yasuda and Masaki Matsumoto

Abstract Our purpose was to design the backrest of meeting chairs. We investigated how a backrest structure influenced the sitting comfort of a meeting chair. Sensory values of sitting comfort were measured through a paired comparison method and body pressure distributions. Subjects were selected from a consumer group and an expert group who worked at an office furniture company. Body pressures and contact areas between the human body and the chairs were measured. As a market test, 663 people sat on the sample chairs. The sensory evaluation results were examined through a factor analysis. The results were as follows: (1) The sitting comfort evaluated by the consumers had a positive correlation with those of the experts. (2) Two factors were common and significant in evaluating sitting comfort of meeting chair in both groups: "soft at back" and "not tiring." (3) The adjectives related to "sitting comfort" had a relationship with the body pressure distribution and the bending properties of the backrest. (4) The "sitting comfort" of the meeting chair could be predicted by its physical properties. (5) The results of the market test conform with the results of the sensory test.

Keywords Sitting comfort • Sensory evaluation • Body pressure distribution • Factor analysis

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_12,

1 Introduction

Consumers are paying closer attention to the *kansei* elements of products, in addition to their functionality. Office furniture, which is essential for many jobs, requires many functions. While functions such as portability and storage are valued in meeting chairs, *kansei* elements such as "sitting comfort" are also important. Backrests and seats are the important parts of chairs that directly touch our body, so their designs are important not only as functional elements but also as *kansei* elements. Therefore, we have developed some chairs by focusing on their "sitting comfort." Many studies have reported on the design of office and meeting chairs [1–3]. Obata et al. reported on the tendency of office chairs in postures and body pressure distribution. Matsuoka et al. reported on how a transverse radius of cushion can influence the sitting comfort of OA chairs. However, little attention has been paid to the relationship between backrest structure and "sitting comfort" during the design of meeting chairs. The subject panels in many sitting comfort studies consisted of only consumer groups or expert groups [4–6]; therefore, the relationship between the two groups was not investigated. Based on the relationship between the two, chair manufacturers could more efficiently develop sitting comfort the *kansei* element for consumers. Our primary goal was to develop a meeting chair that incorporated *kansei* elements. We studied methods for predicting the sitting comfort of chairs by through pressure distributions and other instrumental measurements for the efficient development of chairs. To obtain a basic knowledge of the predicting method, we investigated how a backrest structure influenced the sitting comfort through sensory evaluations and by measuring body pressure distributions. We also investigated the relationship between experts and consumers in regard to sitting comfort. A market test was also performed to verify of the validity of these methods.

2 Methods

2.1 Samples

We used five meeting chairs (Fig. 1) whose shape and size of frame were the same, and only backrest structures were different. Each backrest of the chairs was made with polypropylene or olefin resin, and the hardness of each backrest was different. Details of the backrest are shown in Table 1.

2.2 Sensory Tests

Sitting comfort of each chair was judged by tactile sensation using the Scheffe-Nakaya's paired comparison method. Evaluation adjectives related to "sitting comfort" were "soft (at seat, at back)," "fitted (at seat, at back)," "oppressive (at

Fig. 1 Meeting chair. Sample chairs were composed of a same frame and a same seat, and only backrest materials were different

Table 1 Details of the backrest

Symbol	Material	Hardness by durometer
No. 1	Olefin	55
No. 2	Polypropylene	66
No. 3	Olefin	46
No. 4	Olefin	42
No. 5	Olefin	56

seat, at back)," "elastic at back," "stability at back," "tired," "stability of posture," "comfortable," "easy," and total judgment. These adjectives were chosen based on previous studies [3, 5–7]. Before sensory tests, these adjectives were described in Japanese, and the answers were obtained in Japanese. Ten pairs of test samples were randomized and presented to subjects. For evaluating sitting comforts, subjects sat on each sample for 2 min or longer and could sit on each chair by repeating. Sitting comfort of those five chairs was also evaluated using the ranking method. Subjects were 6 males and 1 female in the consumer group who worked at an office, and on what kind of chair they were sitting every day. And 17 males and 7 females in the expert group who worked at an office furniture company. Developers of these meeting chairs have been excluded from the expert group; therefore, the expert group did not know the details of the samples.

We calculated statistically mean preference scores of chairs for each adjective and used the factor analysis to study the sitting comfort, and the technique of the information theory [8] to study the evaluation structures of the sitting comfort from the calculated mean preference scores. The information theory to clarify structures of a response for stimulation was used for analyzing the hand evaluation of fabrics [9] or the evaluation of sitting comfort [7].

Transmitted information $T(X;Y)$ is that how much efficiency is transmitted into the received signal from the input and is defined by Eq. (1).

$H(X)$ is the entropy of the input to the channel or the input signal, $H(Y)$ is the entropy of the output of the channel or the received signal, $H(X;Y)$ is the joint entropy of input and output or co-occurrence information, $HX(Y)$ is the conditional

entropy of y or the additional information, and $HY(X)$ is the conditional entropy of x or the equivocation. Each entropy is calculated as follows:

$$T(X;Y) = H(X) + H(Y) - H(X;Y) \tag{1}$$

$$H(X) = \log_2 n \tag{2}$$

$$H(Y) = \sum_{j=1}^{n} P_j \cdot \log_2 \frac{1}{P_j} \tag{3}$$

$$H(X;Y) = \sum_{i,j} P_{ij} \cdot \log_2 \frac{1}{P_{ij}} \tag{4}$$

$$H_X(Y) = H(Y) - T(X;Y) \tag{5}$$

$$H_Y(X) = H(X) - T(X;Y) \tag{6}$$

where n is the number of signals of samples. P_i is the probability of state i, and P_{ij} is the transition probability to state j.

2.3 Physical Properties

Bending properties of the backrest were measured in accordance with the determination of strength and durability by JIS S 1203. Details of the method are shown in Fig. 2. For measurement of displacements of the backrest as bending properties, legs of chair were fixed in a ground, and a load of 950 N was put on a seat. Then, we pressed a point at position from the upper at 100 mm and at the center of left and right of the backrest by any load of 200 N to 400 N. A change of position of the point in pressing direction and that of top point were measured. We defined the position of their point as the displacement and their top point as the deflection.

2.4 Body Pressure Distribution

Contact areas and pressure distributions between their bodies and a seat or a backrest of chairs were also measured by using the tactile sensor system (BIGMAT-2000, NITTA Co., Ltd.). The system consists of mats that are made up of thin flexible sensors, and the sensors were set on a seat and a backrest. Measuring area was 430 × 480 mm (2,064 points) for each mat. Subjects were 7 males in the consumer group.

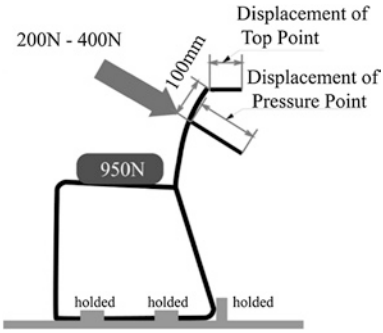

Fig. 2 Measuring method for bending properties of backrest

2.5 Market Test

The preference survey of the five above-mentioned chairs was performed at an exhibition show held in Mie Prefecture. For 663 people who were the visitors of the show, the five chairs were shown and sat on each chair. After sitting on five chairs, they made to choose one chair which it was comfortable to sit on as a meeting chair.

3 Results and Discussions

3.1 Subjective Measurements

From the results of the paired comparison method, we tested their judgments by the number of circular triads and the coefficient of consistency for each subject. Therefore, all subjects had their ability of judgment.

We calculated statistically mean preference scores of five chairs for each adjective and tested the main effect and combined effect of theirs. For the consumer group, main effect of "soft (at seat, at back)," "fitted at back," "oppressive at back," "elastic at back," "tired," and "easy" were significant at 5 % level and combined effect of all the adjectives were not significant at 5 % level. For expert group, main effect of all the adjectives except "stability" were significant at 5 % level and combined effect of all the adjectives were not significant at 5 % level.

Mean preference scores of each adjective evaluated by the consumer group are shown in Fig. 3 and those by the expert are shown in Fig. 4.

For the consumer group, sample No. 4 was evaluated as soft at back, fitted at back, elastic at back, and easy and No. 2 was as hard at back, oppressive at back, tired, and not easy. For the expert group, No. 4 was evaluated as soft at back, fitted at back, elastic at back, comfortable, and easy and No. 2 was as hard at back, not elastic at back, oppressive at back, tired, uncomfortable, and not easy.

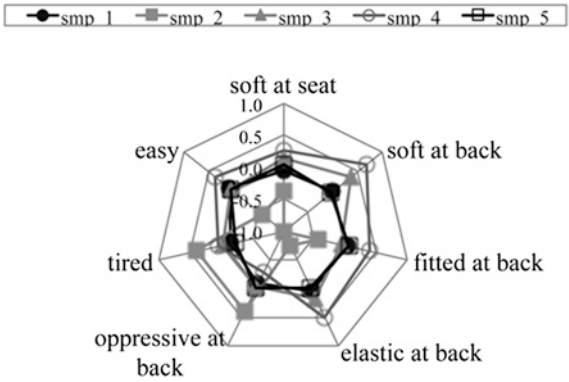

Fig. 3 Mean preference scores by the consumer group

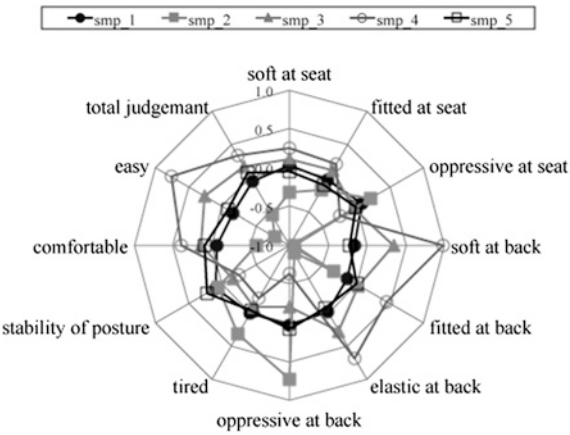

Fig. 4 Mean preference scores by the expert group

The results of the two groups were similar, though the experts judged more clearly than the consumers. Mean preference scores of seven adjectives evaluated by the consumer group had a positive correlation with those by the expert. For adjectives except "tired," there were significant correlations at 5 % level between mean preference scores of each group.

From the results of ranking method shown in Fig. 5, for the two groups, No. 4 was evaluated as high priority and No. 2 was as low. Therefore, we found that the backrest structures influenced sitting comfort of meeting chairs.

3.2 Factor Analysis

The sensory evaluation results were also examined by factor analysis. We obtained the factor matrices using the principal factor solutions without repeated

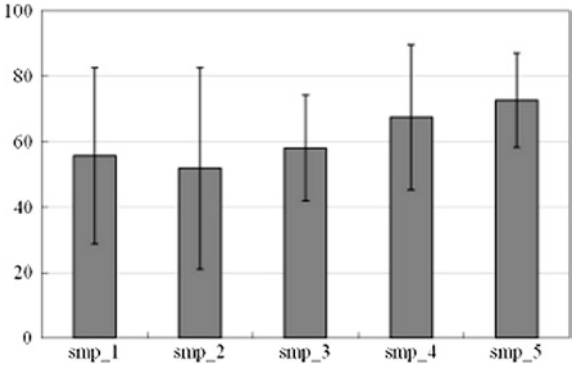

Fig. 5 Mean preference scores evaluated by ranking method

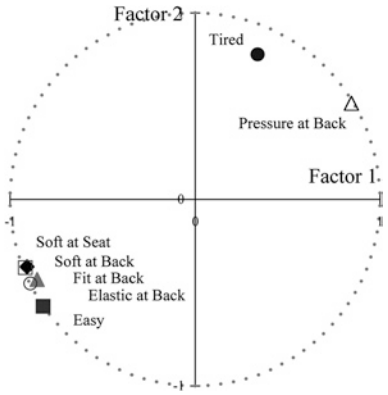

Fig. 6 Factor loadings of each adjective for the consumer group

assumption of communality, and the results of factor matrices were rotated using the varimax method.

From the results of factor analysis for the consumer group, two common factors were obtained (Fig. 6). Factor 1 is related to "soft at back," "fitted at back," "elastic at back," and "easy," and factor 2 is related to "tired" and "oppressive at back." It was found that the consumer evaluated sitting comfort using two adjectives, "soft at back" and "not tiring."

From the results for expert group, two common factors were obtained (Fig. 7), namely factor 1 is "not tiring," and factor 2 is "soft at back." Therefore, for the two groups, two factors—"soft at back" and "not tiring"—were common and significant in evaluating sitting comfort of meeting chair, whose backrest structure only was changed.

Figure 8 shows the factor loading scores of each chair evaluated by the consumer group (black symbol) and the expert group (gray symbol). It can be seen that No. 4 chair was evaluated as soft at cushion, and No. 2 chair was as tiring. The results of the two groups were very similar.

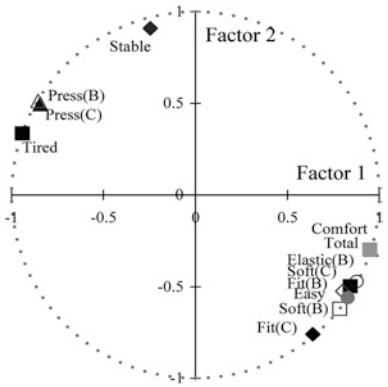

Fig. 7 Factor loadings of each adjective for the expert group

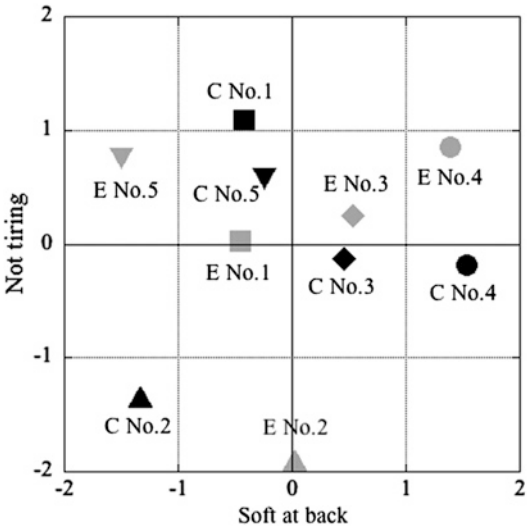

Fig. 8 Factor loading scores. *C* consumer, *E* expert

3.3 Body Pressure Distribution

We examined the standard deviation in the contact area of each sample, for excluding the influence of the individual variation. Figure 9 shows the result of the contact area between the backrest and the human back. As shown in Fig. 9, the contact area of No. 4 was the largest and that of No. 2 was the smallest. When the contact area at the backrest was large, the upper part of the body was supported by the backrest. So we examined the load ratio of backrests to seats. Figure 10 shows the load ratio of theirs. No. 2 was the lowest in sample; therefore, the backrest of

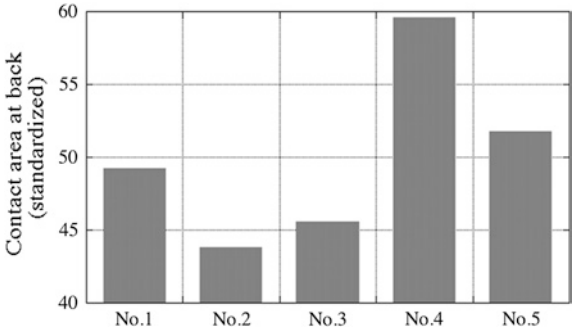

Fig. 9 Contact area of the backrest

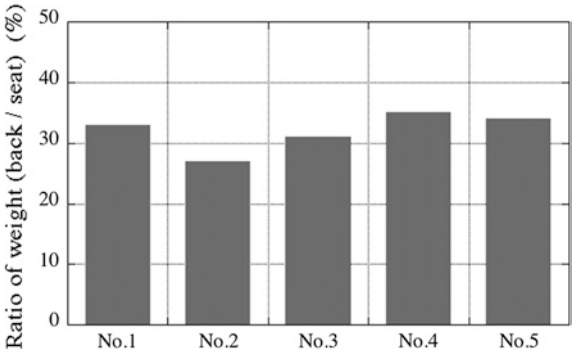

Fig. 10 Load ratio of seats and backrests

No. 2 was not used for sitting. We found that the backrest structures influenced the body pressure distribution between their bodies and backrests.

3.4 Correlation Between Sensory Evaluations and Body Pressure Distribution or Physical Properties

The correlation coefficients between sensory values and body pressure distributions were examined. The contact area at the back was closely related to "fitted at back" and "elastic at back," and the pressure at back was related to "tired" in the two groups. It was found that the adjectives "fitted at back" and "elastic at back" were judged by the contact area at the back, "tired" was evaluated by the pressure at the back. The displacement and the deflection were closely related to "soft at back," "fitted at back," and "easy."

We found that the body pressure distribution or physical properties had good correlation with sitting comfort of meeting chairs. The sitting comfort could be predicted by body pressure distribution or physical properties.

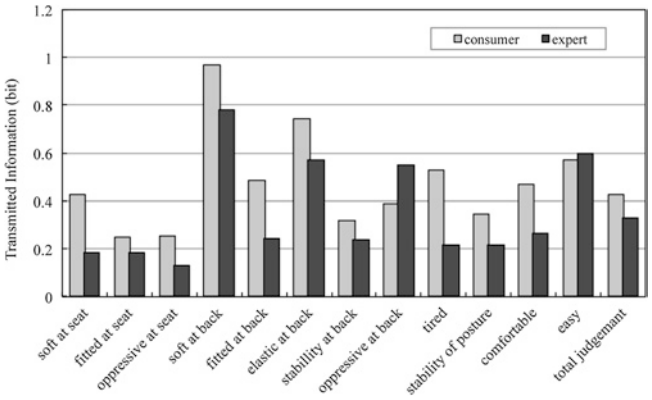

Fig. 11 Transmitted information of each adjective

3.5 Transmitted Information

Transmitted information calculated by the result of sensory evaluation is shown in Fig. 11. The transmitted information of consumers tended to be larger than those of experts. Therefore, we considered that experts group could evaluate sitting comfort of meeting chairs using the small amount of transmitted information.

3.6 Market Test

The results of market test for 663 consumers are shown in Fig. 12. No. 4 was the most preferred, and No. 2 was not most preferred. No. 4 was evaluated as soft at back, fitted at back, elastic at back, and easy by the sensory test for consumer and expert, and No. 2 was as hard at back, oppressive at back, tired, and not easy by the sensory test for consumer and expert. The results of market test have a correlation with the results of body pressure distribution. The contact area at the back was closely related to the preference of consumers.

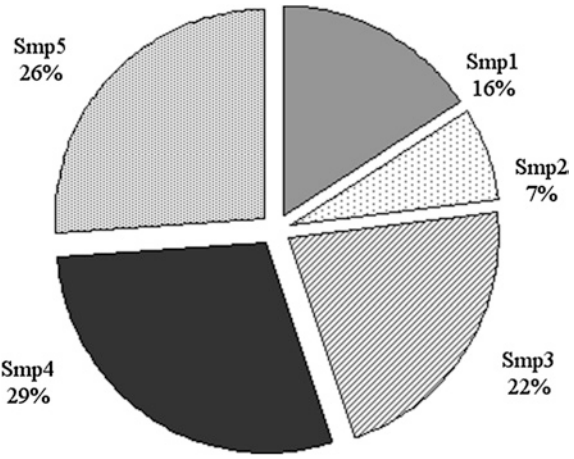

Fig. 12 Results of the market test

4 Conclusions

A backrest structure was investigated to determine its influence on sitting comfort thorough sensory evaluations and body pressure distributions. We also investigated the relationship between experts and consumers with regard to sitting comfort. The results were as follows:

1. The material of the backrest influenced the body pressure distribution and the sitting comfort of the meeting chair.
2. The sitting comfort, as evaluated by consumers, had a positive correlation with those of the experts.
3. Two factors were common and significant in evaluating the sitting comfort of meeting chair in the two group: “soft at back” and “not tiring.” Only the backrest structures were changed.
4. The adjectives related to “sitting comfort” had a relationship with the body pressure distribution and the bending properties of the backrest. The “sitting comfort” of the meeting chair could be predicted through its physical properties.
5. The expert group could evaluate the sitting comfort of the meeting chairs by using a small amount of transmitted information through sensory evaluation.
6. The results of the market test conform with the results of the sensory test.

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Branding Luxury Through Affective Value Case of Swiss Watch Industry

Shinichiro Terasaki and Shin'ya Nagasawa

Abstract This study focuses on affective value as the key to luxury brand building. Products that invoke affective value imply craftsmanship, history and endorsements of brand personalities that define these items. We cannot commercialize this invisible value, regardless of the delivery of affective value, through a combination of various media such as magazines and selective distribution. In this study, case of the Swiss watch industry is explored to illustrate the communication strategy of affective value, which will be applicable to manufacturers that have unique technologies, but lack the effective communication of affective value. Swiss watchmakers used to emphasize the precision of their wristwatches; after the Quartz Shock, they began to communicate affective value so as not to directly compete with Japanese precision watches. This chapter concludes that it is indispensable for luxury watchmakers to communicate affective value in an exclusive manner to imply rarity-the key for creating customer appetite for affective products.

Keywords Branding • Affective value • Luxury • Watchmakers

1 Introduction

The rapid industrialization and technological progress in emerging economies have enhanced the worldwide commoditization of both services and products. Even leading global companies such as Sony, Sharp and Panasonic are losing their competitive advantage due to this rapid industrialization. Twenty years ago, such a drastic and rapid change in the business environment was unimaginable. For a

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_13,

long time, Japanese manufacturers emphasized the excellence of their products' functional features in their marketing activities while losing customer share, given the increasing needs of emotional appeal to today's experienced consumers.

Compared to Japanese makers, European luxury brands such as Hermès and Louis Vuitton have sustained distinguished reputations and have successfully survived intense competition for over a century. We assume that the core value of these brands is not only in their functional benefits but also in their affective value, thereby not having to compete on price. In fact, many researchers argue that luxury has a high "ratio" of intangible value to price [1–4].

The strategies of European luxury brands are unique and differentiated in the market place. For example, a G-Shock watch is functionally far superior to most luxury watches: It is more precise and directly shows the time with a digital face. G-Shock differentiates their products from competitors through color, material and design variations, even though these physical features are easily copied. However, some consumers are willing to pay a premium for authentic Swiss-Made mechanical watches. What accounts for the enormous differences between affective products and ordinary ones? Why do European luxury brands successfully appeal to experienced consumers? The following two hypotheses attempt to answer these questions: (1) consumers are attracted by intangible facets of affective products and (2) luxury brands are skilled at communicating affective value to consumers.

To support the validity of the aforementioned hypotheses, consider the following argument made by the ex-president of Louis Vuitton Japan, which has maintained high profitability by providing affective products over a century. Kyojiro Hata insists that in addition to efficient business processes, Japanese makers should attach added value to their products to prevail over international competition: This value is not simply quantified but represents an affective appeal to customers [5]. This argument illustrates the importance of attaching affective value to products to make them more appealing to customers.

According to Atsushi Osanai, an ex-employee of Sony and an Associate Professor at Waseda University, Sony previously emphasized the superior functional features of their products compared with Apple. Sony's press releases, however, are currently similar to Apple's and include more comments describing the affective aspects of their products rather than their functions [6]. This implies that affective value communication is essential in contemporary marketing activities.

This study examines Swiss watchmakers to illustrate their scheme of affective value communication with customers to promote their brands.

2 Literature Review

2.1 Overview of Luxury Industry

Before the 1980s, luxury business used not to introduce modern expertise of business management because most luxury brands had been operated as a family business.

Table 1 The scope of the luxury goods and services industry [7]

Luxury brand/service industry	Apparels and accessories
	Jewelry and watches
	Leather goods
	Cosmetics and perfumes
	Wines and spirits
	Automobiles and air transportation
	Hospitality and concierge
	Selective retailing

However, the scope of the luxury industry has been quite diversified particularly after the late 1980s when luxury conglomerates started to be formed: LVMH was born in 1987 and so was Richemont in 1988. The figure below visualizes the overview of the current luxury industry (Table 1).

According to Table 1, luxury brand/service industry is divided into eight categories, and luxury watches are categorized as "jewelry and watches." Since many jewelers are, in fact, watchmakers as well: Cartier and Van Cleef & Arpels, for example, it is reasonable to combine watch and jewelries in one category.

In this research, we analyze the affective value communication in luxury watchmakers.

2.2 Luxury Watches as Affective Products

This study examines luxury watchmakers in Switzerland. Originally, the primary value in Swiss watches is functionality to show time precisely. However, the importance of this value significantly decreased along with technological development of wristwatches and globalization. Substitutes such as "Made in Japan" quartz and digital watches had threatened its existence and values particularly during the 1970s and the early 1980s. In fact, many Swiss watchmakers went into a decline particularly in the 1970s due mostly to Quartz Shock brought by Seiko.

In contrast, Vacheron Constantin and Jaeger-LeCoultrer, for instance, were able to survive even in this miserable time by incessant communication of affective value. Yutaka Nishimura, a president of Richemont Japan, pointed out that the key success factor in luxury business derives from the maximization of luxurious feelings and added values that come from histories, endorsements and shopping experiences [8].

Vigneron and Johnson [9] identify five values of luxury: (1) Conspicuousness, (2) Uniqueness, (3) Quality, (4) Extended-self and (5) Hedonism. The former 3 can be called as non-personal-oriented perception, and the latter as personal-oriented perception that could be difficult to assess numerically because of the affective nature. Particularly, Hedonic value of luxury overlaps affective value because it encompasses, for instance, intrinsic enjoyment and satisfaction [10], sensory gratification [11], and sensuality [12]. As such, luxury goods can be regarded as affective products in this research.

2.3 Luxury Strategy in Mechanical Watches

Several studies related to luxury watches have been made especially on business historians who narrate the story of mechanical watch industry. Giacomel [13] provides an overview of the mechanical watch industry, particularly in Japan, and traces its historical development from consumer portraits to luxury watches. Donzé [14] writes the historical development of the entire Swiss watch industry, referring to the "Quartz shock" in 1969 when the industry suffered serious recession. Although studies above are valuable to understand the industrial structure, references associated with business management are needed to analyze the secrets of the Swiss watch revival.

Carcano and Ceppi [15] explore the contemporary challenges for Haute Horlogerie, considering market penetration strategies not only in mature market place, but also in emerging economies. This study illustrates the comprehensive analyses of luxury watch industries from the angle of business management. However, there are still few studies that deal with case studies of luxury watchmakers in comparison with luxury fashion brands.

After a comprehensive study of the luxury industries by Chevailier and Mazzalovo [16] and Kapferer and Bastien [17], Hoffman and Coste-manire [18] explores luxury watches as part of their research. Besides the limited literatures on luxury watch industries, it seems little findings about the process of affective value communication with customers in luxury watchmakers. Concerning marketing promotion, significant difference is found between watch and jewelry and fashion and leather goods: the marketing communication of watches is craftsmanship-driven and that of fashion and leather goods is fashion-driven [19]. For fashion and leather goods, the influence of designers is much larger than watch and jewelry brands. The innovation of fashion and leather goods mostly depends on designers; Marc Jacobs in Louis Vuitton, Gianfranco Ferré in Christian Dior and Tom Ford in Gucci, for example. Instead, designers are mostly "unknown" in watch brands, for such brands promote craftsmanship rather than cut-edging fashion. Hence, it must explore the communication strategy of luxury watches to expand the scope of luxury brand management.

In this chapter, the case of the Swiss watch industry will illustrate how Swiss watchmakers can successfully manage their affective value of their products to make the tight engagement with customers. This would provide tips with companies struggling to avoid needless and intense price competition in the contemporary market.

3 Swiss Watch Industry

3.1 Industrial Structure and History

Swiss mechanical watch and clock-making industry underwent rapid expansion during 1770–1786, whereas its advantage was threatened by emerging technology. In the middle of the twentieth century, when Seiko, a Japanese watch

Table 2 Complementary roles of advertising and public relations for luxury goods [24]

	Advertising	PR
Audience	Large	Limited
Good for	Awareness	Preference

manufacturer began to produce the "Quartz," a high-precision watch, the Swiss mechanical watchmakers, including many machine-tool factories, voluntarily went out of business. The name of the first commercialized quartz watch is Seiko Astron. Quartz was superior to mechanical watches as it was far lighter, inexpensive and precise. If you were to purchase a Swiss mechanical watch, such as Patek Philippe, you would be warned that it loses 2 min every year [20]. In this instance, functional benefits such as price and performance prevailed over the competition.

To counter the falling demand, the Swiss mechanical watchmakers focused the strategy toward affective value communication. For instance, companies tried to deliver affective values such as superior craftsmanship, history and authenticity to customers. Unlike technological excellence that is tangible, visible and palpable [21], affective value is intangible and more difficult to communicate, thereby building competitive advantages over the rivals.

Currently, the mechanical watch industry has returned to be one of the key drivers of Swiss national economy. Leading brands such as Zenith and Tag Heuer conducted significant public relations activities, delivering affective aspects of the products through the appropriate media. According to a communication and brand heritage manager in Swiss watchmaker, the use of brand ambassadors began since the 1960s as the influence of mass media expanded [22]: Even though the brand had ambassadors such as racers, the brand could not use them systematically as a promotion tool. Such PR activities had started just before the Quartz shock, and wristwatches had no emotion before the Quartz Shock [23].

The reason to choose PR rather than advertising is that advertising is adept at building brand awareness for mass audiences, while PR is suitable for communicating to selective audiences who are interested in affective products [24]. Hence, PR generally works well for affective products like Swiss mechanical watches. For Swiss watchmakers, reaching thoroughly is more important than reaching widely. The complementary roles of advertising and PR for value-added goods are shown as Table 2.

The total value of Swiss watch exports stood at CHF17 billion in 2008, compared with CHF10.2 billion in 2000 and CHF4.3 billion in 1986 [25] even though the number of exported watches has continuously decreased since 1993 [14]. This suggests that Swiss watches had focused on luxury watch making rather than the production of ordinary functional watches.

In contrast, the share of Japanese watches shrunk from 21 % in 1994 to 11 % in 2009 [14]. Seiko was, in fact, the most successful watchmaker in product innovation, whereas such technological rarity was strongly replaced by communicational innovation lead by Swiss brands. This implies R&D related rarity is not enough for sustainable growth of watchmakers.

Fig. 1 Musée d'Horlogerie du Locle [26]

3.2 Attributes of Luxury Watch Brands

Figure 2 indicates the positioning of luxury goods in the prestige market. In this diagram, brands are divided according to the following two aspects: the degree of prestige and accessibility. This chart is based on the following two studies: Vigneron and Johnson [9] 's "Defining Three Levels of Prestige," and another one is Alleres [27] 's "A Hierarchy of Luxury Goods Products." Vigneron and Johnson [9] regard luxury brand as the most prestigious brand within prestige brands followed by premium and upmarket brands (Fig. 3). Alleres [27] divides luxury brands into three categories: exclusive luxury, intermediate luxury and democratic luxury in accordance with social hierarchy: elite, professional and middle class (Fig. 4).

As shown in Fig. 2, Swiss watches, excluding some fashion watch brand such as Swatch, cover the exclusive and intermediate luxury, for some luxury watches such as Piaget prices over, in some cases, 100 million USD that is far more expensive than Rolls Royse.

The target of Swiss luxury watches is, therefore, fairly exclusive. In fact, the average price of leading models equipped with "tourbillion mechanism" is largely over 100 thousands USD except for Frederique Constant who sells a watch with tourbillion named Slim Line tourbillion manufacture at approximately 40 thousands USD, and many models have a price equivalent to that of a luxury automobile. Figure 2 is the mixture of the above two theories into one chart to describe luxury brands more concretely and precisely.

In the 1990s, the Swiss watch industry decided to concentrate on the production of high-end, luxury timepieces, which generally sell for much higher prices. China may be the world leader in terms of volume (80 % of global output), but it has

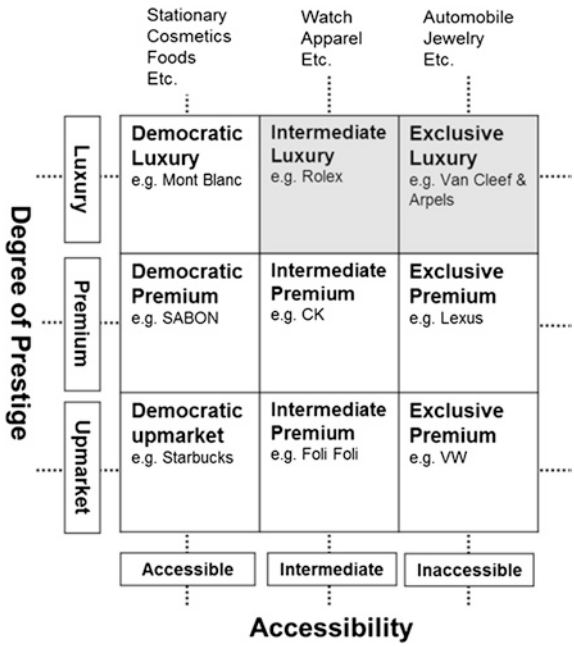


Fig. 2 Positioning of luxury watch brands by prestige and accessibility

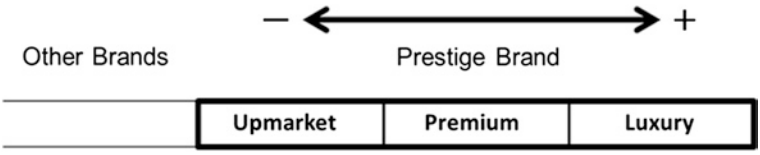
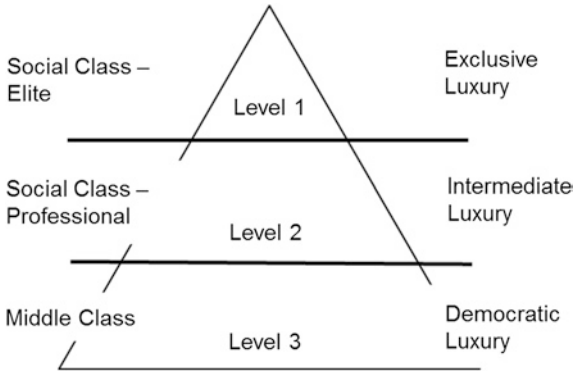


Fig. 3 Defining three levels of prestige. *Source* Vigneron and Johnson [9]

Fig. 4 Hierarchy of luxury goods products [27]



a long way to go before it can supplant Switzerland as the top exporter by value (see [25]). Kapferer and Bastien [17] explain the reason that customers accept this price range. They insist that customers of luxury brands pay money not only for its functional value, but also for its charm and guarantee of authenticity. The flaw such as inaccuracy of time could be a charm and guarantee of authenticity [20].

It is evident that Swiss watches have a worldwide reputation for high quality, unrivaled manufacturing, know-how and technology. A law "regulating the use of the name 'Swiss' for watches" was passed in 1971 setting out the minimum conditions that must be fulfilled before a watch merits the "Swiss-Made" label [28].

Presence Switzerland, a promoter of an authentic image of modern Switzerland worldwide, states that products with "Swiss" label is a sign to customers that they are buying a product of outstanding quality and reliability [25].

As a promotional strategy and law system indicate, a strong sense of pride and philosophy of being "Swiss" or "Switzerland" labeled brands account for a large part of its value, and the brand authorized to use the term "Switzerland" or "Swiss" is trying to emphasize those aspects. In fact, Web sites of Swiss watchmakers show exactly which feature of their brand they would like to highlight. As seen on the Web site of specialized watch companies such as Officine Panerai, Tag Heuer and Zenith, the primary emphasis is on their manufacturing technologies, brand origins and histories. This is unique feature of leading watchmakers and differentiates them exclusively from watches originated in fashion brand. Hermès watch is a typical example. Although Hermès occupies the top of the hierarchy in Luxury brands, the watch is less reputational compared to the privilege status of the bags. In Basel World, Hermès watch cannot share the booth of the primary floor where classical watchmakers occupy instead. Other similar examples are Fendi, Dior and Harry Winston. The core value of fashion brands usually derives from their designer and aspects of their products. On the other hand, the core value of leading watch brands roots in their craftsmanship and history, which connects customers emotionally with their brand. Customers of Swiss watchmakers thoroughly understand the manufacturing process, technology and history of the brand.

Also, Federation of Swiss watch industry illustrates the core values of Swiss watches. It says that the intrinsic value of the "Swiss-Made" label is the result of considerable efforts on the part of watchmaking companies. It also claims that they are ultimately responsible for maintaining their reputation, and they always cooperate together and provide the customer with the best of guarantees [28].

4 Case of World Watch Fairs

4.1 Overview

Switzerland holds two major international watch and jewelry exhibitions every year: Basel World (Fig. 5) and Salon International Haute Horlogerie (SIHH). Basel World is an open exhibition, while SIHH is an invitation-only conference

Fig. 5 Basel World 2012 [29]

for professional guests. Here, we analyze the affective communications of Swiss watchmakers through these two watch conferences.

In Basel World, approximately 100,000 visitors from the industry, general customers and journalists from all over the world visit to see the latest timepieces. The fair attracts over 2,000 exhibitors, including almost all of major watchmakers in Switzerland. Swiss watchmakers utilize this event as a sales and communication channel because almost half of their annual business deal is done at this conference [30]. It indicates that Swiss watchmakers are willing to connect to a wide range of selective customers under a limited condition.

In SIHH, around 12,500 visitors (1/10 of Basel World) are strictly allowed to enter the place. The visitors will be retailers, watchmakers and designers, importers, exporters, collectors, distributors and industry professionals [31]. Compared to Basel World, the number of exhibitors is significantly limited: eighteen brands from Richemont Group, the second largest luxury conglomerate, such as IWC, Piaget and A. Lange & Söhne exclusively dominates SIHH. Richemont has an advantage over LVMH in the world watch exhibition in that Richemont can focus only on SIHH: LVMH needs to hold exhibitions two times: one is in Geneva correspondent to SIHH and the other one is in Basel World, which is economically disadvantageous. Some independent watchmakers such as Audemars Piguet, Roger Debuis and Richard Mille are allowed to attend SIHH, but this is highly exceptional. Unlike Basel World, accessible watch brand such as Tissot and Swatch are not available in SIHH, focusing exclusively on fine watchmakers with high price ranges. SIHH would be described as the place of privileged. SIHH severely restricts the visitors to make the exhibitors highly exclusive. In addition, Richemont does not join Basel World, the biggest "open" access world watch fair, to avoid Swatch Group [32] that has more diversified watch brands from accessible to inaccessible ones.

Kevin Lane Keller identified three most notable trade-offs in luxury marketers face; exclusivity versus accessibility; classic versus contemporary images; and acquisition of prospective customers versus retaining existing customers [33]. Richemont intends not to attend Basel World probably not to make the umbrella brands accessible, keeping them exclusive from ordinary visitors, even though they might scale back volumes and sales points. Carcano and Ceppi [15] points out that the key to exclusive scenario is to preserve firstly profitability and brand equity and then to keep growing revenues. Richemont follows this exclusive scenario better than LVMH and Swatch Group.

Readily due to the limited information of SIHH, Basel World only is analyzed as a case study from here.

4.2 Privileged Negotiation Spaces

Basically, there are two areas in the exhibit space in Basel World: global luxury brands based in Hall 1.0 and the "others." Certainly, Basel World is open to public, but there are some limitations to retain their brand status. For example, Hall 1.0 is available exclusively for fine watchmakers such as Rolex, Patek Philippe, Blancpain and Omega. Some fashion-origin brands such as Chanel and Gucci also share the space of the main floor, but this is an exceptional case. Brands who occupy Hall 1.0 can be regarded as the most reputational watchmakers. Although Seiko used to launch the booth in Hall 1.0, they lost the space in 2013 largely due to the domination of LVMH and Swatch Group. Thus, only privileged watchmakers are allowed to open the exhibitions in Hall 1.0 to remain exclusive.

Moreover, there are spaces for business talks and breaks in each exhibition booth available only for the invited customers. Detailed and careful attention to create the world of the brand identity could be recognized. For example, in the booth of Tag Heuer, special customers receive preferential treatment from the brand in the private room and have business talk face to face over a bottled drink with Tag Heuer brand logo. This could be an important element which helps to drive customers be more engaged in the brand. Thus, "exclusiveness" which is essential aspect of the luxury brand is secured. Jasmina Steele, international communication director at Patek Philippe mentioned that Basel World, offered them a privileged opportunity to welcome their partners, and he demonstrated a comparatively forward-looking stance on its participation next year [34].

In conclusion, Swiss watchmakers dominate exclusive negotiation places in Basel World, excluding "trendy" watchmakers originated in fashion and leather Goods. This environment implies the prestige status of Swiss watches that generates added values to validate the inaccessible price settings. In addition, special spaces are provided exclusively with VIP customers who are willing to purchase the latest timepieces much faster than the "others." This comfortable sales environment contributes to the customer engagement firmly and induces repeat purchases year by year.

Fig. 6 Gucci booth in Basel World 2012 [29]

4.3 Booth to Describe Brand Universe

Basel World provides watchmakers to have a great opportunity to display their timepieces at sophisticated environment with exclusive manner. Kapferer [2] points out that esthetic dimension of the products is utilized as an entrance barrier to create a distance or distinction between consumers and non-consumers. In Basel World, esthetic dimension of the products is enriched by the artistic visual merchandising at the booth to make visitors selective.

For the exhibitors, each booth is the space where customers take an education about the whole facets of the brands. Exhibition halls are no longer simple show rooms, but stages where clients have affective experiences and fantasy worlds (the name of the halls explicit this idea: hall of emotion, hall of experience, hall of dreams, etc.) [35]. For instance, Gucci recreates its craft center and displays the production process of its signature watch for women "bamboo watch" in the booth (Fig. 6). Since the language of luxury brands is mostly nonverbal [17], the emotional relationship with customers will not be created simply by words. Hence, this manufacturing space helps to describe the universe of Gucci, delivering the imagination of the manufacturing processes to the visitors.

Similar, but more elaborated presentation of the brand universe was seen in Bvlgari booth. The brand has had year-round contracts [36] with a hotel near the venue of Basel World so that it can create an extraordinary atmosphere of the brand and communicate it to customers without any interference from its competitors (Fig. 7). This year-round contract implied the exhibitors' positive evaluation for the event. As such, every visitor experienced the theme of the latest Bvlgari collection, and moreover, special spaces were exclusively provided with VIP customers.

Fig. 7 Bvlgari's booth near Basel World 2012 [29]

Bvlgari has conducted this communication before the acquisition by LVMH even though the brand's financial status had not been sound enough. More important is its way of doing things, its referents, its esthetic and its models of expression [17]. This suggests the importance of exclusive communication toward customers when selling affective products, sharing privileged experience with them. The affective communication has been applied in the way exhibitors create the appearance and atmosphere of their exhibition booth.

4.4 Short Summary

Considering the whole communication processes, luxury watchmakers make an engagement with customers through privileged merchandising places in a fairly exclusive manner. The mode of the Swiss watchmakers seems to be controlled based on the code of luxury communication. The difference between privileged negotiation space (Sect. 4.2) and booth to describe brand universe (Sect. 4.3) is the degree of the communication durability: The former focuses more on intensive communication at the booth, and the latter intends to last the relationship with customers with continuous brand communication as Bvlgari does. The secret booths are provided exclusively with VIP customers who are likely to be invited in the next year as well. It could not be available in the detailed information about the way to retain customers at the authors' field research. However, given the stable number of visitors in Basel World, the retention strategy works for most of the customers.

5 Implications and Research Limitations

This study attempted to identify the delivery of affective value in Swiss watch brands. The results indicate that it is important to add exclusivity to affective value communication: In the case of Basel World, for example, we can see the "manufactured" communication of exclusivity both in negotiation spaces and booths, to describe their brand universe.

Swiss watchmakers began to communicate affective value after the Quartz Shock so as not to compete with Japanese precision watches. Owing to their intrinsic affective nature, Swiss watchmakers successfully communicated craftsmanship, histories and celebrity endorsements, while deploying the crafted certification of Swiss Made. This warranty differentiated Swiss watchmakers from fashion-origin luxury brands such as Hermès, Fendi and Harry Winston, who cannot occupy booths in Hall 1.0 in Basel World, where Swiss watchmakers exclusively dominate.

Swiss watchmakers readily focus on the two largest watch fairs so as not to dilute their brand equity. As for luxury goods, reaching thoroughly is more important than reaching widely as mentioned in Sect 3.1. Through their domination of the primary hall, Swiss watches differentiate themselves from trendy fashion watches, impressing customers with the invisible facets of Swiss-Made timepieces. Moreover, some brands offer privileged spaces for VIP customers to let them be fully involved in the world of their brand. Each booth is also deployed as an educational site to thoroughly communicate the affective facets of their timepieces with the customers.

Overall, exclusivity penetrates the entire process of affective communication for Swiss watchmakers. Because their timepieces are not instantly consumed, luxury watchmakers must impress customers with something "special." This specialty is provided with the exclusive treatment of their customers.

This study has limitations that must be acknowledged and addressed. Further investigation is required to clarify the process of building the relationship with VIP customers. In addition, if possible, field research in SIHH would be helpful to explore the affective value communicated by the most exclusive brands.

In addition, the case of Swiss watchmakers is not applicable to commodities such as print chapter sold on the Internet. Some commodities cannot be associated with any type of affective value such as craftsmanship, history or endorsement, and consumers do not expect these values from these Goods. Companies should provide functional values or benefits such as affordable prices and instant availability when they are required to broadly deliver this value to consumers.

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Button-Sound-Quality Evaluation for Car Audio Main Units

Shunsuke Ishimitsu

Abstract Society widely appreciates the idea of sound being a normal part of a product's operation. As a result, much attention has been directed at designing various sounds that are treated as noise, such as automobile acceleration. Car drivers detect variations in the sound characteristics between different buttons of an audio system; e.g., the pitch, tone color, loudness, and duration. These characteristics can affect the desirability of both a car and its audio system. In this study, we evaluated the sound design of transient signals for 11 different button sounds. To accurately represent button sounds, one of the time–frequency representations, wavelet transform, which structure is similar to an auditory time–frequency resolution feature, is used. An impression was extracted using the semantic differential method, and the relationship between the representation of the wavelet transform and its sound impression was investigated.

Keywords Sound design • Button sound • Audio • Car interior • Wavelets

1 Introduction

Society recognizes the idea of sounds being a normal part of product operation. As a result, much attention has been directed at designing various sounds that are treated as noise, such as the sound of an automobile accelerating or a vacuum cleaner [1–3]. The mechanical sounds generated by the buttons of a car audio unit have been found to contribute to a user's perception of the car itself [4]. Drivers detect variations in sound characteristics, such as the pitch, tone color, loudness, and duration, between

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_14,

different buttons; these characteristics appear to have a psychological effect on the driver. The restful, lower sound generated by executive cars gives the impression that the button sounds are integral parts of the car's luxury status. As another example of the relationship between the quality of a sound and a person's perception of reality, it is possible that some of the characteristics previously thought to relate to the tactile sensations of striking a golf ball [5] are actually influenced more by the sound of the impact. Kuwano et al. [6] asked 10 subjects to rate sounds using seven-point adjective scales ranging "hard–soft," "sharp–dull," "refreshing–not refreshing," "powerful–weak," and "vivid–dead." Strong correlations were obtained between the subject's perceptions and the psychoacoustic metrics [7] of loudness and sharpness of the measured impact sounds. These metrics are widely employed in sound-quality evaluations and were also used in these two studies despite being developed for steady, continuous sounds. However, impact sounds are not steady and continuous. The features of these sounds are widely extracted via frequency analysis based on the Fourier transform. The analysis also assumes that the signal being analyzed is periodic and stationary. To accurately represent button sounds, it is necessary to analyze time characteristics as well as frequency characteristics; this is known as a time–frequency $(t-f)$ representation. Typical tools of analysis include the spectrogram, Wigner distribution [8], and wavelet transform (WT) [9]. The $(t-f)$ resolution features of a WT are characterized by a multiple structure with high-frequency resolution in the low-frequency range and high time resolution in the high-frequency range. This structure is similar to an auditory $(t-f)$ resolution feature. This method, used in applications in a wide range of fields [10, 11], performs analysis using the affine transformations (similarity transformations and translations) of a base function known as an analyzing wavelet (AW), whose distribution is localized in both time and frequency.

In this chapter, an impression was extracted employing the semantic differential (SD) method, and the relationship between the representation of a WT and its sound impression was revealed.

2 Time–Frequency Analysis

2.1 Wavelet Transform (WT)

A WT is used in multi-resolution analysis to match auditory $(t-f)$ resolutions. The WT is obtained by calculating the inner product of the signal $f(t)$ and AW $\psi(t)$ [12, 13]:

$$WT_f(b,a) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} \psi^* \left(\frac{t-b}{a} \right) f(t) \mathrm{d}t \quad (1)$$

Variable a is a scale parameter used in similarity transformations. Variable b is a shift parameter used in the translation of $\psi(t)$. The WT is initially expressed in the $(t-f)$ time–scale plane, but can be regarded as an approximation of the $(t-f)$ distribution using a time- and frequency-localized AW. We selected a Morlet wavelet in a preliminary experiment.

2.2 Experimental Condition

Eleven types of button for use in six car audio unit models were evaluated. Data were recorded in an anechoic chamber. Each button was pushed three times, and the sound was recorded with a microphone placed about 30 cm from the car audio unit. The sound made by pushing the button (push sound) and the sound made by releasing the button (back sound) are depicted.

2.3 Analysis Conditions and Results

Psychoacoustic metrics (such as the measurements of loudness and sharpness) are used to numerically represent the psychoacoustical features of hearing [7]. The ISO standard 532B relates to loudness for stationary sound. The metrics are widely employed in sound-quality evaluations and were also used in these studies [5–7] despite their having being developed for steady, continuous sounds. However, loudness is used to evaluate stationary sounds and cannot be adequately used to evaluate non-stationary sounds such as button sounds.

As a result, we decided to compare the time–frequency structure and the jury test score.

WT results for each main unit are shown in Figs. 1, 2, 3, 4, 5, and 6. Each figure includes the discrete Fourier transform (DFT) magnitude and the WT of push sounds and back sounds. Morlet wavelets were used as the AW.

Low-frequency button sounds tended to receive a high score in the jury test. As the sound frequency increased, the evaluation score decreased. Evaluation scores were also affected by the duration of the energy burst.

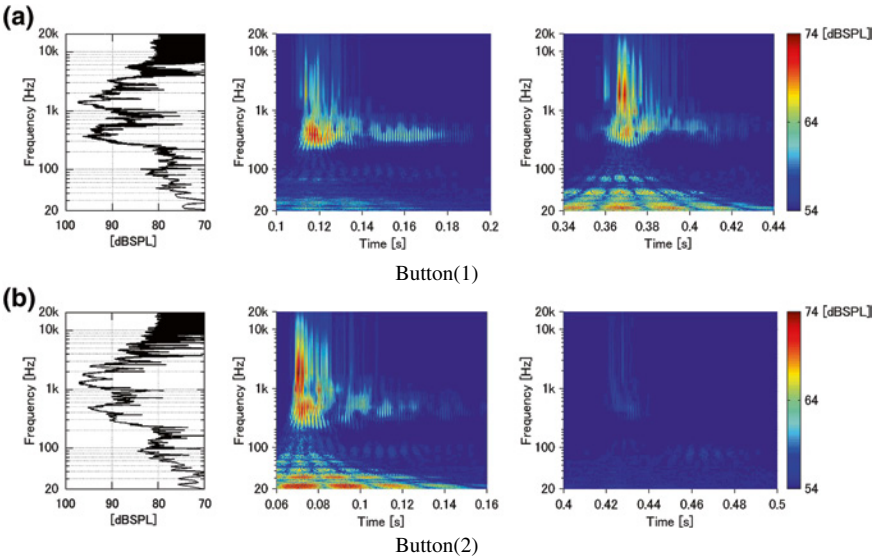


Fig. 1 Magnitude response of the main unit 1: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **a** Button (1). **b** Button (2)

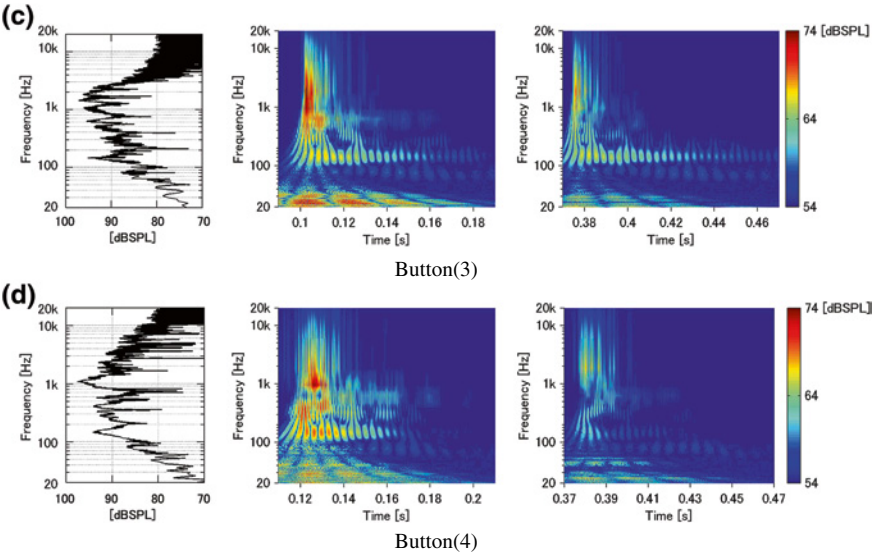


Fig. 2 Magnitude response of the main unit 2: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **c** Button (3). **d** Button (4)

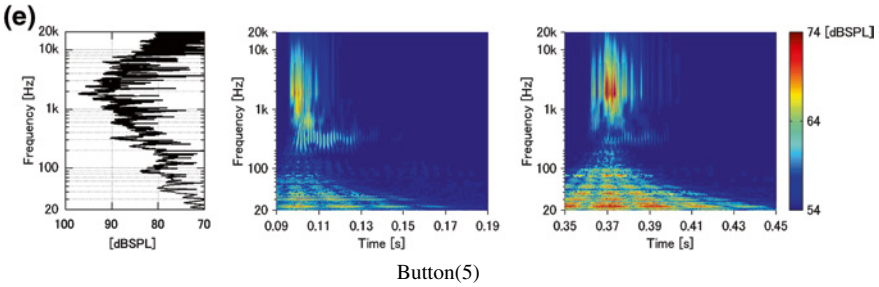


Fig. 3 Magnitude response of the main unit 3: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **e** Button (5)

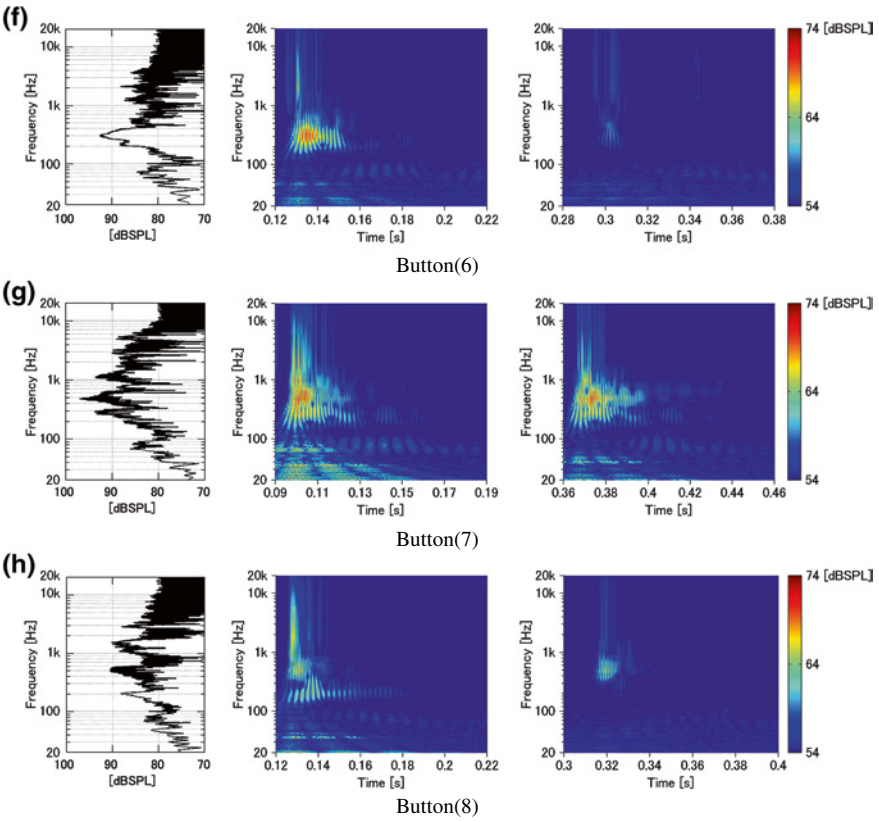


Fig. 4 Magnitude response of the main unit 4: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **f** Button (6). **g** Button (7). **h** Button (8)

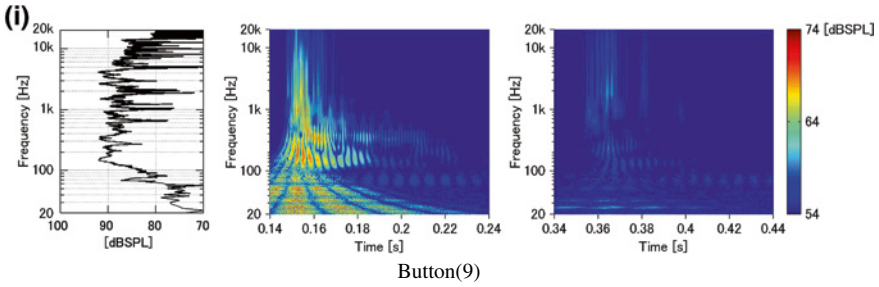


Fig. 5 Magnitude response of the main unit 5: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **i** Button (9)

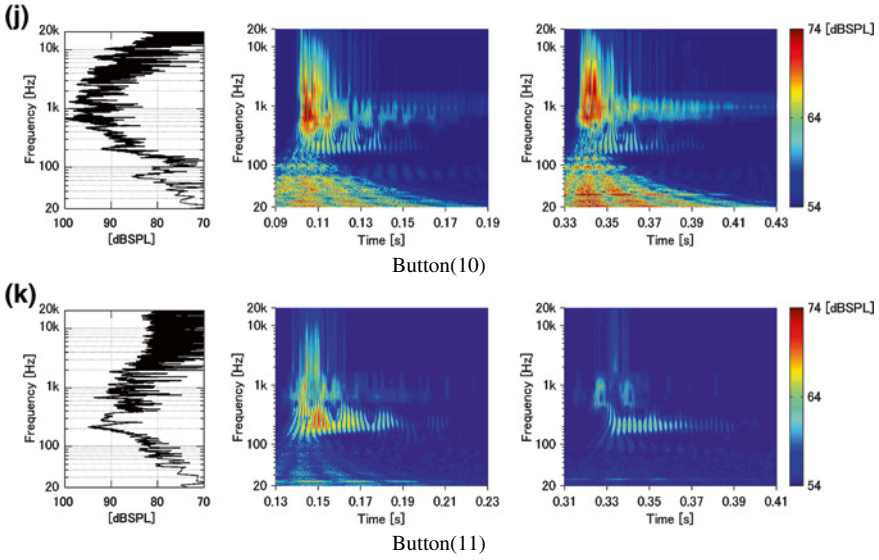


Fig. 6 Magnitude response of the main unit 6: (*left*), DFT of push and back sound; (*center*), WT of push sound; (*right*), WT of back sound. **j** Button (10). **k** Button (11)

3 Jury Test

3.1 Quantification of Psychoacoustics

"Loudness," "pitch," and "sound quality and tone" were used for psychoacoustic quantification [7]. Loudness is equivalent to a physical quantity, known as the sound pressure level. Sound frequency is related to pitch, and the time-varying

structure and spectrum are related to sound quality and tone. These are called the sensation dimensions. However, when sound quality is examined, dimensions such as "brightness" and "hardness" can be found. Quantifying the number of dimensions involved in producing the magnitude and pitch of sound needs to be simple. The SD method allowed us to quantify the sensation dimensions in the experiment. The method employs many adjective scales expressing sound quality and tone, and it measures sound using these scales. Factor analysis was carried out to evaluate the common factors from these results, determine, and quantify dimensionality.

3.2 Auditory Experiment and Result

A jury test was conducted employing the SD method with 67 healthy people forming the jury. Sounds were reproduced through headphones. The evaluation paper used in the jury test is shown in Fig. 7. The age and gender distribution of subjects in the jury is shown in Fig. 8. The experimental results are shown in Fig. 9.

First, each adjective was matched with a button.

Button (6)—"dark"—"deep"—"simple"—"soft"—"heavy"—"like"—"high-class"—"low"—"charming"
Button (11)—"round"—"warm"—"fresh"—"natural"
Button (7)—"beautiful"—"pleasant"—"relaxed"—"heart"
Button (3)—"simple"
Button (1)—"common"—"simple"
Button (8)—"small"—"weak"—"fine"—"thin"—"unsatisfactory"—"delicate"—"short"
Button (2)—nothing
Button (9)—nothing
Button (5)—"light"—"thin"—"high"—"cold"
Button (10)—"large"—"strong"—"clear"—"force"—"bold"—"showy"—"hard"—"long"—"artificial"—"dry"—"coarse"—"thick"—"bright"—"sharp"—"cheap"—"jarring"
Button (4)—"loose"—"uneasy"—"dislike"—"complicated"—"dirty"—"boring"—"blurred"

WT showed that the back sound of button (4) produced a sweep sound at 100–600 Hz. The adjectives "loose," "uneasy," and "dirty" were associated with this sweep sound distribution. Continuous low-pitched sounds were associated with button (3), but these sounds did not affect the auditory impression. A continual high-pitched sound was associated with button (10), and this sound was described as "long" and "cheap." However, sound-quality matching was insufficient because the correlation was between adjectives.

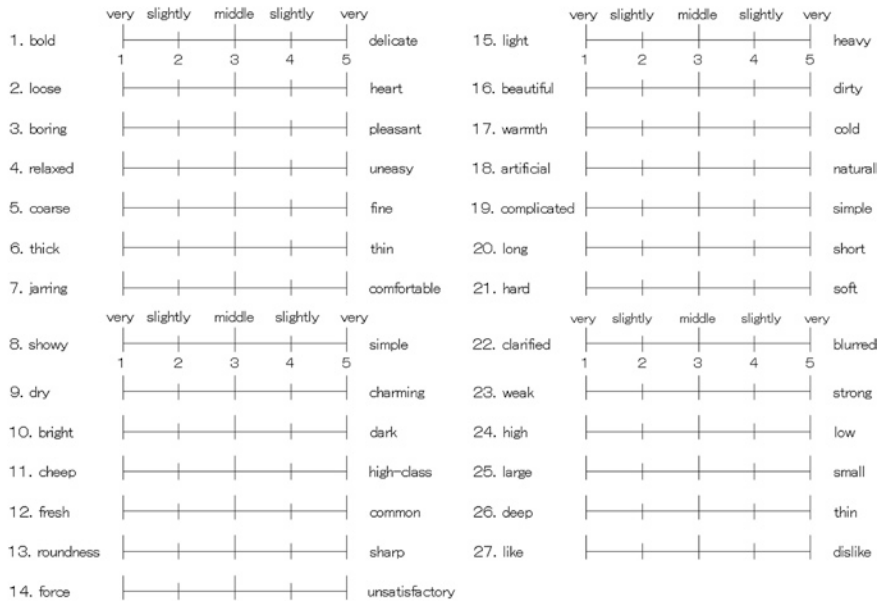
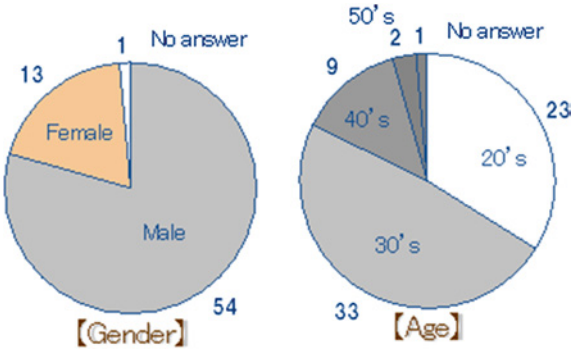


Fig. 7 Evaluation paper

Fig. 8 Subjects



3.3 Factor Analysis

Factor analysis and WT matching analysis of the experimental results were carried out. The relationship between each button sound and factor was investigated by selecting 10 pairs of significantly different adjectives from a set of 27 pairs of adjectives. Factor loadings and factor scores are shown in Table 1 and Fig. 10, respectively. The principal divisor method and the varimax rotation method were used for factor extraction.

A metallic factor, an esthetic factor, and a force factor were extracted sequentially from the first factor. These are "hard," "comfortable," and "force" sounds;

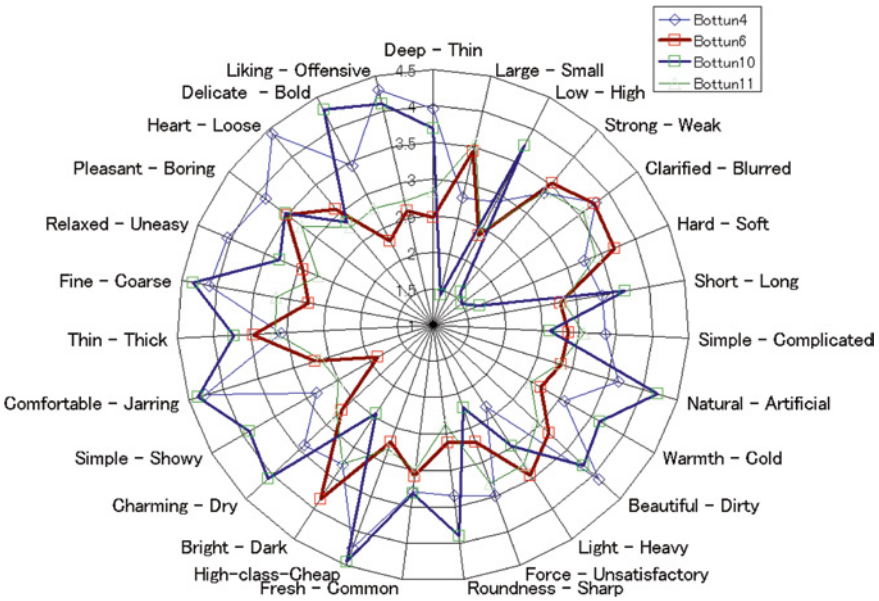


Fig. 9 Subjective evaluation

Table 1 Factor loadings

	Metallic	Esthetic	Force	Similarly
Hard–soft	0.91	−0.20	0.33	0.97
Clear–blurred	0.90	−0.10	0.41	0.98
Low–high	0.86	−0.39	−0.01	0.90
Simple–showy	−0.63	0.52	−0.46	0.88
Comfortable–jarring	−0.22	0.95	−0.14	0.96
High-class–cheap	−0.36	0.91	0.12	0.96
Fine–coarse	−0.09	0.88	−0.42	0.95
Force–unsatisfactory	0.15	−0.02	0.95	0.92
Strong–weak	0.65	−0.20	0.74	1.00
Large–small	0.50	−0.45	0.71	0.95
Factor contribution	36.41	32.02	26.48	94.90

therefore, their jury test scores were high. Moreover, the accumulation contribution was fully satisfied.

"Like" button sounds had low metallic factor and force factor scores and had a high esthetic factor score, as shown in Fig. 10. When a button sound was as assigned the "dislike" property, the metallic factor and force factor scores were high, but the esthetic factor score was low. These results correspond with the results of WT experiments shown in Figs. 1, 2, 3, 4, 5, and 6.

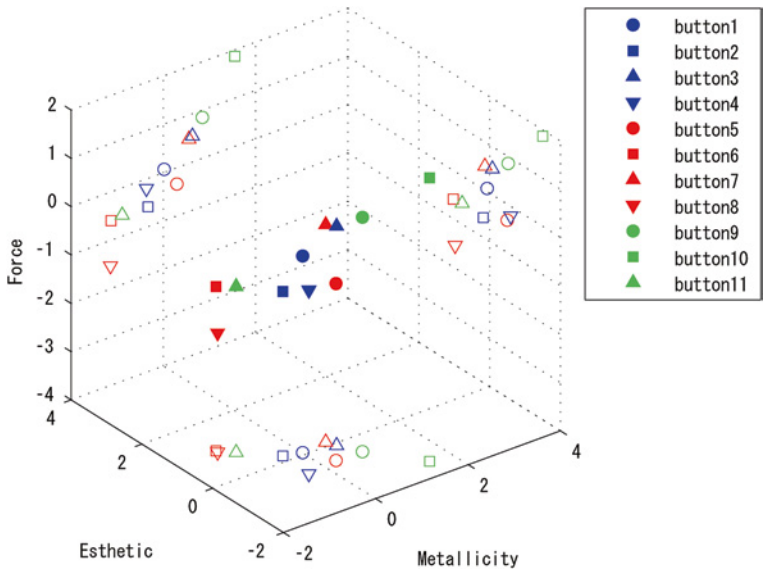


Fig. 10 Factor score

4 Conclusions

We evaluated sound design using 11 different button sounds. Although psychoacoustic metrics are widely employed in sound-quality evaluations, loudness is used to evaluate stationary sound and cannot be adequately used in the evaluation of non-stationary sounds such as button sounds. As a result, we decided here to compare time–frequency structures and jury test scores to evaluate sound quality. First, an impression was extracted employing the SD method, and the relationship between the representation of the WT and its sound impression was investigated. After matching WT characteristics and auditory impressions, the results showed that a low-frequency button sound made a favorable impression, and a high-frequency button sound made a negative impression. The auditory impression of both button sounds was classified into esthetic, metallic, and force factors on the basis of these results. “Like” button sounds had low metallic factor and force factor scores and had high esthetic factor scores. When a button sound was assigned the “dislike” property, the metallic factor and force factor scores were high, but the esthetic factor score was low. These results should assist button sound design in the future.

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Characteristics of the Design and Production Process for Italian- and Japanese-Made Tailored Jackets in the Global Market

Tsuyoshi Otani, KyoungOk Kim, Keiko Miyatake, Kimiko Sano and Masayuki Takatera

Abstract We studied differences in the production processes of high-end garments manufactured in Japan and Italy and intended for sale on the global market. We analyzed the roles of *modélistes* from these countries to understand how differences in their work styles influenced the characteristics of the final products. A jacket designed by a Japanese designer was produced in both Japan and Italy. We compared the components of each jacket before and after assembly. In Japanese garment factories, work can only progress after previous steps have been inspected. Conversely, Italian workers only inspect the final product. There was also a difference in the use of keeping tape and interlining. It is common for Italian *modélistes* to select the sub-material, depending on the design. However, cost and production volume is more important in Japan. Although advanced production technology exists in Japan, there is a "lost art" that has disappeared in the trial and error conducted in the pursuit of efficient production: an expert's control of the production process, which takes more time. However, this "lost art" is still used in Italy. This should be considered when analyzing the globalization of fashion in Tokyo.

Keywords Global market • Tailored jacket • Italian-made jacket • Japanese apparel • *Modélistes* • Craftsmanship

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_15,

1 Introduction

We examined the issues surrounding the manufacture of ready-to-wear clothing. Ready-to-wear is known in the fashion industry as make-to-stock (MTS). There are two basic functions of clothing: protection and adornment. Clothing that is judged to have a high proportion of the latter is simply referred to as "fashion." Fashion companies oversee some or all aspects of the design, manufacture, and sale of fashion. In this chapter, the term "fashion business" refers to all aspects of this process. The term "products for the global market" refers to products intended for sale throughout the world. In this study, we assess the design process of fashion clothing based on the following assumptions.

1.1 Attributes of Fashion Clothing

Fashion clothing, as referred to in our study, is not art. Art is a finished product, and evaluation takes place afterward. However, when a work of art is completed, it never transforms into another work. The clothing in this study is not intended as art. It is a product, a commodity to be sold (i.e., exchanged for money). Because fashion clothing is MTS, it is necessary to prepare all aspects of design, production, and sale in advance. Moreover, the effect of mass production is based on the relationship between the fixed costs—such as a percentage of period costs—and the manufacturing costs. Therefore, in a large-scale business, a significant amount of funding can come from unspecified sources. Large-scale businesses can make a significant amount of profit. Thus, it is more effective for fashion companies to market globally, rather than limit themselves to their domestic market. In this case, hiring staff with a high level of proficiency in clothing designs that are accepted in global markets is important for companies wishing to maintain a high international presence. In other words, fashion designers must have design talents and skills that are in demand on the global market. These are different elements than an artist must take into consideration.

1.2 The International Presence of Japanese Fashion Clothing

Japan's presence on the international clothing market is informed by the following:

(a) Most fashion clothing supplied to the Japanese domestic market depends on overseas companies' capabilities for design, production, and/or sales. 95 % of the fashion business in Japan is dependent on imports [1], including raw materials.
(b) Exports of raw materials and finished fashion clothing made in Japan are very low.

(c) The amount of fashion clothing that is made by Japanese fashion companies and shipped to foreign markets (i.e., outside of Japan) is also small. In addition, these companies tend to be small and their overseas sales ratios are very low. In 2010, the total exported amount was 50 billion yen (approximately 500 million USD). However, the imported amount was 250 billion yen (2.5 billion USD) [1].
(d) It is also uncommon for foreign fashion companies to employ Japanese designers, or for Japanese designers to be hired or commissioned by foreign fashion companies to promote their designs, production, and sales. Moreover, when this does occur, it is generally with the ultimate intent of pattern-making within the design process or for sales in the Japanese market.

As seen from the above points, the Japanese fashion business has a high international component in terms of imported product sales within the Japanese market, but its international presence in other fields (i.e., exports of finished products, talent, or raw materials) is very low. In particular, Japanese designs play a very small role on the international fashion stage.

1.3 Modélisme and Stylisme in the Design Process

The process of creating clothing designs is divided into functions of *stylisme* and *modélisme* [2]. In French, *stylisme* is the stage at which designers (*stylistes*) create and design templates for ready-to-wear lines. *Modélisme* occurs when pattern-makers (*modélistes*) take those designs and create prototypes for the season. In traditional *maison de couture*, the design department takes charge of the *stylisme* and the *atelier* department is responsible for the *modélisme*. A creative director oversees both departments. Recently, however, companies known for "fast fashion" have been increasing their presence in the fashion business. Fast fashion businesses wait until the season has begun and then quickly make inexpensive copies of the most sought-after looks [3]. In fast fashion, a team consisting of designers and merchandisers comprehensively operates both departments based on an integrated database of information processing systems [4].

Because we have a significant interest in the *stylisme* of ready-to-wear lines produced by a *maison de couture* (known as *nouvelle couture,* high-end ready-made clothes), we primarily address *modélisme* by conducting reverse-engineering and product-design experiments.

It is difficult to directly observe the creative director's design process (*stylisme*). *Stylisme* may be affected by the *modélisme* and manufacturing steps. There is a complementary and sometimes confrontational relationship between *stylisme* and the management and sales departments, which are fields in which a creative director may not have very much experience.

Our previous study dealt extensively with these issues [5, 6]. In this report, while we address *modélisme* according to the data obtained in the design and production experiments, we do not focus as much on the analysis of *stylisme*.

1.4 "Tokyo Fashion"

When we think of "Japanese fashion," there is no universal image. When we think of "New York fashion" or "Paris–Milan fashion," prominent *maisons* and companies spring immediately to mind. The names of famous designers are often synonymous with their houses. Although they would be artists in their own right, they are better-known as fashion designers and creative tastemakers.

In this respect, even though Tokyo is the world's second largest fashion market [1] (second only to New York), a particular image does not dominate our collective consciousness. Therefore, for purposes of this study, we will assume that the product manufacturers and wholesalers in Japan and the Japanese retail department stores (Isetan, Takashimaya, Mitsukoshi, etc.), because of their market and sales volume influence, represent Tokyo fashion.

Aside from the aforementioned participants, there are other types of fashion companies in the Japanese market, such as select shops (United Arrows Ltd., Ships Ltd., and Beams Inc.), casual fashion businesses (Point Inc. and Shibuya 109), specialty store retailer of private label apparel (SPA) (Fast Retailing Co., Ltd.), and discount chains. However, it is difficult to claim that these companies are representative of Tokyo Fashion, as their combined sales volume is still lower than any one of the major department stores [1].

1.5 Characteristics of the Design Process

Italian apparel industry is evaluated as a successful case [7]. Thus, we selected an Italian-made jacket as an example of successful global fashion. A tailored jacket is a good example of a garment that requires a high level of skill and technique to produce. We compared Tokyo and Milan fashion to understand the effects of the design process on the global market. This study details the typical characteristics from the knowledge obtained by the experimental design in a series of our research projects.

1.6 Experimental Design of a Tailored Jacket fo the Global Market

In our example, we will examine how luxury ready-to-wear tailored suits for sale in Milan are designed.

Although the overview of the design process examined in this experiment has already been explained, the results of our experiments are introduced based on the manufacturing process and by considering the tasks of the *modélisme* (*atelier*).

In a *maison de couture*, the entire process is controlled by a creative director in charge of the design and its final specifications. The creative director is also

responsible for sales in each season. For *haute couture*, each garment is made in-house at the *atelier*.

However, *nouvelle couture* is manufactured at a mass-production factory that is unconnected to the *maison de couture*. The *atelier* handles the design and production of a sample for an exhibition or runway show, while a trial product for mass production is made by a mass-production factory. After the creative director confirms and checks the trial product and production processes and places the order at the factory, the factory begins production.

A *modéliste* (pattern-maker) plays a major role at the atelier. Although some think a *modéliste* is superior to a designer, this is not the case. If there is a difference of opinion between a *modéliste* and the creative director, it is the creative director who makes the final decision. Even though it is said that the designer draws the original illustration and makes notes on the design, it is the creative director who strongly influences a customer's decision to purchase because he or she is also responsible for marketing the clothing line. *Modélistes* assist in making the actual garments from the designer's illustrations and notes. Although a *modéliste's* work is an important part of the production process, their position is supportive and not well-defined; their work has not been examined in studies on clothing construction. Nonetheless, a *modéliste's* work is important for the affective engineering and end result of the final garment [8–10]. However, we performed this investigation because the specifics of production processes for high-end garments are still unclear.

In this study, we examined the differences in Japanese and Italian production processes for *nouvelle couture*. To do this, we designed and produced a women's tailored jacket in Japan and Italy; we accomplished this by only using Italian production processes. In this chapter, we describe the details of each stage of the production process.

We compared jackets manufactured in Japan according to Italian production processes. We also compared the garment parts before and after assembly, as well as the ironing treatments and usages of interlining and keeping tape.

2 Experimental Design and Production

2.1 Producing a Tailored Jacket in Japan and Italy

We prepared two jackets as experimental samples. They were both designed by a Japanese designer. The designs were produced in both Japan and Italy. Table 1 shows the design and production system for the jacket samples.

We selected a designer who had been working as a designer of ladies' garments to be the creative director in charge of the entire production process. This designer established the garments' concept and then drew an illustration for a jacket (Fig. 1).

Table 1 Design and production conditions for jacket samples

	Design name		
	J jacket	I jacket	I jacket 2
Designer	All three samples were made from a design by a Japanese designer		
Patterns	Japan	Italy	Italy
Modéliste	Japanese working in Osaka, Japan	Japanese working in Milan, Italy	Japanese working in Milan, Italy
Production factory location	Osaka, Japan	Milan, Italy	Osaka, Japan

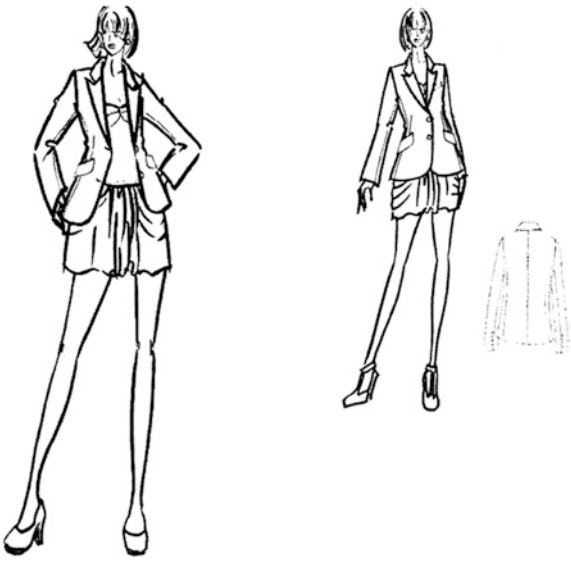


Fig. 1 Illustration of jacket design [5]

We chose *modélistes* and factories in both Japan and Italy to produce the designed jackets. Both jackets were produced using Italian production processes. The steps of the producing processes are as follows:

1. The creative director designed a jacket. She prepared an illustration and notes on the design.
2. *Modélistes* in both Japan and Italy produced trial products of the jacket.
3. The creative director and the *modéliste* in Japan inspected the trial products. The Japanese pattern was revised after inspection; specifically, the patterns for the silhouette, armhole, and sleeve were modified.
4. The patterns were converted into a CAD system format. The specification was for production of 100 pieces to be made in Japan. These converted patterns became the final patterns.
5. The production factories in Japan and Italy produced jackets using the final patterns (J Jacket and I Jacket, respectively).

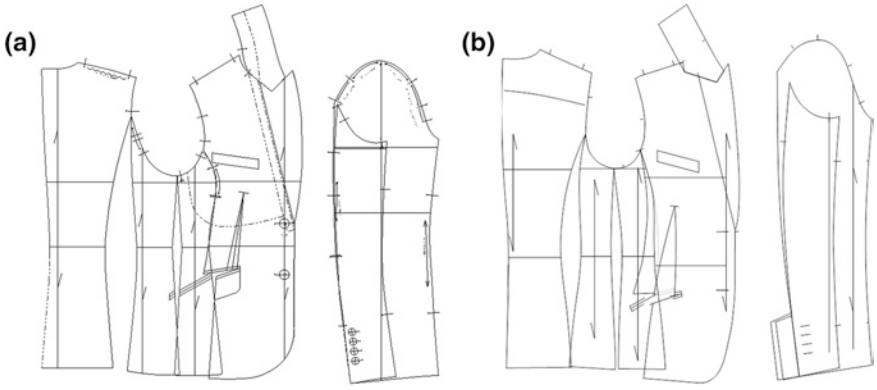


Fig. 2 Jacket patterns made in Japan (**a**) and Italy (**b**)

6. The *modéliste* in Japan made a jacket with patterns made in Italy according to the Italian production system (I Jacket 2) to compare the results of each pattern with same textile, sub-materials, and skills.
7. We compared the production process stages between Japan and Italy by comparing J Jacket and I Jacket 2. The evaluation points were:
   (a) Comparing the body and sleeves before assembling the parts.
   (b) Comparing the front, side, and back styles of the samples.

2.2 Results and Discussion

2.2.1 Characteristics of the Design Process for Patterns in Japan and Italy

Figure 2 shows the body and sleeve patterns made in Japan (a) and Italy (b). We interviewed both the Japanese and Italian *modélistes* about the pattern-design process of each country. During the interviews, we investigated the characteristics of the pattern-design process of each country. *Modélistes* have their own basic patterns, so our *modéliste* designed the jacket patterns in Italy using jacket patterns drawn from his basic stock. These patterns have been improved little by little over time. The patterns are also influenced by the trends of the times. The process of pattern design of Italy was as follows:

1. Several basic patterns were stocked by the *modélists*.
2. The *modéliste* selected the most appropriate patterns based on the designer's illustration and concepts.
3. The *modéliste* created a new pattern using his basic patterns but incorporating the new design.

In Japan, however, basic patterns are selected from the previous season's designs. The process of pattern design of Japan was as follows:

1. The *modéliste* looked for necessary patterns from similar designs and products from the past.
2. Patterns were chosen from among past patterns.
3. Design patterns were made by assembling the chosen patterns to match the design.

There were differences between the pattern-making process in Japan and Italy. The Italian process was based on the *modéliste*'s personal *kansei* and experience, while the Japanese process was based on previous data. The Italian method took more time than the Japanese. Similarly, with the making of suits, it took more time to produce a garment using Italian processes.

2.2.2 Comparing Jacket Parts Before and After Assembly

Figure 3 shows the finished jackets. To examine each production stage, we compared the components of I Jacket 2 and J Jacket before and after assembly (Table 2).

(a) The shape of armhole on sleeve and body

Figure 4 shows the armhole set in the body, and Fig. 5 shows the sleeves. There was a difference in the length and width of the front and back armscye curves. The shape of the armscye in I Jacket 2 was square while that of J Jacket was round. The shape of the armhole was also different. The armhole line of I Jacket 2 and J Jacket are known as "cat's eye" and "egg," respectively. Therefore, we found that there would be a few differences between the shapes of the final product showing in Fig. 11.

These differences also made a difference in the wearing of the garment and the comfort of the wearer. The armhole in the body of each jacket also corresponded to the shape of the sleeve cap, which made some differences in comfort.

The comfort and fit of a garment can only be evaluated by actually wearing it. Comfort is dependent on the customer's figure and final taste of any given country. A question thus arises: "Will the design for the domestic customer's preference be suitable to the international market?" This can be further analyzed by initiating studies on globalization of garment manufacturing.

(b) Amount of space in the bust

Figure 6 shows that the darts around the bust of I Jacket 2 were more generous than that of J Jacket. Furthermore, I Jacket 2 showed a more three-dimensional shape in the bust even when laid out flat. In the curve of the front panel line, a large curvature was visible in J Jacket (Fig. 6b). Therefore, there was a different amount of ease in the busts that made a three-dimensional shape. The different amount of shaping means there is difference between the angles of the

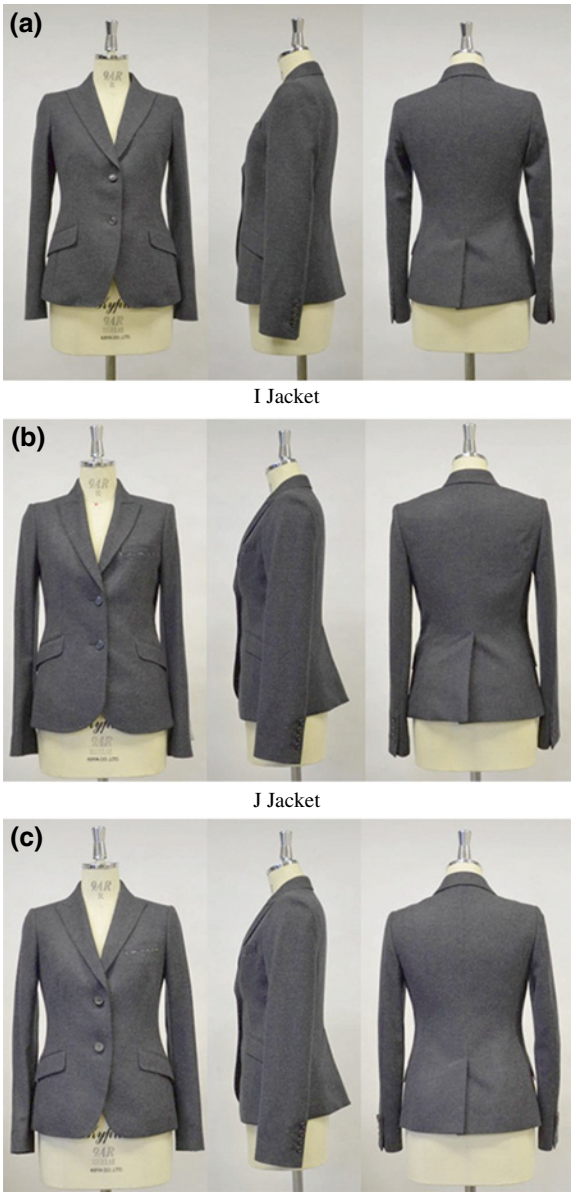
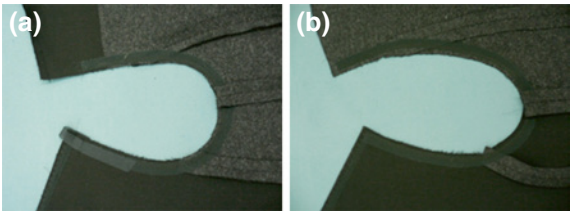


Fig. 3 Finished jackets. **a** I jacket. **b** J jacket. **c** I jacket 2

sewing line curves. This discrepancy might arise from differences in the basic patterns, as the pattern naturally has a strong influence on the silhouette of a garment.

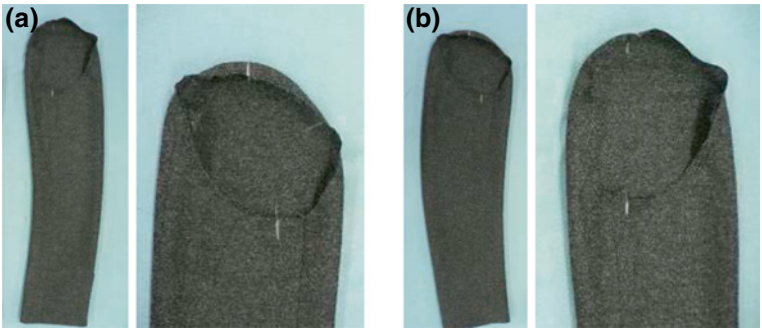
Table 2 Measured sizes of jackets made in Japan and Italy (in centimeters)

Part Jacket	Shoulder width	Bust	Waist	Bottom width	Armscye width	Sleeve width	Length	Sleeve length	Armscye depth	Armhole length
J jacket	38.9	90.6	76.5	92.4	13.0	31.5	61.6	65.8	22.0	45.5
I jacket and I jacket 2	38.0	90.5	79	99.5	12.5	31.3	58	62.6	20.8	42.2



I jocket 2 J jocket

Fig. 4 The armhole in the body. **a** I jacket 2. **b** J jacket



I jacket 2 J jacket

Fig. 5 Sleeves. **a** I jacket 2. **b** J jacket

(c) Around the armholes

Even though the side panel lines of I Jacket 2 showed similarities in their length and lines, the side panels of the J Jacket showed significantly asymmetrical lines (Fig. 7). The differences in those lines in I Jacket 2 and J Jacket are not just a result of differences in the patterns. They result in higher production efficiency in sewing. Moreover, it was also related to the properties of the materials used. These differences might arise from the differences in working environments and the sensibilities of the garment manufacturers.

(d) Laminated area with adhesive interlining

The area of the front that was laminated with adhesive interlining was different between J Jacket and I Jacket 2 (Fig. 8). The laminated area with adhesive

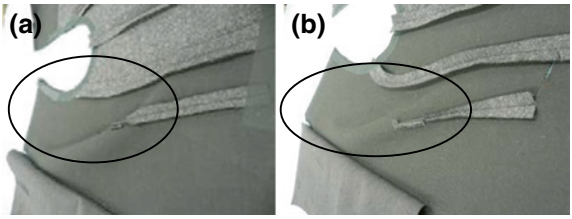


Fig. 6 The *circled areas* highlight the amount of darting in the bust. **a** I jacket 2. **b** J jacket

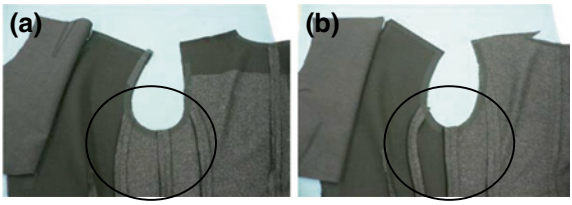


Fig. 7 Armholes. **a** I jacket 2. **b** J jacket

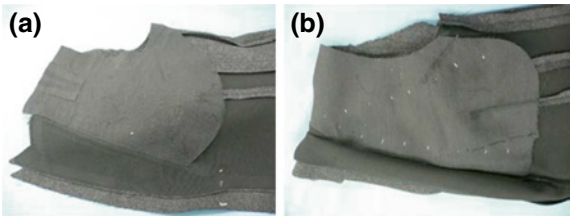


Fig. 8 Jacket body and portions with interlining. **a** I jacket 2. **b** J jacket

interlining on the bust was related to both shape retention and workability [11]. Therefore, it was necessary to consider the balance between the quality of the product and workability in the design steps.

(e) Sleeves

We also found differences in the armhole curves and shapes, and the width of the upper arm of the sleeves (Fig. 9). The cylindrical portion of I Jacket 2 sleeve fell almost vertically. The lower arm (the part from elbow to wrist) was bent toward the front. Furthermore, the cuff line of I Jacket 2 faced forward and the back style was slightly bent.

(f) Comparison of jackets from the front

Figure 10 shows the differences between the jackets' front sections. They are as follows: (1) The angle of the chest and waist pockets; (2) the curve of the front hem; (3) the shape of the line edge of the lapel; (4) the position of the collar gorge; and (5) the line of the collar gorge.

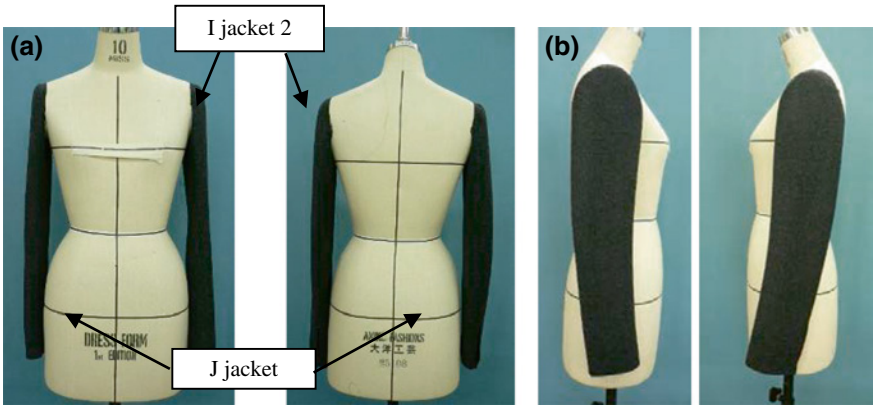


Fig. 9 Sleeves showing comparison of angles. **a** Front and back views. **b** Side views

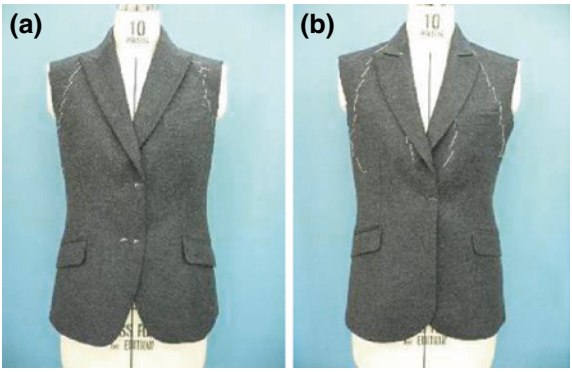


Fig. 10 Front body. **a** I jacket 2. **b** J jacket

These differences originate from the pattern-drawing stage. There are two approaches to drawing patterns. The first considers changes in trends over time. The patterns are based on the proportional positions calculated from the height and the circumference of the current style. In the other approach, the patterns are based on visual judgment by both designer and the *modéliste*. In this visual judgment, the style and the silhouette are mainly considered.

(g) Comparison of jackets from the side

From the side, we observed differences in the overwrapping position of the left and right body in the waist and in the length of the armscye (Fig. 11). The Italian *modéliste* said that the position of the overwrapping part in the waist is the current

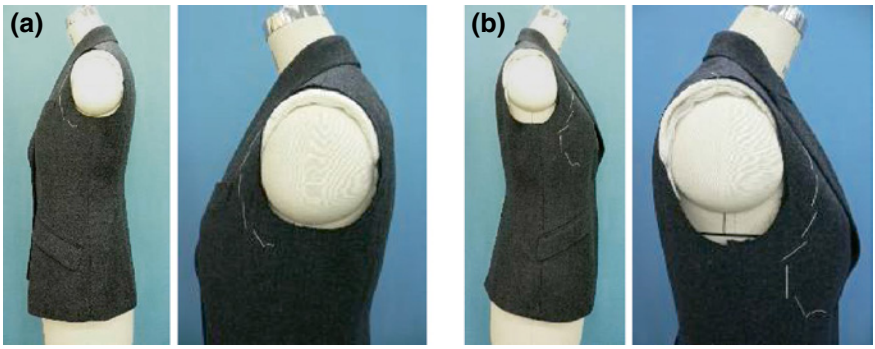


Fig. 11 Side body. **a** I jacket 2. **b** J jacket

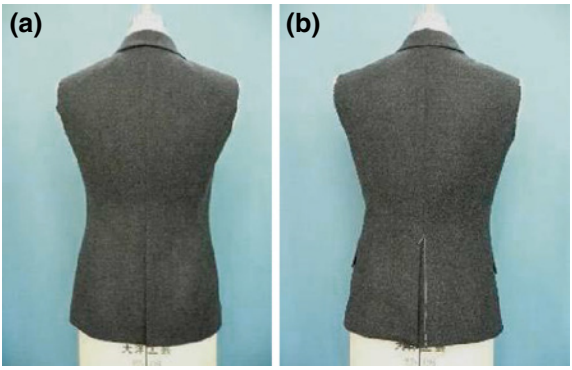


Fig. 12 Back body. **a** I jacket 2. **b** J jacket

style. Thus, it might depend on the preferences of the producer and the consumer. We observed similar tendencies in the depth of the armscye.

However, the cylindrical part of J Jacket was slightly bent forward; the cuff also faced forward. In addition, the cuff shape was round and the back was straight. Changes in the sleeve were affected by the different design patterns of the sleeve and differing preferences of silhouette in each country. Differences between the ironing processes and the sewing process also affected the sleeve shape. Without adjustable ironing treatment and sewing process, the suitable curve of sleeve cannot be obtained.

(h) Comparison from the back

We observed differences in the silhouette of the panel lines around the waist and in the shape of the vent (Fig. 12). The styling of the back of the body was the starting point of the drawing pattern (especially from the back center) and was also an important component of the balance of the whole garment. We also

considered the overall balance and productivity in matching the fabric to the garment for the back style.

3 Conclusions

There were considerable differences between the appearances of the I Jacket 2 and the J Jacket. Naturally, the design of the finished product was influenced by the production process. Therefore, it was essential to have precise instructions for product designs. Careful examination and inspection of production processes was also very important.

We concluded that the differences in production processes between Japan and Italy were due to the intended purpose of the finished products. The hierarchies of the production staff were also different in Japan and Italy. There are significant differences in the workflow between Japanese and Italian manufacturers. In Japan, any given stage can only proceed once the results of the previous stages have been thoroughly inspected. After confirming the designer's opinions of the design, Japanese workers finish the production process faithfully according to the provided specifications. Conversely, the Italian method only considers the quality of the final product. Additionally, *modélistes* in Italy have the prerogative to voice their opinions about the sewing and other techniques used during production.

We found that the specification sheets provided to the garment factories in Italy are very simple documents. We also found differences between the tape and sub-materials used in each factory, which affected the outcome of the final products. In Italy, it is common for the factory and *modéliste* to select the sub-materials (such as the multi-puff and keeping tapes) depending on the design. In Japan, however, cost and production volume are more important when producing a sample; for example, the selection of shoulder pads is carried out by designers. As for the interlining, this is jointly decided upon by the designer and the *modéliste*—the factory simply follows their decisions. Therefore, in Italy, if fabrics are specified through a simple specification sheet and patterns, the factory can produce a sample there. When the order moves to the sewing factory, the garment is primarily under the control of the factory personnel.

Our primary conclusion is that although advanced production technology exists in Japan, there is a "lost art" absent from the process: the expert personal touch in *modélisme,* which requires more time. Because of the continued pursuit of more efficient production processes, this level of craftsmanship has nearly disappeared in Japan. However, it is still in use in the fashion houses of Italy. For the globalization of Tokyo fashion to be successful, we must to remember and consider the utility of this "lost art."

We believe this study can contribute to further understanding of garment manufacture and fashion design. We hope this study will also be helpful for the advancement of the globalization of Tokyo fashion.

Acknowledgments We thank Dr. Masahiro Sugawara. This work was supported by JSPS fellows and JSPS KAKENHI Grant Numbers 23240100 and 24220012.

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Online Shopping and Individual Consumer Adaptation: The Relationship Between Fabric-Identification Ability and Prior Knowledge

Tomoharu Ishikawa, Kazuya Sasaki, Hiroko Shimizu and Miyoshi Ayama

Abstract This chapter describes the adaptation of individual consumers with regard to shopping for clothes online. Consumers who shop online are sometimes disappointed if the textural and tactile properties of purchased clothing differ from their expectations. However, some observers can determine cloth quality quite well from an image. Understanding how such observers identify fabric is critical for developing a technology for presenting cloth information that is adaptable for each observer. To accomplish this, we performed a fabric-identification experiment in which we asked 18 observers to distinguish pieces of cloth through blind tactile perception while viewing cloth images on a display. We also conducted a questionnaire survey to quantify each observer's knowledge of fabrics, experience, and interest by using polar questions and visual analog scales (VASs). From these results, the relationship between fabric-identification ability and prior knowledge was investigated for each observer.

Keywords New-type online shopping • Individual observer adaptation • Fabric-identification ability • Fabric knowledge

1 Introduction

Online shopping has become increasingly prevalent in recent years: In particular, the purchase volume of clothing and accessories has been increasing [1]. However, differences can exist between the first visual impression of a cloth image and the

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_16,

tactile and visual perceptions of the actual cloth [2], even though high-quality displays are widely used [3]. Because the number of Internet users is expected to rise to approximately 45 % of the world's population in the next 4 years, preparing for electronic commerce—such as business to consumer (B2C) and consumer to consumer(C2C)—on a global scale is important. Related research includes the relationship between tactile and visual perceptions of cloth. In addition, research has been conducted on the relationship between the tactile perception of actual cloth and the visual perception of images of cloth. For the former, research has been conducted relating the mechanical properties of cloth materials using the Kawabata Evaluation System for the handling evaluation of actual cloth [4]. Furthermore, studies have investigated the relationships between structure and the glitter evaluation of actual cloth [5] and between processing technique and the texture recognition of an image of cloth [6]. For the latter topic, a study presented the logical relationship between the visual evaluation of a cloth image and the tactile evaluation of an actual cloth [7]. Another study showed the psychological relationship between the visual and tactile perceptions of 2D and 3D images and the tactile feelings of actual cloths [8]. Furthermore, digital textile tools have been developed that can be interactively operated with tablets such as the iPad [9]. However, these studies do not evaluate the relationship between the observer's individual features, such as knowledge and experience, and the ability to identify fabric using visual and tactile perception.

To investigate the relationship between an individual's fabric-identification ability and his or her amount of experience and knowledge, we conducted a fabric-identification experiment along with a questionnaire survey that used polar questions and a visual analog scale (VAS). In the questionnaire, observers were asked polar questions regarding their knowledge of fabric names and their visual, tactile, and wearing experiences with the fabrics. In addition, fabric knowledge and interest were psychologically measured according to a VAS. In the fabric-identification experiment, each observer was asked to distinguish a piece of cloth through blind tactile perception while viewing a test image of the cloth on a display. The effect of drape-fabric complexity and the accurate estimation of light-source position were investigated as conditions in the fabric-identification experiment. Eighty-eight test images were created for the experiment. Eleven fabrics, selected for their different characteristics, were prepared, and four photographs of each fabric were taken using a Nikon D50 digital camera. The 44 original photographs were then inverted. The original and inverted 44 test images were used in the fabric-identification experiment and designated as erected and inverted images, respectively. To explore the effect of the visual observation field size of drape fabric, four window sizes were utilized that drastically restricted the field of view by differing degrees. A total of 352 images were employed as experimental stimuli. Based on the obtained results, the correlation between the observer's fabric-identification ability and his or her prior fabric knowledge is discussed.

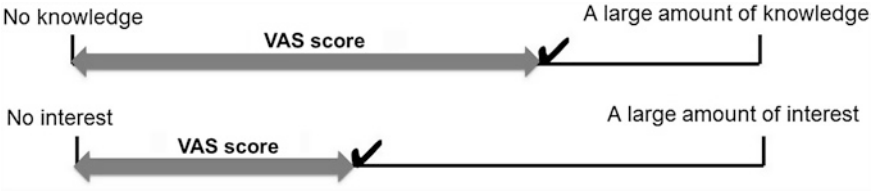

Fig. 1 VAS for measuring knowledge and interest in fabrics

2 Questionnaire Survey and Psychological Measurements

2.1 Conditions

To investigate the observer's knowledge and experience of each fabric, we conducted a survey using a questionnaire and psychological measurements using a VAS. Eleven fabrics were selected based on their different characteristics: silk lace, ox fabric, Indian-style material, chiffon crepe, velour, velvet, satin stretch, satin organdy, jacquard silk chiffon, silk satin, and satin back shantung. In the questionnaire, the observers were asked four polar questions:

1. Do you know the fabric name?
2. Do you have experience seeing the fabric?
3. Do you have experience touching the fabric?
4. Do you have experience wearing the fabric?

In addition, knowledge and interest in general fabrics were psychologically measured using a VAS (Fig. 1). The observers marked points that they felt represented their knowledge and interest in different fabrics on the VAS. The VAS scores were determined by measuring the length from the left end of the line to the point marked by the observer.

2.2 Results

Each observer's knowledge of the fabric name and his or her visual, tactile, and dressing experiences with each test cloth were calculated. Figure 2 shows each observer's amount of knowledge and past experience regarding all test cloths as assessed by the polar questions. The asterisks in this figure denote the 10 students who were majoring in clothing studies (c-students).

The results show that most c-students had more knowledge and experience with fabrics than the engineering students (e-students). A few e-students, however, had more prior knowledge and experience than some c-students. Figure 3 shows the knowledge and interest of each observer as expressed by a percentage according to the

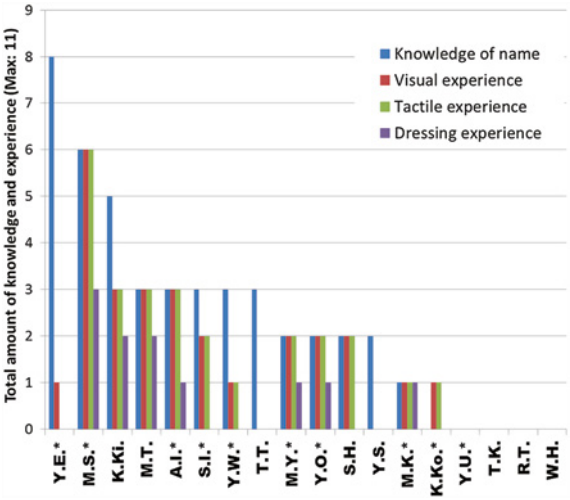

Fig. 2 Participants' prior knowledge and experience

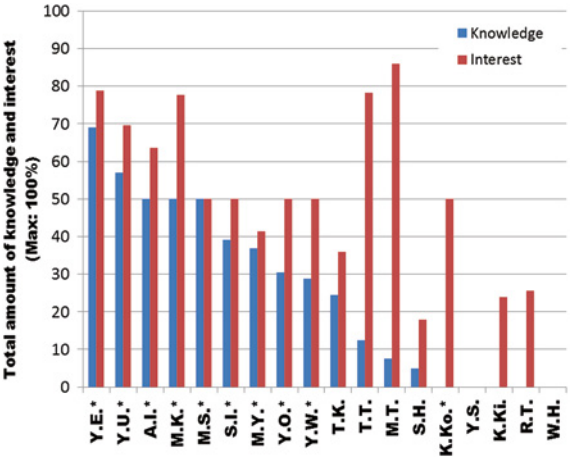

Fig. 3 Amount of knowledge and interest of participants according to VAS

VAS score. The VAS score results reveal that most c-students had higher percentages of knowledge and interest than the e-students. In particular, the two groups of observers can be comprehensively divided by their respective percentages of knowledge.

3 Fabric-Identification Experiment

3.1 Experimental Conditions

3.1.1 Test Cloths and Test Images

The test cloths were prepared from 11 fabrics that were cut into 20 cm × 20 cm square pieces—that is, the size specified by Japanese Industrial Standard (JIS) L

Fig. 4 Setup of equipment and photography

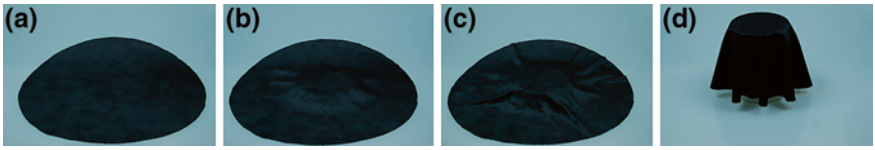

Fig. 5 Pictures of the different levels of drape complexity (sample fabric: velour) **a** complexity of 0, **b** complexity of 1, **c** complexity of 2, and **d** complexity of 15

1096 [10]. A small square tag was attached to a corner of each piece to indicate the front surface of the piece. Each fabric for the test images was cut into a circular piece with a diameter of 40 cm. Four types of pictures were taken of each fabric with a digital camera (Nikon D50 with the following settings: exposure value of 13.9, shutter speed of 1/80 s, and F14 aperture). Pictures were taken of the circular cloths covering acrylic cylinders of three heights (1, 2, and 15 cm) to create drapes of different complexities. The diameter of the acrylic cylinders was 12 cm, in accordance with the JIS L 1096 drape tester [10]. The different acrylic cylinder heights (1, 2, and 15 cm) corresponded to the drape complexity levels (1, 2, and 15, respectively). The fourth type of picture involved placing the circular cloth flat on the table. Because the draping of the fabric was nonexistent, the drape complexity level was 0. Figure 4 shows the setup of the equipment and the photography. Figure 5 shows the four types of pictures taken of the fabrics, using velour as an example. In total, 44 pictures were taken to serve as test images.

3.1.2 Experimental Stimuli

To investigate the accuracy of the estimated light-source position, 88 test images were placed into two groups: The original 44 test images were the *erected image*

Fig. 6 Experimental booth and apparatus

group and the inverted 44 test images were the *inverted image* group. Additionally, to explore the effect of visual field size on the observation of the drape fabric, four window patterns were designed to restrict the visual field. One pattern that did not have a window was denoted *N-win*. The other three patterns had window sizes of 2 cm × 2 cm (2 × 2), 4 cm × 4 cm (4 × 4), and 8.5 cm × 8.5 cm (8.5 × 8.5). In total, 352 images (11 fabrics × 4 drape complexity levels × 4 window sizes × 2 groups) were employed as experimental stimuli.

3.1.3 Experimental Procedure, Booth, and Equipment

The experimental procedure was as follows:

1. An observer *O* enters the experimental booth (Fig. 6).
2. An experimenter *E* explains the experiment to the observer.
3. *E* places 11 fabric cloths in a box.
4. *E* presents a homogenous gray image on the display.
5. A test image is presented on the display.
6. *O* inserts his or her hands into two slits of the experimental apparatus, only touching the test cloth in the box.
7. *O* indicates the selected cloth that corresponds to the test image to *E*.
8. *E* records the number of test cloths judged correctly.
9. *E* returns the display to the homogenous gray image.
10. *E* returns the test cloth to the box.
11. *E* presents the next test image on the display.

The ambient light in the experimental booth was provided by a fluorescent light fixture on the ceiling of the room. The horizontal and vertical illuminance values near the center of the display were approximately 523 lx and 230 lx, respectively. The experimental stimuli were presented on the 15.4-inch display of a personal computer (VAIO PCG-9S2N). The distance between the display and the observer's

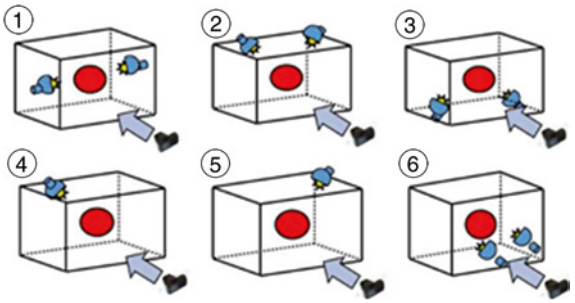

Fig. 7 Illustrations of light patterns

eyes was approximately 60 cm. Each observer was given unlimited time to carry out the evaluation. To avoid comparisons between successive images, a homogeneous gray plane (N5) was presented between each pair of experimental stimuli. Each observer evaluated 352 images in four sessions. The order of the sessions was randomized among the subjects. The observers were comprised of 18 participants with normal color vision; 8 were e-students and 10 were c-students.

To estimate the accuracy of the light-source position, illustrations of six light patterns were presented to each observer, who would then select one pattern. Figure 7 shows these light patterns. The no. 2 and no. 3 light patterns correspond to the erected and inverted images, respectively.

3.2 Results

The number of correct answers for each test cloth under all conditions was used to evaluate each observer's fabric-identification ability. Figure 8 shows the total number of correct answers for each observer.

The c-students typically had more correct answers than the e-students, but a few c-students had fewer correct answers than the e-students. The results suggest that the c-students were comprised of two groups that either were or were not susceptible to changes in window size and drape complexity. The total number of correct answers for the erected images exhibited the same tendency as the total number of correct answers for the inverted images. The total number of correct answers for light-pattern recognition for all observers is shown in Fig. 9. A correct answer involved selecting the no. 2 pattern when observing an erected image or the no. 3 pattern when observing an inverted image. The light-pattern recognition responses indicated a different tendency than the fabric-identification ability of each observer. Additionally, the correct answers for light-pattern recognition of erected and inverted images exhibited different trends. The results suggest that there is little correlation between light-pattern recognition and fabric-identification ability.

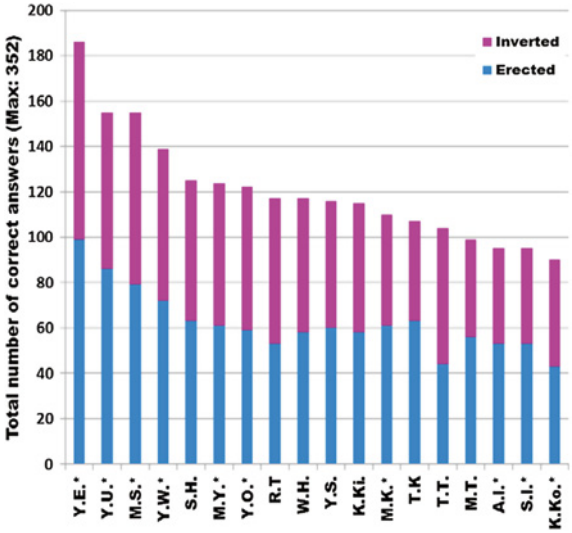

Fig. 8 Total number of correct answers for each observer

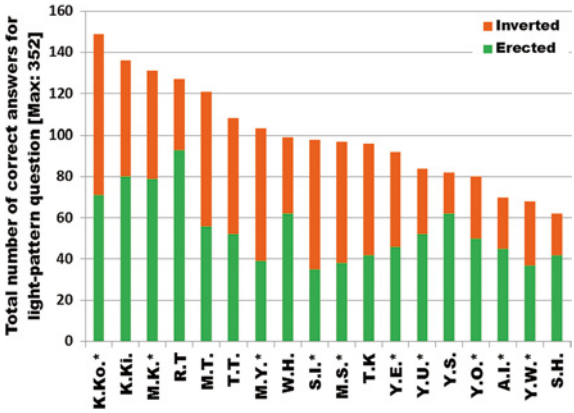

Fig. 9 Number of correct answers for two light patterns

4 Correlation Between Fabric-Identification Ability and Prior Fabric Knowledge

The correlation between the total number of correct answers and the amount of knowledge and experience was calculated, revealing a positive correlation between correct answers and knowledge of fabric names. In particular, there was a higher correlation for the c-students ($R = 0.62$). These results are shown in Fig. 10.

In addition, a positive correlation between the total number of correct answers and the amount of fabric knowledge was revealed from the VAS. In particular, there was a higher correlation for the c-students ($R = 0.63$). These results are shown in Fig. 11.

However, there was no correlation between the total number of correct answers and the amount of interest in fabrics as determined by the VAS. Unsurprisingly,

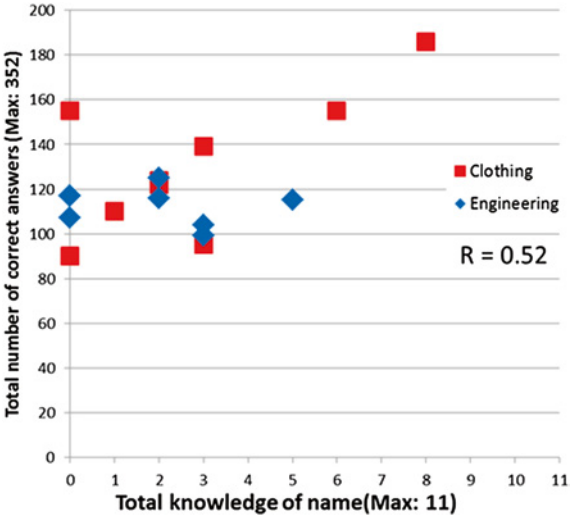

Fig. 10 Correlation between the total number of correct answers and knowledge of fabric names

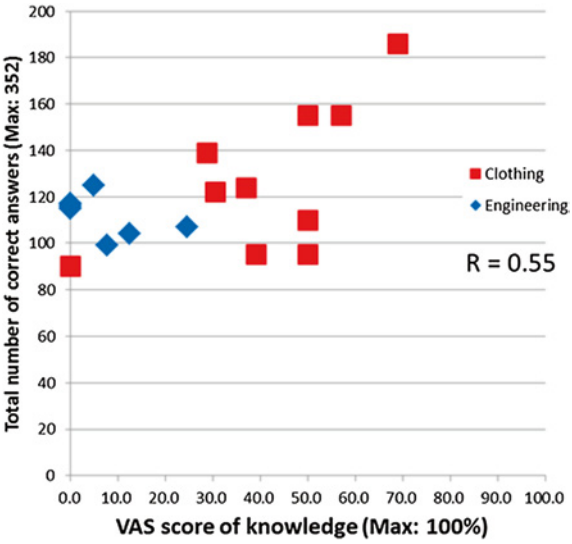

Fig. 11 Correlation between the total number of correct answers and knowledge of fabrics as determined by the VAS

there was no correlation among the total number of correct answers for the light patterns, the results of the questionnaire, and the results of the VAS measurement.

5 Conclusion

We conducted a fabric-identification experiment, a questionnaire survey, and VAS measurements to investigate the correlation between fabric-identification ability and prior fabric knowledge for 18 observers. After calculating the correlation

coefficient of the total number of correct answers and the amount of knowledge and experience, we found a positive correlation between the total number of correct answers and knowledge of fabric names as revealed by the VAS. Therefore, fabric-identification ability can be estimated from the amount of fabric knowledge obtained by the polar questions or the VAS, even if the image information of a cloth is affected by the presence or absence of a fabric drape, the restriction of the visual observation field size for the drape fabric, or a change in the light-source position. In conclusion, by conducting questionnaire surveys and fabric-identification experiments using many observers and fabrics, it is possible to obtain basic data for developing technology for presenting cloth information that can be adapted for each observer. Furthermore, the results shown in this chapter are connected to the following innovative projects: developing a base technology for new online shopping that is adapted to each consumer, clarifying new human cognitive mechanisms for clothes from a scientific standpoint by investigating the relationships between different sensory receptors (visual and tactile perception), and proposing new educational techniques adapted to each observer's ability to judge cloth texture by clarifying the influence of the observer's prior knowledge and experience with fabrics in judging clothing textures.

Acknowledgments This research was supported by JSPS KAKENHI grant numbers 24220012 and 25330316.

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Reading Emotion of Color Environments: Computer Simulations with Self-Reports and Physiological Signals

So-Yeon Yoon and Kevin Wise

Abstract The affective experience of a color environment has rarely been tested in actual physical settings. In addition to the challenges of manipulating and controlling colors in a real-world setting, an environment with multiple attributes and colors is more difficult to empirically study. Advanced computer graphic technology allows photorealistic representations of an environment, with the ability to control visual attributes and manipulate colors in the environment. Using Kobayashis color image scale (CIS) theory (Kobayashi in Color Res Appl 6:93–107, 1981) [1] and multimodal measures of user experience based on the interaction of emotion and cognition in processing visual messages, this study explores the feasibility of this framework for future research in color emotions. Ultimately, this study aims to support decision makers of commercial and health-care environments with a more reliable and empirical basis for user experience.

Keywords Emotion • Affective experience • User experience • Color • Environment • Bio-signal • Physiology

1 Introduction

Color is known to evoke emotional reactions and is thus a critical consideration for the planning and design of built environments. Although existing literature acknowledging the significance of color on people both emotionally and psychologically, little has been proven through empirical testing of what different color

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_17,

environments mean to people. The spectrum of research on color is very broad; however, a recent meta-analysis of more than 3,000 citations [2] displayed inconsistent views and few empirical findings regarding the emotional and psychological effects of color. The challenge in controlling and manipulating color variables (and potentially confounding variables such as light quality) is amplified when the target is a real-world environment.

Today's advanced computer-simulation techniques can shed light on empirical color studies. High-fidelity computer simulations offer great advantages in representing real objects and environments while controlling the variables of interest and the experimental settings, thus minimizing confounding elements. Bateson and Hui [3] claimed that such realistic images of settings can lead to results similar to what would be found in actual environments.

Although real-world testing is difficult, today's advanced computer graphics technology offers new possibilities for high-fidelity simulations. Over the last few years, applications of three-dimensional (3D) computer graphics have rapidly expanded in many areas such as psychological therapy, patient education, and health-care facility design. In a realistic simulation setting, the physical conditions of existing or potential physical spaces can be manipulated and tested for their impact on people. Therefore, design decision makers can predict the user's experience.

This study is part of a larger quest to gain evidence-based knowledge of the cross-cultural meaning of interior environments for global marketers and design decision makers of health-care facilities. This study experimentally tested color emotions in computer-simulated environments using high-fidelity graphics. Multimodal measures of emotional responses were explored using subjective self-reports for semantic and emotional responses, in addition to two physiological measures for emotional experiences: skin conductance and corrugator supercilii. With this study, we propose a new approach toward better understanding emotions in color environments using a proof of concept experiment. This study aims to develop an empirical research framework to explore the mind and body interaction to explain and further study the psychological and emotional effects of a color environment on people in the environment.

2 Affective Meaning of Color Environments

Color is one of the most important visual properties in every designed environment. Color researchers have investigated the association of color to many different variables including preference, meaning, and psychological effects. However, much effort has been on individual colors rather than combinations. Classic color-preference studies [4] suggested that people favor one color and tend to consistently choose it over other colors. Whitfield [5] studied wall color preferences for residential interiors. The results indicated that individual differences in gender, age, and social status were related to their color preference. Yoon et al. [6] demonstrated significant differences in interior color meanings represented in a series of adjectives between young and older adults in their experimental study. Ireland et al. [7] examined different

preferences in color saturation levels among people with different anxiety levels. They found that participants with a high-anxiety level preferred less-saturated shades across six colors tested than did participants with a low-anxiety level.

Osgood et al. [8] suggested that meaning is a process linked to linguistic and situational variables of the individual. In other words, meaning is an individual's interpretation and expression of ideas rooted in his or her own prior experience, which is beyond the immediate experience. According to Butterfield [9], color meaning in interiors is defined as a subjective interpretation of the designed environment based on an individual's reaction to the colors or the color combinations.

Rapoport [10] stated people form their interpretation and meaning of an environment from the cultural norms for the appropriate use of design elements in his well-known book, The Meaning of the Built Environment. Therefore, different sociocultural groups have different meanings for the built environment, and similar meanings occur among the people who belong to the same sociocultural group and share similar experiences.

Beyond the different backgrounds of users and individual differences, measuring color emotion in built environments is complicated because one color has multiple dimensions and an environment seldom consists of a single color. To conduct systematic research of color combinations, Kobayashi [11, 12], of Nippon Color & Design Research Institute developed the color image scale (CIS) to understand how a single color and combinations affect emotions. His research focuses on the association of colors and words (i.e., adjectives) describing feelings and psychological emotions. Kobayashi provides a 180-word Image Word Database of feelings such as cheerful, chic, clean, domestic, enjoyable, free, fresh, friendly, and graceful connected to more than 1,000 color combinations. The color combinations were suggested in four application fields: fashion, interior design, product design, and visual media.

The CIS was devised by the use of analysis of variance, cluster analysis, factor analysis, and the semantic differential method. Kobayashi claims that the associations of colors to image words are based on semantic axes (e.g., cool/warm and soft/hard) and can be used for universal application. His research methodology and practical application guidelines have been widely accepted by major industries in many countries in Asia as well as in Europe. Kobayashis theory has been examined through studies in a variety of contexts including interiors, e.g., [13]. In addition to the inherent complications in empirical research with color environments described here, known issues in accurate measures of emotional responses must be addressed in terms of the current study.

3 Measures of Emotion

Emotional response can be measured in at least three different ways affective reports, physiological reactivity, and overt behavioral acts [14]. In this study, we only considered self-reports and physiological measures to understand affective experiences.

3.1 Self-Reports

One of the most common methods to understand and evaluate emotional responses to designed objects has been adjective-based subjective self-reports. Many affect inventories have been developed specifically to measure people's reports of internal feeling states. Originally, Wundt [15] labeled the three basic dimensions of affective meaning among stimuli (i.e., words, objects, events) pleasure, tension, and inhabitation. Subsequent empirical work has confirmed Wundt's theoretical categories that pleasure, arousal, and dominance are pervasive in forming judgments for a broad range of symbolic and perceptual stimuli [16].

Despite the quest originally started by psychologists for affect inventories measuring emotion, it has been only in the last two decades or so that researchers in marketing looked at emotions combined with user experience. Among various approaches to emotions, it is consensual that emotions are a multifaceted phenomenon consisting of subjective feelings, physiological reactions, and behavioral intentions (approach/avoid). Mauss and Robinson [17] stated that a consensual, componential model conceptualizes emotions as experiential, physiological, and behavioral responses to personally meaningful stimuli (Fig. 1). Adjective-rating scales have been widely adopted in measuring human experience, both semantic and affective. Those self-reports can be valid and are likely to work where one is experiencing an emotion and he or she must be aware of and capable of reporting on momentary feelings. To address this problem, Lang [18] devised a picture-based instrument called the Self-Assessment Manikin (SAM) to measure the pleasure, arousal, and dominance associated in response to a stimulus.

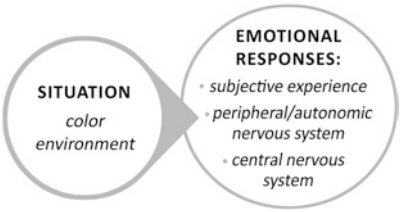
The SAM has been popularly used by subsequent researchers to measure emotional responses in a variety of contexts including reactions to images, sounds, pictures, and advertisements [16]. More recently, the Product Emotion Measurement instrument (PrEmo; http://www.premotool.com/), an online nonverbal method, was introduced and popularly used for quickly assessing peoples affective experience. Previous studies claimed that environmental stimuli can affect pleasure and arousal and also influence behaviors [19]. Arousal has been recognized as a significant dimension of human emotion [20]. As seen in Fig. 1, environmental psychologists Mehrabian and Russell [21] proposed the stimulus–organism–response (S-O-R) paradigm to explain the relationship among stimuli, environments, responses, and behavioral intention in the context of marketing and consumer behavior research.

3.2 Physiological Measures

Using self-reports (whether verbal or nonverbal), it is relatively simple to tell a particular emotion. However, scientific evidence of emotion remains one of the most challenging yet important issues in affective engineering. In order to account

Fig. 1 Research framework based on the S-O-R model

Fig. 2 A component model of emotions



for such a challenge, the application of psychophysiological measures to the study of cognitive and emotional processing of information is considered as one of the greatest methodological advances in the field of media psychology [22]. Psychophysiological measures of emotional processing of media include electromyography (EMG), galvanic skin conductance, heart rate variability, and electroencephalography (EEG).

Unlike language-based subjective self-reports, the key benefits of psychophysiological measures include the ability to index dynamic mental processes in real time (Fig. 2).

Abundant research has been conducted on the connection between emotion and peripheral nervous system activity, which is the interaction between mind and body. Media psychologists have used indices of peripheral nervous system activity to measure emotional processing of media content based on the concept that the mind is manifested by brain activity influenced by signals from the body. Psychophysiological measures of emotion focusing on central nervous system activity are developed to directly index specific brain activity (central nervous system) during emotional experiences. However, brain activities (EMG) are not considered within the scope of the current study.

3.2.1 Arousal and Valence

Among many discrete feeling states (i.e., emotion and affective experiences), researchers have identified the most widely superordinate dimensions as arousal and valence [16]. Learning from media psychologists interested in how the mind processes emotional content for many decades, psychophysiological measures

reliably and validly index superordinate dimensions of emotion rather than discrete affective feeling states [23] such as anger, enjoyment, fear, and surprise.

The dimensional theoretical perspective on human emotion arousal and valence has been most widely adopted by media psychology researchers utilizing psychophysiology measures [22]. According to the dimensional approach, emotion as affective experience has two dimensions of motivation: Valence is the directional dimension of pleasant versus unpleasant emotional responses, and arousal is the intensity dimension of emotion [24]. Skin conductance and facial EMG are the two psychophysiological measures extensively used in research on emotional process in media.

3.2.2 Skin Conductance: A Measure of Arousal

The peripheral nervous system comprises the autonomic and somatic branches. Skin conductance, also known as galvanic skin response (GSR), indexes sympathetic activation in the autonomic branch of the peripheral nervous system. Skin conductance is known to have a reliable correlation to arousal. Another advantage of skin conductance is that GSR provides continuous data and detects a very subtle level of arousal [22].

3.2.3 Facial EMG: A Measure of Valence

Facial EMG, extensively used as a psychophysiological measure of the valence of emotional processing, consists of the somatic nervous system underlying facial muscle activity for emotional expression. A substantial body of psychophysiological research has identified that specific facial muscles are consistently activated responding to variance in the valence of emotion. The specific muscles are the corrugator supercilii, orbicularis oculi, and zygomaticus major. Researchers studying emotional processing of media have exclusively focused on measurement of activity within these specific facial muscles [25]. Previous work indicates that the zygomaticus major muscles and orbicularis oculi muscles measure pleasantness of emotional valence, and the activity of the corrugator supercilii muscles increases according to the unpleasant dimension of valence [26, 27].

4 Method

4.1 Participants

Thirty-four undergraduates were recruited from an introductory communication class at a large Midwestern University to participate in this study. Students received course credit for their participation. Physiological and self-report data

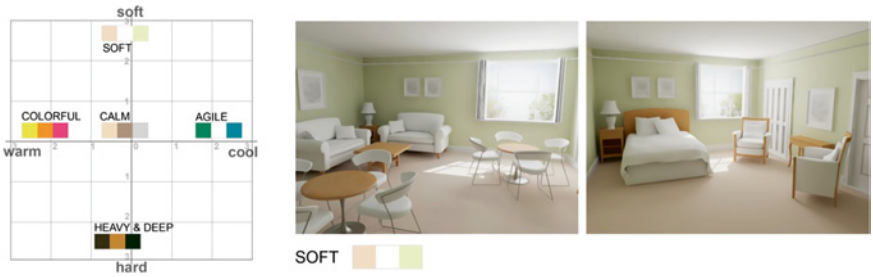


Fig. 3 Five color combinations for the study and color simulation example

from two participants had to be discarded due to experimenter error, equipment malfunction, or excessive noise in the data, resulting in a significant number of missing values. Therefore, final analyses reflect data from 32 participants.

4.2 Stimuli

For the study, five color palettes based on Kobayashis color image theory were developed, and they were applied to two different types of interiors one bedroom and one public dining space. Color stimuli were developed using 3D Studio Max with Vray (Autodesk, San Francisco, CA) photorealistic rendering engine and presented on the a computer screen.

Based on Kobayashis color theory [1, 11, 12] and the CIS, five of the most distinct color combinations were selected and simulated to represent five color schemes, i.e., soft, colorful, calm, heavy and deep and agile, using computer-generated 3D models. Color combinations selected for the experiment are considered suitable for interiors, and thus, the presented color environments are emotionally very subtle stimuli that might not stimulate individuals to process the color information in a distinct manner. Color Spyder (Datacolor, Lawrenceville, NJ) was used to calibrate colors on the screen. Figure 3 shows the five color combinations chosen for the study on the map of two main axes—soft/hard and cool/warm—and simulated interior shots of soft color combination.

4.3 Procedure

Participants spent 30 s on each of five color combinations. The order in which each color combination was viewed was randomized for each participant. There were no prior manipulations of any of these tasks. Participants were instructed to view each color combination. The only other instruction was not to look away from the color environment stimuli provided during the 30-s period.

4.4 Adjective Ratings

Nine adjectives from the CIS chart known to bring distinct feelings were used in the 7-point Likert scale adjective ratings to examine Kobayashis color image theory. The adjectives include pretty, wild, warm, neat, soft, cool, agile, calm, metallic, colorful, heavy and deep, and hard. Five professional interior designers selected the most agreeable color combination from each group representing the adjective.

In addition, the participants were asked to evaluate the color environments in terms of arousal and valence by using the SAM scale of Lang [18].

4.5 Dependent Variables

Adjective rating and the SAM scales were administered, and the data were collected using MediaLab (EmpiriSoft, New York, NY). Physiological signals were measured, amplified, and recorded using Coulbourn V-series modules (Coulbourn Instruments, Whitehall, PA) linked to a PC computer. The WinDaq software program (DATAQ Instruments, Akron, OH) coordinated the sampling and storage of physiology data. All physiological signals were sampled at 167 Hz.

4.5.1 Skin Conductance

Skin conductance was measured by placing two 8 mm silver/silver chloride (Ag/AgCl sensors) (InVivo Metric, Healdsburg, CA) on the palm of each participant's non-dominant hand after the area was wiped down with distilled water to control for hydration. The skin conductance signal was sampled at 167 times per second and averaged off-line over each second of exposure.

4.5.2 Corrugator Supercilii EMG Activity

Facial EMG activity was recorded by placing two 4-mm Ag/AgCl (InVivo Metric, Healdsburg, CA) electrodes over each participants left eyebrow (corrugator supercilii). Each signal was sampled at 167 Hz and averaged off-line over each second of exposure.

5 Results

5.1 Correspondence Between Self-Report and CIS

Figure 4 shows the position of the meanings on the profile graphs. The darker horizontal lines demonstrate how much participants agree with the meanings corresponding to the CIS.

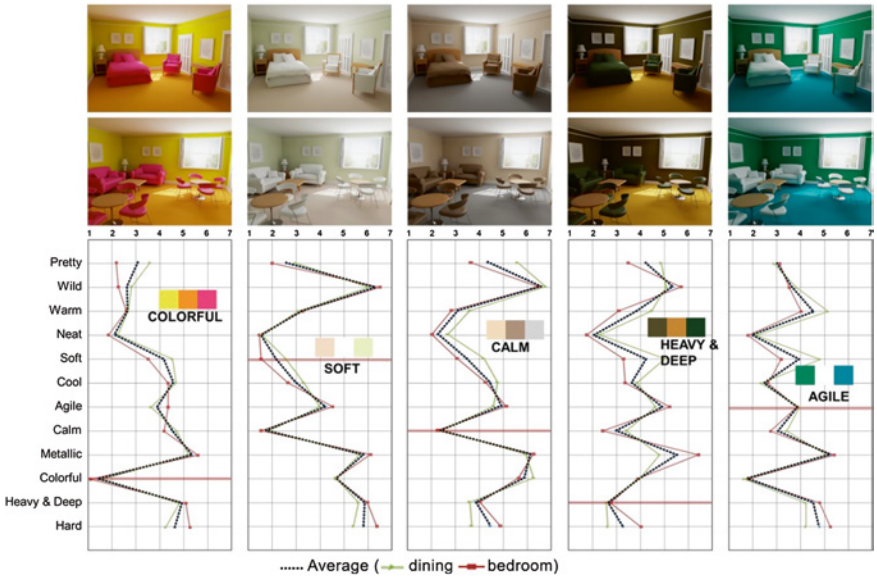


Fig. 4 Profile analysis (1 = totally agree, 7 = totally disagree)

As shown in the profile graphs, the semantic ratings for two interior types (bedroom and public dining) were consistent throughout the five color combinations. Among the five, the agile combination was not perceived as agile. Except the agile combination, the other four combinations were rated as strongly agree with their CIS meanings. Throughout the five, it was found that neat feeling was rated as strongly agree. It is probably because the computer-simulated interiors do not display any additional items besides the main furniture. Ratings for soft and calm color combinations created very similar profiles; the two adjective items were rated consistently close to each other in all color combinations.

5.2 Self-Report Arousal and Valence

Figure 5 is average affective ratings of the five color combinations on the SAM scale plotted into a 2-dimensional affective space [20]. It was illustrated pleasant ratings for colorful, soft, and agile combinations while heavy and deep and calm combinations were rated neutral. Colorful was the only color combination rated as positive ratings in arousal. Compared to the other color combinations, the colorful consists of three colors with similar saturation (i.e., intensity or chroma) and value (i.e., lightness) levels. All five color combinations chosen for this study are considered analogous color schemes. For colorful and heavy and deep combinations, all three colors are next to each other on the color wheel; for soft, calm and agile, there are two adjacent colors and one neutral color in each combination.

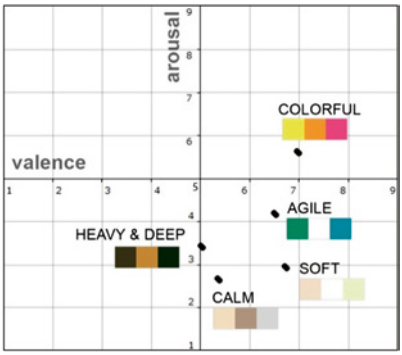


Fig. 5 Five color combinations in a 2-dimensional affective space (SAM valence and arousal ratings)

Analogous color schemes are easily found in nature and color theories often characterize them as harmonious and pleasing to the eye. The colorful combination consisting of vivid colors was perceived the highest ratings in arousal and pleasant levels. Calm and soft color combinations with light grayish and pale tone colors received low arousal score. From the plot, no apparent correlation between arousal and valence scores was observed.

Participants reported soft and calm combinations similar in arousal rating, which is consistent with the profile analysis results. However, it was interesting to note that the soft combination was rated more pleasant than the calm combination. Calm and heavy and deep, the two least pleasant color combinations have more gray tones. While the two maps CIS and SAM do not present explainable associations, participants did rate the calm combination with the lowest scores in arousal.

5.3 Physiological Measures

5.3.1 Arousal (Skin Conductance)

Figure 6 shows the second-by-second pattern of skin conductance level (SCL) (averaged across all participants) elicited by each color combination during the 30 s of exposure. There are two different features to consider when interpreting skin conductance data. The first feature to interpret is the skin conductance response (SCR) that occurs in the first few (1–4) seconds following stimulus onset. This is the electrodermal component of the orienting response (OR). The OR is most simply described as a What is it? response [28]. The purpose of the OR is to facilitate the encoding of unexpected or important information so that the organism can prepare an appropriate response. The relative magnitude of this phasic skin conductance reflects the level of novelty and/or importance of the stimulus. Because there is little important (from an evolutionary standpoint) information in the pictures that participants were exposed to, in this case the SCR likely reflects novelty.

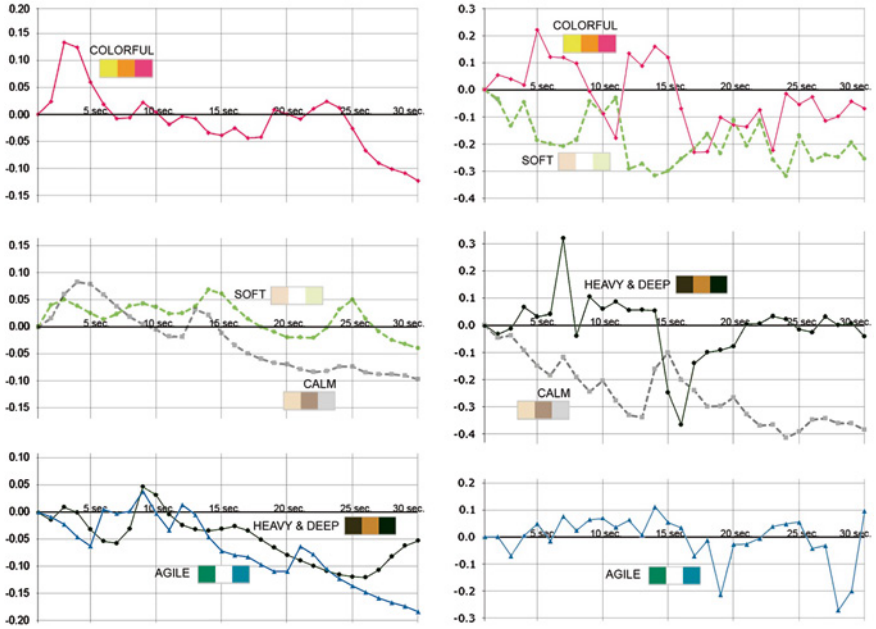


Fig. 6 Change in skin conductance activation for 30 s (*left column*), change in corrugator supercilii activation for 30 s (*right column*)

Figure 6 (left column) suggests that the colorful combination elicited the greatest initial SCR across all participants. The soft and calm combinations elicited smaller initial peaks in skin conductance, and the agile and heavy deep combinations failed to elicit an initial response.

The second feature of the skin conductance data to consider is the pattern of activity over the entire period of exposure. Because these pictures are static and, in terms of threat or reward, does not contain a great deal of important information, one would expect SCL to gradually decrease over the duration of exposure. As seen by looking at the entire 30 s responses in Fig. 6, this was generally the case. The greatest sustained arousal was elicited by the soft combination, followed by the colorful combination.

5.3.2 Unpleasantness (Corrugator Supercili)

Figure 6 (right column) shows the second-by-second pattern of corrugator activation (averaged across all participants) elicited by each color combination during the 30 s of exposure. The magnitude of responses is grouped loosely by darkness of combination, with agile, colorful, and heavy deep eliciting more activity than calm and soft.

6 Conclusion

The affective or emotional quality of environments is becoming more important in today's highly competitive marketplace. Emotional dimensions often lead to different behavioral decisions, and a delightful environmental experience belongs to the affective rather than to the rational domain. In health-care environments, understanding emotional and psychological effects is a critical user experience for both patients and caregivers. Considering the direct and indirect influence on recovery and workplace performance and satisfaction, design decision makers are learning the role of emotional satisfaction beyond efficiency and effectiveness in design.

Color is one of the fundamental design elements in every environment. Despite numerous efforts to understand the effect of color environments in such fields as design and marketing, little empirical evidence exists due to the inherent challenges in studying the topic in the real-world environment with language-based self-reporting.

This study proposes a new approach for examining this long-lasting area of research, with computer-simulations and multimodal measures of emotion learning from clinical psychology and media studies. High-fidelity simulations have the freedom of representing photorealistic views of built or virtual environments while controlling every environmental element, including color and lighting.

Previous studies noted critical drawbacks in verbal instruments to study affective experiences for various constituents, including the elderly, the cognitively impaired and subjects from different language backgrounds [6]. Psychophysiological measures are used in addition to self-reporting to better capture the emotional responses of users to different color environments for this study. Physiological measures help indicate peoples emotional and cognitive states while interacting with represented environments by understanding their physiological states.

In this study, we administered both self-reports and physiological measures to better examine color emotions in two types of the same-sized environments, a bedroom and a public dining room. Adjective-rating scales [1], the SAM pleasant-valence arousal scale and psychophysiology measures skin conductance and facial EMG were used to test five color combinations known to draw distinct images from the CIS [1].

Self-reporting data showed that participants' assessments of the characteristics of each color combination accurately reflected the names of each combination in the CIS. The SAM ratings showed that these combinations were generally perceived as calm and pleasant. Physiological data showed that brighter combinations tended to elicit both greater arousal and greater unpleasantness.

The limitations of this study, and any study using computer simulations and psychophysiology measures, include validity issues the extent to which the simulation-based experimental situations resemble real-life experiences. The simulation certainly provides a filtered experience through the screen, even when the computer-generated content is completely life-like. In addition, the procedures of psychophysiological data collection, with electrical sensors and the preparation process, may introduce anxiety.

As an attempt to more systematically simulate color environments, we borrowed interior color schemes from Kobayashis color theory. To better investigate the link between environmental color properties and physiological signals, simpler and more intense color stimuli can help establish the knowledge base at the exploratory research phase. While the adjective ratings on the color images were somewhat consistent with the CIS, these verbal concepts may or may not relevant to the purpose of designing more emotionally satisfying environments, beyond understanding different meanings. Future work should further explore the impact of color saturation and value levels, based on our findings that show more effects on emotions than hues and focusing on emotions by using skin conductance, facial EMG, and heart rate. Although heart rates were not considered for this study, the cardiac signal is known to be a good indicator of cognitive resources when encoding information from the environment.

Acknowledgments We thank the Einaudi Center for International Studies in Cornell University for their generous support for this experimental study.

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Reviewing the Role of the Science Fiction Special Interest Group via User Interfaces: The Case of Science Fiction Movies

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Abstract Science fiction (SF) feature films offer viewers a glimpse into the future, revealing unique interfaces, social systems, and complex human relations. In this paper, we report a trial conducted by the Science Fiction Special Interest Group (SF-SIG) to gain insight into probable human-centered design (HCD) trends. First, characteristic scenes from the movie *Minority Report* were analyzed. Our argument and analysis began with a top–down arrangement of scenes in descending order of importance. Second, we classified extracted characteristic scenes while considering the worldview of the movie. As a result, suggestions were obtained pertaining to the direction of HCD in the near future. The results of this analysis can be immediately applied as a design tool.

Keywords Human-centered design (HCD) • User experience (UX) • Science fiction (SF) movie • User interface

1 Introduction

Human-centered design (HCD) is a concept where design artifacts are developed with a focus on the human being, i.e., the user. Artifacts are currently diversified, but recognition regarding the importance of HCD is growing. HCD is soon expected to play an important role in the realization of a highly

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_18,

information-centered society. The evolution of information technology, particularly user interface (UI) technologies, has been rapid. Although the combination of a keyboard and a pointing device is still the primary technique for human–computer interaction, other interfaces such as touch panels and gesture recognition systems are increasingly important alternatives for user interfaces. Therefore, an investigation of the factors that popularize certain interfaces is required when considering prospective HCDs. HCD researchers have recently shifted their focus to the concept of user experience. User experience (UX) is important from an HCD viewpoint when coupled with the context in which a user interfaces.

Thus far, the relationship between humans and design artifacts has been considered through various contexts and scenarios, including the human–environment relationship, where an artifact's suitability to a given user scenario is examined. Science fiction (SF) films feature ideas for the future, illustrating unique interfaces, social systems, and human relations. They can provide significant allusions to HCD developments. Therefore, we intend to study the interactions in SF films and apply the gained knowledge to the prediction of the evolution of interaction design and HCD. Accordingly, in 2011, HCD-Net established the Science Fiction Special Interest Group (SF-SIG), a research consortium that examines futuristic interfaces shown in SF films from an HCD viewpoint. Because the SF-SIG primarily consists of industrial designers, an argument based on a concrete design experiment is supported. In this paper, we introduce our methods of analysis and the results of the analysis using the film *Minority Report* as the first target activity of the SF-SIG.

2 Procedure and Analysis

The SF-SIG extracted and examined scenes of interest from *Minority Report*, an SF movie released in 2002. The movie has been examined so extensively that it has gained schoolbook status as research material in the interface design community [1–3]. Nearly 30 specialists from institutions such as MIT scrutinized various interface-related technologies depicted in this movie [4]. The process adopted by the group is described as follows. The viewpoints and the arguments of the participants, which were examined, are arranged in the order of importance. Each SF-SIF member then watches the movie and extracts the characteristic scenes that are deemed relevant to HCD.

The procedure for the argument and the analysis is as follows:

1. Participants classify interfaces on the basis of perceived usefulness.
2. Classified interfaces and their effect on HCD are analyzed.
3. Each interface and its effect on HCD are then discussed.

Each of the aforementioned steps is explained in detail in the forthcoming sections.

Table 1 Items used for scene extraction and characterization

Item	
Title	Name of scene
Focus scene	Typical setting of scene
Point description	Simple explanation of scene
Category	Evaluation axis for classification
Time	Time stamp of onset and termination of scene

Table 2 Categories

Gesture	Visualization	Biometrics
Display technology	Display device	KANSEI expression
Voice operation	Imbalance	Symbolic expression
Automatic control	Precision operation	

2.1 Analysis Based on Classification by Participant Interest

The argument and analysis begins with the top–down arrangement of the scenes in descending order of importance. We isolated the scenes considered to be related to HCD that corresponded to individual themes, such as "gesture interface" and "tangible interface." To standardize the information gathered from the extracted scenes, participants characterized each extracted scene using the items listed in Table 1.

We prepared a worksheet for arranging the viewpoints of the extracted characteristic scenes according to Table 1. Each member defined categories of his/her own accord, and these categories were merged based on discussions with other participants. Eventually, 11 categories were agreed upon, as listed in Table 2 below. Afterward, as the participants analyzed another film, three categories—"Analog direct operation," "Advanced situation/Image recognition," and "Game element"—were added to the original list of 11, totaling 14 categories.

2.2 Characteristic Scene Extraction

Eight SF-SIG members isolated the characteristic scenes. Arguments regarding the extracted scenes were carried out using the worksheet, and these arguments were amalgamated onto one sheet (Fig. 1). In all, 45 characteristic scenes were included on the basis of the format prescribed in Table 1, focusing on the titles and the simple descriptions.

Fig. 1 Prepared worksheet for categorizing viewpoints of scenes (each scene is obscured intentionally)

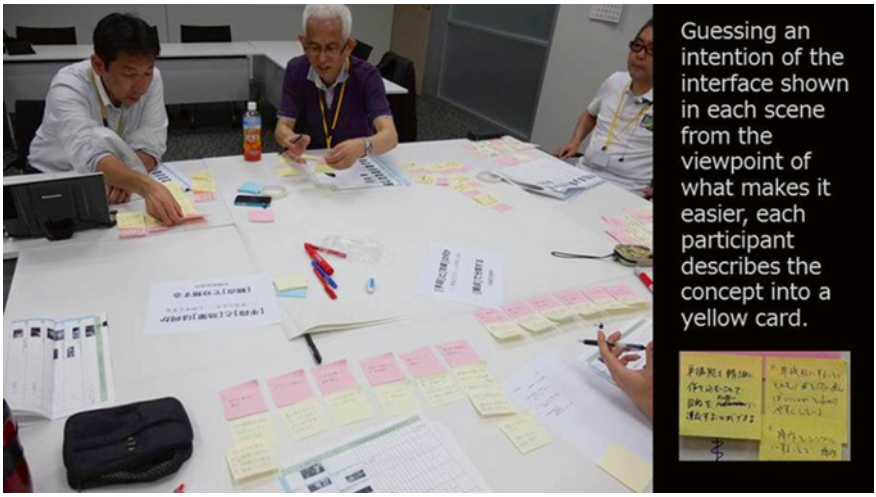

Fig. 2 By estimating the intended purpose of the interface in each scene, each participant describes the concept on a *yellow* card

2.3 Argument on Each Interface and Its Effect

For this step, we used a bottom–up approach. That is, while considering the world-view of the movie, we analyzed each characteristic scene and merged the small classifications into a mid-sized classification before defining a major division. Concretely, we categorized similar effects by focusing on the UI and its effect shown in each scene. This work was performed bilaterally using cards on a large desk, the procedure of which is as follows:

1. By estimating the intention of the UI shown in each scene with regard to what the interface simplifies, each participant describes the concept on a card (Fig. 2).

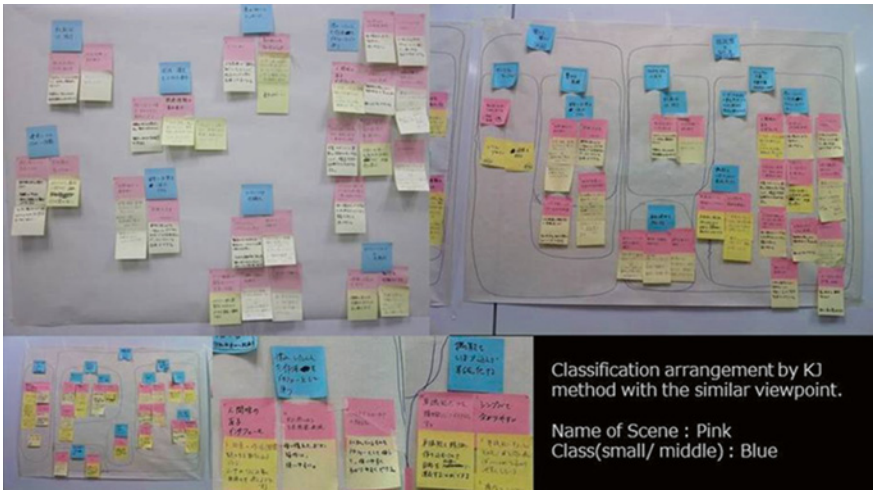

Fig. 3 Classification arrangement by KJ method on the basis of functional similarities (name of scene: *pink*; class *blue*)

2. All participants combine their cards and identify the similarities among them.
3. Cards with similar intentions are grouped together, and a label is attached to each group (Fig. 3).
4. The groups are divided by class, if needed, to form a larger category. Next, the entire composition is examined, particularly, the relationships between the groups.

3 Classification Analysis Results

The results of this work are outlined for the purpose of broad interface classification as shown in Fig. 4. The detailed classification depicts the set of description cards corresponding to each scene.

- Cognitive group representing scenes that "**Aid Users' Understanding**"
- Sensitivity group representing scenes that "**Amplify Pleasure**"
- Cognitive science and ergonomic groups representing scenes that "**Abolish Resistance**"
- Engineering group representing scenes that "**Obtain the Desired Result**"
- A group representing scenes that "**Decrease Load via Rationalization (Total Optimization)**".

Herein, the items listed under the "Decrease Load via Rationalization (Total Optimization)" group are unique to SF films and are related to the design of increased mobility or civilized existence in general.

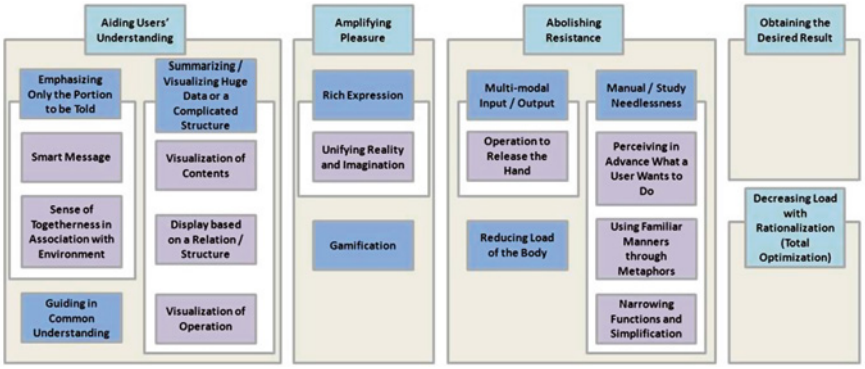

Fig. 4 Classification of user interfaces taken from *Minority Report*

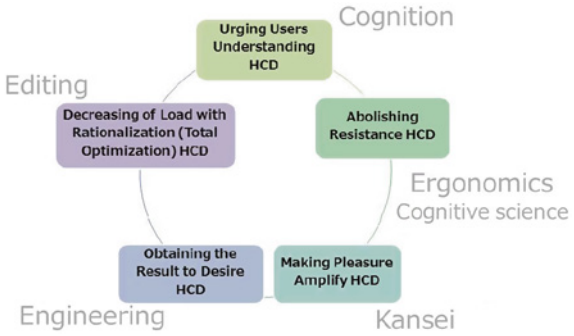

Fig. 5 Matching classifications with user interface viewpoints

Furthermore, these classifications correspond to the conventional UI viewpoints shown in Fig. 5, meaning that the characteristic scenes extracted from the movie using the proposed method complement the UI viewpoints. Thus, each movie scene is matched with one UI viewpoint and refers to these as a precedent example of the UX expression.

4 Discussion

We discussed in detail the results obtained from the analysis of prospective user interfaces shown in the movie *Minority Report*. Our approach is neither global in explaining SF movies, as reports by Aaron Marcus [5, 6], nor an analysis limited to a specific UI, as in *Make It So* [7]. Rather, we analyzed the state of experience in the context while remaining consciously aware of the UX. It is believed that UI design knowledge can be acquired and reused to develop unknown design targets by

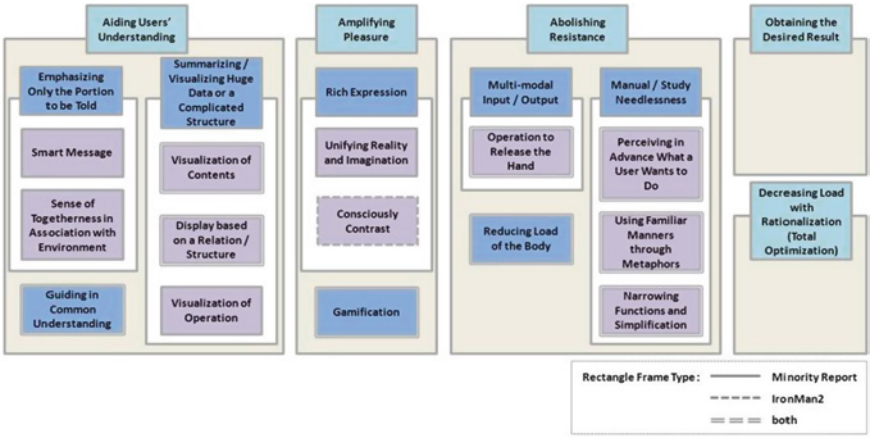

Fig. 6 Classification of user interfaces from *Minority Report* and *Iron Man 2*

objectifying and maintaining UI design viewpoints using this method. That is, the results of this study are expected to affect the design of unique interfaces in HCD-related research. For example, when data must be visualized, by referring to the visualization section in Fig. 4, we believe that new ideas based on the data's relevance to other elements can be obtained. Moreover, the method of intention and the realization of each scene as arranged by the group can be used as a sample for mounting. In other words, each viewpoint is connected to a scene from the movie, and these scenes can be referred to as examples of user interfaces or those of UX expressions.

5 Flexibility Verification of UI Classification

For the first trial for verifying the classification of user interfaces performed for *Minority Report* (Fig. 4) in Chap. 3, we conducted an analysis using the same procedure for *Iron Man 2* to classify the extracted UI.

As a result, additional categories of UI classifications from the extracted scenes of Iron Man 2 were applied to the classification system from the analysis of *Minority Report*. Concretely, only "Consciously Contrast" was added to the subordinate of "Rich Expression" in the "Amplify Pleasure" group. Except for this, the items under the classification system of *Minority Report* were applied in their original state (Fig. 6).

6 Conclusions

In this paper, we reported a trial conducted by the SF-SIG to gain insight into HCD trends of the near future. First, characteristic scenes from the movie *Minority Report* were analyzed. Our argument and analysis began with a top–down

arrangement of scenes in descending order of importance. Second, we classified the extracted characteristic scenes while considering the worldview of the movie. As a result, suggestions were obtained pertaining to the direction of HCD in the near future. Furthermore, the applicability of the obtained UI classification to another SF film was verified. The results of this analysis can be immediately employed as a design tool.

Although security, digital signage, and gesture interfaces are expected to gain more technological leverage, they were not considered in this trial and should therefore be studied in future trials. To improve the usability of this method, we intend to build upon this work by gathering information from other SF films in a similar manner. We will also aim to develop a library consisting of the results of our approach to be used as a dictionary in actual business settings. The library will perform a systematic arrangement that can be visually, concretely, and immediately checked by an actual scene. Furthermore, we will certify the effectiveness of this research using the gathered information for validating new products and business process enhancement designs.

Acknowledgments This chapter was written on the basis of the results of active analyses and discussions among SF-SIG members. We would like to express our gratitude to HCD-Net for its support for the SF-SIG and to all SF-SIG participants.

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Sleep Quality and Skin-Lightening Effects of White Mother Chrysanthemum Aroma

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Abstract In this study, the volatile compounds of white mother chrysanthemum flower were analyzed through gas chromatography-mass spectrometry (GC–MS) and gas chromatography–olfactometry (GC–O) analysis approaches. To investigate the effect of white mother chrysanthemum odor on sleep quality, polysomnography sleep tests and subjective evaluations were performed. A skin-lightening test was performed to investigate the effects of the newly developed night cosmetic cream. During the polysomnography sleep test, 20 female subjects were tested on two separate days: one with fragranced cream and the other with fragrance-free cream. The skin-lightening test was composed of two groups: 10 subjects applied fragrance-free night cream and other 10 subjects applied fragranced night cream. They applied the cosmetic cream to their faces once a day before sleep for 4 weeks. The results show that sleep efficiency was significantly affected by the mother chrysanthemum odor but found that the reconstituted fragrance of white mother chrysanthemum flowers had a skin-lightening effect through sound sleep.

Keywords Polysomnography • White mother chrysanthemum odor • Sleep efficiency • Subjective evaluation • Sleep stages • Overall sleep quality • GC–MS analysis • GC-O analysis • Skin-lightening effect • Night cream

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_19,

1 Introduction

Sleep plays an important role in keeping good health and well-being throughout our lives. We spend approximately one-third of our life in bed, and a synergy of psychological and physical conditions affects the quality of sleep [1]. A sufficient amount of quality sleep can help protect our mental and physical health, quality of life, and safety. The lack of sleep or sleep loss effects on various aspects of performance are numerous and significant. For example, sleep loss leads to more rigid thinking and increased errors in performing a cognitive task [2], safety–critical declines in lane-maintenance performance during simulated driving conditions [3], decreased verbal creativity [4], poor cognitive task performance [5], and increases psychological stress [6]. Sleep also plays an important role in improving skin condition; the lack of sleep can lead to poor skin conditions such as dark skin, atopic dermatitis [7], pruritus, and itchiness [8].

Over the past three decades, research on olfaction has dramatically escalated, with researchers connecting the workings of the olfactory system and the psychological interpretations of odors in terms of mood, behavior, and performance [9–15]. Existing research on the psychological and cognitive aspects of odors is compelling; odors have extensive effects on the human central nervous system [12, 14, 15]. It is reasonable to consider that the human body may respond to odors presented during sleep [16–20]. The exposure to various odors can improve sleep factors, including decreased waking time, increased total sleep time and efficiency, and reduced daytime sleepiness in both young and elderly groups [17, 21–25].

Polysomnographic measurements have been critically important in evaluating the interaction between sleep and physiological changes [26]. Polysomnographic measurements enable to objectively differentiate the effects of sleep from the effects of rest and recumbency. The specific effects of sleep onset, of sleep termination, and of different sleep stages can be separately assessed [27]. Many studies have been performed to analyze sleep quality in the presence of different odors. For example, Polysomnographic measurements have been performed to examine the effects of peppermint [17, 28, 29], lavender [30, 31], jasmine, and lavender [15] odors on sleep; sleep patterns; relaxation effects; alertness; cognitive performance; and mood.

The global cosmeceutical market has an enormous potential among the Asian countries such as Japan, China, and India, which are set to attract major players in the future [32]. Cosmetic and personal care products can be broadly divided into four major categories: skin care, hair care, and oral hygiene, and color cosmetics. Skin care and hair care are the most dynamic sectors in the Asia–Pacific region [33]. The most dynamic products in the skin care sector are skin-lightening products; these products have experienced massive growth and continue to be the best-selling skin care products throughout Asia. Skin-lightening products can be divided into day cream and night cream. Skin-lightening night creams are a 2-in-1 cream that provide moisturizing and lightening effects. Few studies investigated the skin-lightening efficacy of skin care products. In a recent study, [34] evaluated the skin-lightening efficacy and safety of lignin peroxidase (LIP) creams using a regimen of both day and night products

compared with twice-daily applications of a 2 % hydroquinone cream and a placebo in Asian women. In another study, [35] assessed the efficacy and tolerability of a new face care product for the targeted spot treatment of darker pigmented areas in subjects with melasma and evaluated the effects on patient quality of life.

The mother chrysanthemum flower has been used to promote sound sleep in Korea since ancient times [36]. There are two types of flowers in a mother chrysanthemum—yellow and white. These flowers are used for herb tea after drying and placed in pillows to promote better sleep. White mother chrysanthemum flowers have a more sophisticated and characteristic odor than yellow flowers and provide more benefit from an efficacy point of view [37, 38]. To analyze the volatile compounds of the white mother chrysanthemum flower, samples were obtained though a solvent extraction and headspace method, and the active compounds of the white mother chrysanthemum flower aromas were identified through GC–MS and GC-O analyses. Based on the instrumental results, the fragrance of the white mother chrysanthemum flower was created to assess its efficacy in promoting sound sleep.

Although the white mother chrysanthemum flower has a popular reputation in Korea for promoting sound sleep, research studies are lacking. This study examined the effect of white mother chrysanthemum flower odor on sleep quality through objective and subjective measures in healthy female subjects. This study also examined a newly developed night cosmetic cream (containing 0.1 % reconstituted fragrance of white mother chrysanthemum flowers) in terms of its skin-lightening effects on healthy female subjects. We hypothesized that the white mother chrysanthemum flower odor would increase sleep efficiency, overall sleep quality, enhance the level of good feeling, and reduce tension levels and "toss and turn." We also hypothesized that the night cosmetic cream with white mother chrysanthemum fragrance would demonstrate skin-lightening efficacy.

2 Materials and Methods

2.1 Plant Material

The white mother chrysanthemum flowers were collected in the Kugya farm field in Chuncheon, Korea. Sophisticated scent flowers of white mother chrysanthemum were selected for head space and fresh flowers of white mother chrysanthemum were picked for solvent extraction. Solvent extraction was done immediately after picking flowers in the farm field [37].

2.2 GC–MS Analysis

The living flowers of white mother chrysanthemum were covered with a 10-L bell-shaped flask fitted with a Tenax column (30 cm × 3 mm i.e., 60/80 mesh). The inlet end of an air pump was connected with Teflon tubing to the Tenax

column and the outlet end was connected with an activated charcoal column via a Teflon tube. The air was circulated through the charcoal column to the glass flask and the Tenax column at 500 mL/min for 3 h. The volatile components were flushed from the Tenax TA column by heating at 250 °C and directly injected into Hewlet–Packard 5973 mass spectrometer with a PEG-20-M fused-silica capillary column, 60 m × 0.25 mm, 0.25 μm film thickness. The oven temperature was held at 40 °C for 10 min and then programmed at 3 °C/min up to 220 °C, held at 220 °C for 20 min. The carrier gas was He at a flow rate of 1.0 mL/min; the injector port and detector temperature were 250 °C both. The ionization voltage was 70 eV. We picked 301 g of white mother chrysanthemum flowers. Flowers were extracted with diethyl ether for 30 min and 0.5952 g of oil was collected on an evaporator. Oil analyses were performed on a Hewlet–Packard 5973 mass spectrometer with a PEG-20-M fused-silica capillary column, 60 m × 0.25 mm, 0.25 μm film thickness. Oven temperature programmed as follows: 70–220 °C at 3 °C/min, then ending with 40 min at 220 °C. The carrier gas was He at a flow rate of 1.0 mL/min and the split mode had a ratio of 1:40. The injector port and detector temperature were 250 °C and 280 °C, respectively. Identification of the compounds was achieved by matching the mass spectra against NBS/NIST library [37].

2.3 GC–O Analysis

Sensory evaluation was performed by sniffing about head space and solvent extraction both while these components were eluted at the exit port of the gas chromatograph fitted with an effluent splitter. The effluent was proportioned by the splitter at a ratio of 1:10 by passing the former portion to the FID circuit and the latter portion to the exit port. The column and other operating conditions were the same as GC–MS analysis of head space and solvent extraction [37].

2.4 Polysomnography Test

Subjects participated voluntarily and were selected by the ability to adapt to the environs of the sleep laboratory. Subjects with a history or symptoms of sleep disorders, or of abnormal sleep habits were excluded. Subjects participated were free of abnormalities in the sense of smell, and free of otorhinolaryngological diseases. Subjects were asked not to drink any stimulating beverages and avoid strenuous exercise prior to participating in the test. Twenty healthy Korean female individuals ranging in age from 23 to 42 years were participated in this polysomnography sleep experiment; their mean (±SD) age was 31.0 ± 5.39 years. The purposes and procedures of the study were explained to them in detail and they were required to sign a form signifying their consent in their participation.

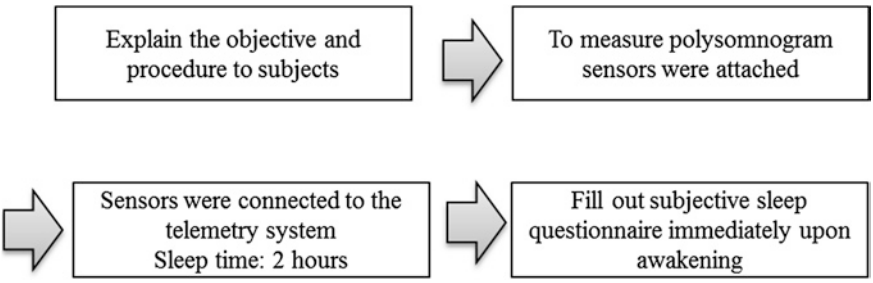

Fig. 1 Experimental protocol

2.5 Skin-Lightening Test

Twenty healthy Korean female individuals participated for skin-lightening test. Twenty females were divided into two groups: 10 subjects applied fragrance-free night cream and another 10 subjects applied fragranced night cream which has 0.1 % reconstituted fragrance of white mother chrysanthemum flowers. They applied the cosmetic cream on the face once a day before sleep at night for 4 weeks. To minimize the influence of solar exposure, all subjects applied sunscreen during the entire test period. In skin-lightening tests, Minolta CM-700D was used to assess changes of L value of skin before and after treatment. For a detailed examination, measurements were performed at least 3 times on the cheek area of the face every 2 weeks.

2.6 Measurement of Physiological Variables

The subjects slept in the sleep laboratory (20.4 ± 1 °C, 50 ± 2 % relative humidity), and electroencephalographic (EEG), electrooculographic (EOG), and electrocardiographic (ECG) data were recorded. The experimental protocol adopted for each subject is shown in Fig. 1. Five electrodes (labeled C3, C4, A1, A2 and O1) and one ground electrode were placed around the cranium to record neuroelectrical activity. These leads were placed based on 10–20 international electrode placement procedure. Six electrodes were used in each subject in order to limit electrode-associated discomfort. These leads were used to determine the stage of sleep the subject was in during any given period of the study. Two channels were used for EOG: one electrode was placed above and to the outside of the right eye and another electrode was placed below and the outside of the left eye. These leads recorded the eye movement during sleep and served to determine sleep stages. Surface chest electrodes were used for recording of ECG, the surface electrodes were placed based on CM_5 method. Polysomnographic data were recorded using the BRAIN QUICK SYSTEM 2, Italy Micromed. When awakening,

subjects were asked about sleepiness, maintenance of sound sleep, anxiety level, and overall sleep quality and ease of entry into a sleep state. The questionnaires were based on a six-point scale consisting of semantic differential method. The subjects slept in the sleep laboratory for 2 h (daytime) in two alternative days, one with fragranced cream and the other with fragrance-free. Participants were not informed that odors were being presented.

2.7 Analysis

Sleep parameters (e.g., total time in bed (TIB) and total sleep time) were collected. The recording was divided into epochs by 30 s. The standard EEG, ECG, and EOG recordings were evaluated and the predominant stage of sleep [39] was assigned to the entire epoch. Sleep quality was assessed using sleep stages. *T* test was done for each pair of variables from all the recorded sleep time for two sleeping conditions (with odor and without odor) to compare sleep quality between the sleeping conditions. Differences of $p < 0.05$ were significant for all statistical analyses. Sleep variables analyzed are sleep efficiency (%), total sleep time (min), sleep latency (min), percentages of stages 1, 2, 3, 4, and rapid eye movement (REM) sleep. Sleep efficiency is an index of time length in bed that is actually spent sleeping, determined by dividing the actual sleep time by the TIB and multiplying by 100. The total time length one spends awake in bed after sleep onset referred as wake after sleep onset (WASO). The sleep onset refers the moment when one falls asleep. Sleep latency is the period of time required for sleep onset after going to bed. REM is the stage of sleep characterized by rapid saccadic movements of the eyes. There are five phases of sleep: stage 1, 2, 3, 4, and REM. Usually when one sleeping, they begin at stage 1 and go through each stage until reaching REM sleep, and then, they begin the cycle again. Each complete cycle takes from 90 to 110 min. Stage 1 sleep is light sleep. During stage 2, eye movement stops and brain waves become slower. Stages 3 and 4 are the first and second stages of deep sleep.

3 Results and Discussion

3.1 Creation of Chrysanthemum Scent

111 components were identified in the head space analysis of white mother chrysanthemum flowers. In the solvent extraction of white mother chrysanthemum flowers, 106 components were identified. The major volatile components of head space and solvent extraction from white mother chrysanthemum flowers are given in Table 1. Sensory evaluation about head space and solvent extraction of white

Table 1 Major components of white mother chrysanthemum flowers from head space and solvent extraction method

Method	Major components	Component quantity (%)
Head space analysis	Phenylacetaldehyde	35.2
	Benzaldehyde	20.6
	Camphor	4.7
	2-phenylethyl alcohol	3.8
	Bornyl acetate	1.7
	Benzyl alcohol	2.3
Solvent extraction	Camphor	44.5
	Camphene	13.4
	Bornyl acetate	9.9
	a-pinene	5.0
	Germacrene D	3.3
	Borneol	1.6
	Caryophyllene	1.2

mother chrysanthemum flowers revealed that camphor, cis-3-hexenol, borneol, phenylacetaldehyde, and 2-phenylethyl alcohol were key components for the characteristic odor of white mother chrysanthemum flowers by GC–O. The fragrance of white mother chrysanthemum flower was created based on the analytical result of GC–MS and GC–O to assess the sound sleep efficacy.

3.2 Subjective Evaluation

When awakening, subjects were asked about the overall sleep quality, deep sleep, sleepiness, toss and turn, tension level, good feeling level, anxiety level and ease of entry into a sleep state. The questionnaires were based on a six-point scale and subjective evaluation conducted in both conditions (with odor and without odor). Score 1 represents high level and score 6 represents the lowest level of the factors toss and turn, and tension level. In good feeling level and overall sleep quality factors, score 6 represents high level and score 1 represents the lowest level. The mean (SD) of the subjective evaluation results is presented (Fig. 2). Sleeping with odor results show that, the average toss and turn score was significantly ($p < 0.05$) lesser, the average tension score was significantly ($p < 0.05$) lesser, the average good feeling score was higher, and finally, the average overall sleep quality was significantly ($p < 0.05$) higher than without odor. With these scores we can conclude that, using the white mother chrysanthemum odor would increase the overall sleep quality and good feeling level and reduce the tension level and toss and turn. In Raudenbush et al. [29], participants reported reduced mental, physical, and temporal workload requirements, decreased effort and frustration, and increased performance and vigor when presented odorant (jasmine or peppermint). In Raudenbush et al. [15], participants rated good feeling level and reduced

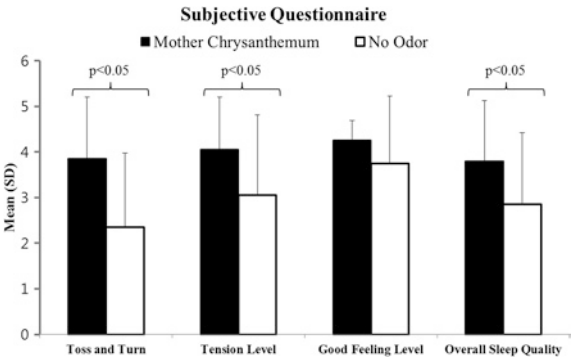

Fig. 2 Subjective questionnaire results comparison between sleeping with and without odor

movement upon awakening while sleeping with jasmine odor comparing with non-odored conditions. The present findings support the past research findings such as odorant administration as an assistant to improve sleep, good feeling level and reduced sleep movement.

3.3 Sleep Variables

Average sleep-stage composition (%) and the standard deviations of the twenty subjects while sleeping with and without odor are shown in Table 2. Average total times in bed were 120.63 (2.46) min and 116.50 (7.83) min while sleeping with and without odor, respectively. Significant differences were found between two conditions. When WASO is increased, it results in poor sleep efficiency. In our case, the average WASO showed a tendency to be longer while sleeping without odor. Therefore, we can expect good sleeping efficiency while sleeping with odor. With reference to WASO, the sleep efficiency is higher while sleeping with odor. High sleep efficiency signifies that a subject fell asleep quickly and did not often awaken prior to being roused at the conclusion of the test period. The REM was also showing a tendency to be longer while sleeping without odor. The sleep latency was almost similar between two conditions, which mean it took similar length of time for the subjects to fall asleep.

The percentage of sleep time during stage 1 was significantly higher while sleeping with odor. Also in the stage 2, the percentage of sleep time was higher while sleeping with odor, and there was no significant difference between the two cases. In the stages 3 and 4, the percentage of sleep time was higher while sleeping without odor. The reason could be the duration of sleep was less and also tests were performed during the daytime. But there was no significant difference between sleep time in stages 3 and 4. Also higher standard deviation was observed in the percentage of sleep time at S3 + S4 sleeping without odor. In a study [15] compared with non-odor control condition, jasmine odor administration led to greater sleep efficiency and reduced sleep movement. Many other studies

Table 2 Average percent sleep-stage composition and standard deviations of 20 subjects while sleeping with and without odor

Parameter	Mean (S.D)	
	With mother chrysanthemum odor	Without odor
TIB (min)*	120.63 (2.46)	116.50 (7.83)
Sleep efficiency (%)	63.50 (22.35)	55.00 (26.84)
WASO (min)	15.42 (15.58)	19.95 (26.96)
Sleep latency (min)	29.55 (18.23)	29.85 (17.71)
Stage 1 (% of sleep period time)*	23.03 (11.94)	14.73 (13.53)
Stage 2 (% of sleep period time)	24.81 (13.81)	23.82 (21.55)
Stage 3 (% of sleep period time)	15.83 (10.21)	21.78 (21.91)
Stage 4 (% of sleep period time)	9.98 (14.23)	11.08 (13.24)
REM (%)	4.97 (9.85)	7.31 (11.02)
S3 + S4 (% of sleep period time)	25.8 (18.65)	32.86 (39.96)

SD: variability across 20 subjects' mean scores
Paired sample *t*-test performed
* $p < 0.05$

indicated that odors have extensive effects on the human central nervous system [12, 14, 15, 40, 41]. Those studies did not considered REM or EOG activity, but in the present study, REM level is lesser while sleeping with white mother chrysanthemum odor. The present findings provide additional support to the past research that white mother chrysanthemum odor presented during sleep has marked effects on sleep behavior. And also found that the human body can respond to odors presented during sleep.

3.4 Skin-Lightening Effect

It showed that the ΔL value of white mother chrysanthemum fragranced night cream group increased up to 3.8 % and 9 subjects among 10 subjects increased ΔL value after 4 weeks, but there was no change of ΔL value at unfragranced night cream group (Fig. 3). After 4 weeks of treatment, a night cream containing 0.1 % reconstituted fragrance of white mother chrysanthemum flowers increased ΔL value showing statistically significant and important skin-lightening efficacy. As hypothesized, the night cosmetic cream with white mother chrysanthemum fragrance has the skin-lightening efficacy. The past research on skin-lightening efficacy with skin care products also reported the similar findings. For example, in a study [35] reported that application of face care product resulted in a significant lightening of melasma in comparison with baseline and in untreated control areas. The melasma area and severity index score dropped by more than 40 % after 8 weeks. In another study, [34] reported that application of day/night LIP cream provided a significantly more rapid and observable skin-lightening effect than hydroquinone 2 % cream or placebo.

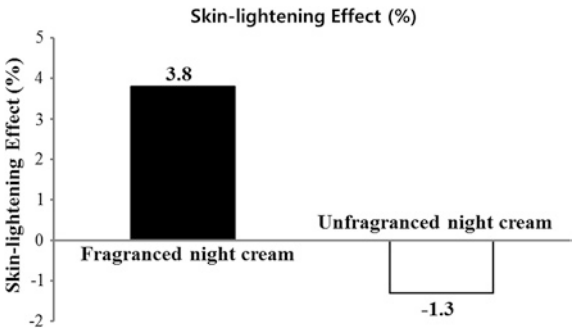

Fig. 3 Skin-lightening effects after 4 weeks comparison between night cream with and without white mother chrysanthemum fragrance

4 Conclusions

The mother chrysanthemum flower has been used to promote sound sleep in Korea since ancient times. Mother chrysanthemum has two kinds of flowers—yellow and white. Although the white mother chrysanthemum flower is more popular in Korea for promoting sound sleep, research studies are lacking. This study is the first to examine the effects of white mother chrysanthemum odor on PSG sleep and skin-lightening efficacy in healthy female subjects. GC–MS and GC-O analyses revealed that camphor, cis-3-hexenol, borneol, phenylacetaldehyde, and 2-phenylethyl alcohol were key components for the characteristic odor of white mother chrysanthemum flowers. The white mother chrysanthemum flower fragrance was created (based on these key components) to assess its effect on sound sleep. The subjective evaluation concluded that using white mother chrysanthemum odor while sleeping increases overall sleep quality and levels of good feeling and reduces tension levels and tossing and turning. Sleep efficiency (%) increased while sleeping with white mother chrysanthemum odor compared with sleeping under non-odor conditions. These findings provide additional support to past research indicating that odorant administration assists in improving sleep, increasing levels of good feeling and reducing sleep movements; the white mother chrysanthemum odor presented during sleep had a marked effect on sleep behavior. It was also found that the human body can respond to odors presented during sleep. In a night cream containing 0.1 % reconstituted fragrance of white mother chrysanthemum flowers, increased ΔL values showed statistically significant and important skin-lightening effects after 4 weeks of treatment. We found that the reconstituted fragrance of white mother chrysanthemum flowers offered skin-lightening effects during sound sleep.

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The Emotional Characteristics of White for Applications of Product Color Design

Nooree Na and Hyeon Jeong Suk

Abstract This study investigates the emotional characteristics of various shades of white. In Experiment I, the emotional characteristics of 13 basic colors were evaluated based on four factors—*flamboyant*, *elegant*, *clear*, and *soft*—and white was identified to be dominantly elegant. In Experiment II, the emotional characteristics of whites were assessed to derive an equation for predicting the emotional quality. In Experiment III, 1:1 scale mock-ups of mobile phones, coated with various shades of white as well as different levels of gloss and texture, were employed for the further emotional assessment in real-life situations. Consistent tendencies were observed in the experiments, confirming the validity of the results. In addition, although color was the most dominant element in deciding product emotion, gloss, and texture were also influential elements. This study provides empirical evidence of the emotional responses to different shades of white and can help designers find an appropriate color for designing white-based products.

Keywords Color emotion • Product color • Color-material-finishing (CMF) • White

1 Introduction

Humans experience diverse colors throughout their daily lives, and it is well known that color affects human emotions and feelings. According to Ou [1], every color has its own characteristics and each color induces different feelings. For example, red is associated

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_20,

with exciting and stimulating emotions, whereas blue is associated with secure and comfortable feelings. Moreover, color is of great importance for deciding product emotion, and it is regarded as a vital element for showing the relationship between a product and its function, shape, and material [2]. Color is what ultimately attracts consumers and convinces them to purchase a product. Therefore, selecting appropriate colors and conveying the desired product emotion are essential in product design.

In comparison to other colors, white exudes a positive impression, reminding users of clean, pure, refreshing, beautiful, gentle, and natural sentiments [3]. White also has a particularly distinct role in perceptional aspect. First, it is the standard for measuring the colorimetric system. Second, as a color gets closer to white, its color tolerance also becomes lower [4]. Third, white is the most universally used color in all industries [5].

A deep understanding of the many roles of white together with its various attributes can potentially open new, interesting lines of topics for designers to incorporate in their works [6]. Thus, it is not only important for product designers to understand the emotional characteristics of colors referred to as 'white'; it is also crucial for them to conduct thoughtful research about the emotional influences of color on products and on plans to commercialize the actual product. However, there are few papers and books that address white because white is generally not considered a color. Therefore, this study attempts to empirically investigate the emotional characteristics of various shades of white. Furthermore, it intends to provide a design guideline for selecting appropriate colors that truly convey the designers' desired emotions for white-based products.

2 Objectives

This study is intended to identify the emotional characteristics of various shades of whites and to provide empirical evidence that is applicable for the product design industry. Accordingly, three objectives were formulated as follow:

1. To explore emotional factors through the quantitative profiling of the emotional characteristics of product color
2. To identify the emotional characteristics of whites depending on nuances
3. To develop a guideline for suggesting the appropriate white during design processes based on the desirable emotional characteristics of a product.

3 Experiment I: Exploring Emotional Factors

3.1 Method

3.1.1 Stimuli

Sixty adjectives that represent emotions stimulated by products or colors were selected through a literature review [7, 8]. After that, a questionnaire was conducted evaluating

Table 1 20 emotional adjective groups for evaluating product color

Charming	Calm/graceful/mild	Cheerful	Classic	Clean/clear
Comfortable	Dignified/elegant/noble	Cozy/soft	Delicate	Cute
Flamboyant	Impressive/stand out	Fresh	Light/weighty	Lovely
Luxurious	Modern/sophisticated	Neat	Sensuous	Weak

Table 2 13 color stimuli extracted from the hue and tone 120 system (color table online)

Color	Munsell Hue	Tone	Code
	5R (red)	V (vivid)	5R/V
	5YR (yellow red)	V (vivid)	5YR/V
	5Y (yellow)	V (vivid)	5Y/V
	5GY (green yellow)	V (vivid)	5GY/V
	5G (green)	V (vivid)	5G/V
	5BG (blue green)	V (vivid)	5BG/V
	5B (blue)	V (vivid)	5B/V
	5PB (purple blue)	V (vivid)	5PB/V
	5P (purple)	V (vivid)	5P/V
	5RP (red purple)	V (vivid)	5RP/V
	N9.5 (white)	N (neutral)	N9.5
	N6 (gray)	N (neutral)	N6
	N1.5 (black)	N (neutral)	N1.5

how well the adjectives convey the emotions induced by a product color. Based on the response s, a list of 20 emotional adjectives was extracted as shown in Table 1.

As basic color stimuli, 13 colors were chosen from the Hue & Tone 120 System and shaped into 3 cm × 3 cm square patches. As shown in Table 2, the collection of colors was composed of 10 hues with vivid tone and 3 neutral colors.

3.1.2 Participants and Procedure

Thirty participants comprised of 16 male and 14 female students took part in the experiment. The average age was 23.60 years with a standard deviation of 2.63 years. Participants assessed 13 basic colors with 20 emotional adjective groups using the 7-point Likert scale (7 point; very appropriate, 1 point; not appropriate).

3.2 Result and Analysis

The reliability test showed that there were significant differences between the colors (Cronbach's alpha value > 0.80, KMO > 0.80). Next, factor analysis was

Table 3 4 Emotional factors from factor analysis

Factor label	Include adjectives
How *flamboyant* is it?	Charming, cute, flamboyant, impressive/stand out, lovely, sensuous,
How *elegant* is it?	Calm/graceful/mild, classic, dignified/elegant/noble, luxurious, modern/sophisticated, neat
How *clear* is it?	Cheerful, clean/clear, fresh, light, weak
How *soft* is it?	Comfortable, cozy/soft, delicate

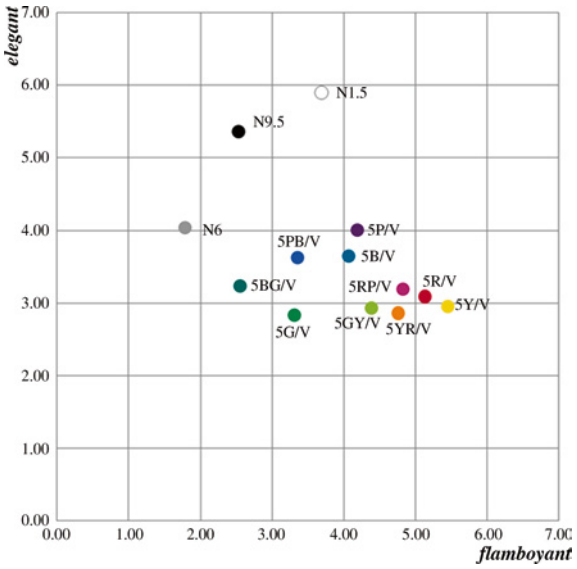

Fig. 1 Emotional characteristics of 13 basic colors

performed to select the emotional factors for evaluating product color. Table 3 shows the four selected factors, which account for 66.39 % of the data. Adjectives like 'flamboyant,' 'stand out/impressive,' 'lovely,' 'charming,' 'sensuous,' and 'cute' were grouped in factor 1 and categorized as *flamboyant*. The remaining three emotional factors include *elegant*, *clear*, and *soft*.

The emotional characteristics of the 13 basic colors were obtained by calculating their mean score and positioning them on a two-dimensional graph labeled *flamboyant* in the horizontal axis and *elegant* in the vertical axis. As shown in Fig. 1, warm colors received high *flamboyant* scores, whereas cold colors and neutral colors did not. Accordingly, neutral colors are not regarded as flamboyant, but rather more elegant relative to vivid colors. Among the neutrals, white dominantly appears to be perceived as most elegant.

4 Experiment II: Examining Emotional Characteristics of Various Whites

4.1 Method

4.1.1 Stimuli

As shown in Table 4, 25 white color patches in various shades were selected from the Natural Color System (NCS). The patches were made up of one neutral color and eight hues with three levels of saturation. In addition, three anchor colors were embedded among the color stimuli to compare the evaluation results with Experiment I. In order to analyze the result quantitatively, the CIE 1976 Lab value of all the color stimuli was measured using a spectrophotometer.

4.1.2 Participants and Procedure

A group of 30 participants comprised of 13 male and 17 female students were recruited. Their average age was 23.33 years with a standard deviation of 3.24 years. All participants were paid volunteers and students without color vision problems. Participants were asked to evaluate the white color stimuli with four emotional factors extracted from Experiment I using a 7-point Likert scale.

4.2 Result and Analysis

A reliability test was conducted on each emotional factor. The results indicated that all evaluation s were reliable (Cronbach's Alpha value: *flamboyant*: 0.84; *elegant*: 0.83; *clear*: 0.73; *soft*: 0.65). Next, using their mean scores, all the white colors were positioned on a two-dimensional graph represented by the *flamboyant* and *elegant* factors. As is the case for the basic colors, various whites displayed respective emotional characteristics according to the different shades of color. As shown in Fig. 2, whites with warm shades were regarded as more flamboyant relative to whites in cold and neutral shades. In order to analyze this distribution tendency quantitatively, multiple regression analysis was performed using the value of hue (a, b), brightness (L), and saturation ($C = (a^2 + b^2)1/2$) as independent variables and the result of the emotional evaluation as a dependent variable. a and b value, signifying hue, had independent effects on the outcome ($+a$: red; $-a$: green; $+b$: yellow; $-b$: blue). The effect of saturation C was not independent,

Table 4 25 White color and three anchor color stimuli selected from NCS (color table online)

Color	Hue Category	Saturation	CIE1976 Lab			Code
			L	a	b	
	Yellow	High	92.63	−1.15	5.35	Y/H
	Yellow red	High	91.60	2.17	3.70	YR/H
	Red	High	91.48	3.27	1.72	R/H
	Red blue	High	92.47	2.12	−1.96	RB/H
	Blue	High	91.02	−0.44	−2.78	B/H
	Blue green	High	91.33	−2.85	−2.35	BG/H
	Green	High	91.88	−3.9	1.01	G/H
	Green yellow	High	91.76	−3.63	5.65	GY/H
	Yellow	Medium	92.43	−0.41	4.65	Y/M
	Yellow red	Medium	91.70	3.09	4.03	YR/M
	Red	Medium	92.17	2.78	1.55	R/M
	Red blue	Medium	92.25	1.79	−1.49	RB/M
	Blue	Medium	90.89	−0.53	−1.8	B/M
	Blue green	Medium	91.79	−2.74	−1.34	BG/M
	Green	Medium	91.66	−3.02	0.84	G/M
	Green yellow	Medium	91.74	−3.27	4.19	GY/M
	Yellow	Low	91.36	−1.03	5.07	Y/L
	Yellow red	Low	91.83	3.36	5.45	YR/L
	Red	Low	91.44	2.28	1.10	R/L
	Red blue	Low	91.69	3.53	−2.67	RB/L
	Blue	Low	90.55	−0.67	−3.17	B/L
	Blue green	Low	90.15	−2.34	−1.85	BG/L
	Green	Low	91.68	−3.71	0.66	G/L
	Green yellow	Low	90.73	−3.54	2.99	GY/L
	Neutral	–	91.46	−0.25	1.23	N
	White	–	92.81	−0.72	0.76	White
	Gray	–	60.90	−0.82	−4.87	Gray
	Black	–	24.96	0.32	0.22	Black

as it is a result of an interaction between *a* and *b* value. However, the *C* value was included in the equation as an independent variable to increase the equation's explanation capacity. By conducting multiple regression analysis, a color emotion equation was derived, as shown in Table 5, which can be used to predict the emotional qualities of white-based products based on the color attributes of white.

How *flamboyant* a color feels is affected by hue and saturation. This means that colors with higher *a* and *C* values and lower *b* values, specifically more saturated and purplish whites, are more flamboyant than other colors. The *elegant* factor depends on the hue and brightness of a color. White color with high brightness, high a value, and low b value enhances the elegant feeling. Finally, the perception of *clear* and *soft* emotions in a color is influenced by hue, saturation, and brightness all together. For example, white in a highly saturated cold shade (low *a* and *b*

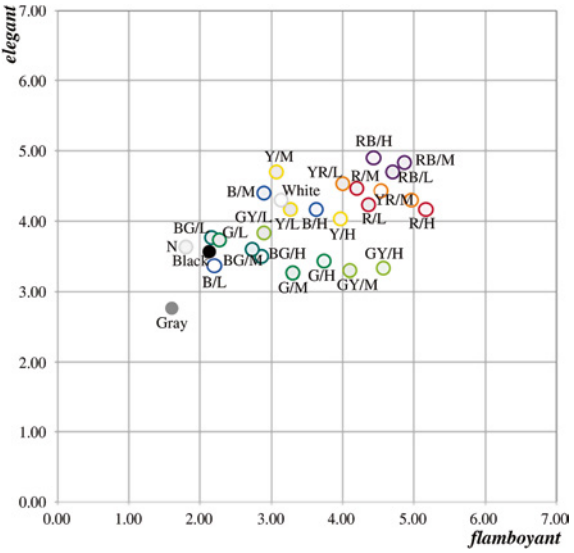

Fig. 2 Emotional characteristics of *white* and anchor color stimuli

Table 5 Color emotion equation using color values

Emotional factor	Color emotion equation using color values (L, a, b, C)	R^2	Sig.
Flamboyant	0.4a − 0.3b + 0.56C	0.76	.00*
Elegant	0.18L + 0.22a − 0.09b − 12.49	0.69	.00*
Clear	0.7L − 0.16a − 0.31b + 0.3C − 60.58	0.68	.00*
Soft	0.27L + 0.09a + 0.16C − 20.42	0.47	.01*

Scale: 1–7
L, a, b, c values are pragmatic measures to express color perceived through human vision

value) with high brightness expresses strong sentiment of clearness, whereas white in a highly saturated red shade (high *a* value) with high brightness feels softer relative to other whites. As such, the distinctive emotional characteristics of a particular white can be predicted by putting its color values in the suggested color emotion equations.

5 Experiment III: Identifying the Effect of CMF on White

5.1 Method

5.1.1 Stimuli

In deciding the Color-Material-Finishing (CMF) elements prior to conducting the experiment, it was assumed that both hue and saturation represent color, that texture

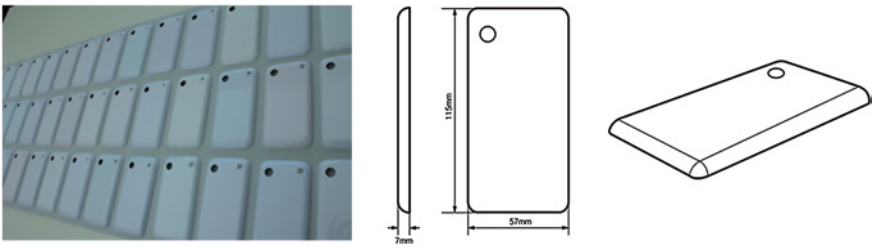

Fig. 3 45 CMF stimuli and stimulus drawing

is related to material, and that gloss equates to finishing. As stimuli, nine whites with different shades were selected among the stimuli used in Experiment II—Y/H, R/H, B/H, G/H, Y/L, R/L, B/L, G/L, N—four hues with two levels of saturation and one neutral color. Afterward, each color was divided into three levels of gloss and texture (gloss: high, medium, low; texture: smooth, medium, rough). In such a manner, a total of 45 stimuli in various hues, saturations, glosses and textures were prepared. To create the feeling of real products for experimentation, stimuli were produced as 1:1 scale mock-ups of mobile phone using plastic (Fig. 3).

5.1.2 Participants and Procedure

Fifteen male and 15 female students participated in the experiment. Their average age was 22.27 years with a standard deviation of 2.25 years. Participants assessed the CMF stimuli using four emotional factors—*flamboyant*, *elegant*, *clear*, and *soft*—on a 7-point Likert scale. The stimuli were arranged in random orders and given to the participants all at once. During the experiment, participants were allowed to freely feel the texture of the stimuli with their fingers to truly grasp the sense of the product.

5.2 Result and Analysis

To analyze the effects of CMF elements on the emotional characteristics, 4-way ANOVA was conducted using hue, saturation, gloss, and texture as independent variables and the evaluation score of the respective emotional characteristics as the dependent variable. As a result, hue had a significant effect on most of the emotional characteristics, including *flamboyant*, *elegant* and *clear*, whereas saturation was significant for only *elegant* and *clear*. Gloss was significant for *flamboyant*, *clear*, and *soft*, and texture had a high significance level for all of the emotional characteristics. In addition, the average standard error of each emotional characteristic depending on respective CMF elements was calculated as shown in Table 6. The results illustrate that the average standard error for hue was highest, followed

Table 6 Average standard error of each emotional characteristic

CMF element	Emotional characteristics (SE)				Average
	Flamboyant	*Elegant*	*Clear*	*Soft*	
Hue	0.088*	0.091*	0.097*	0.105	0.105
Saturation	0.061	0.060*	0.063*	0.069	0.065
Gloss	0.078*	0.077	0.078*	0.080*	0.077
Texture	0.077*	0.075*	0.077*	0.075*	0.076

Table 7 Correlation coefficient of each emotional characteristics based on gloss and texture

CMF element	Emotional characteristics (correlation coefficient)			
	Flamboyant	*Elegant*	*Clear*	*Soft*
Gloss	0.90	0.42	0.76	−0.32
Texture	−0.81	−0.93	−0.80	−0.91

by gloss, texture, and saturation, respectively. The size of the standard error indicates how much each CMF element influences emotional characteristics, where the influence becomes greater with higher standard error. In this study, it was observed that hue plays the most powerful role in determining the emotional characteristics of white products, whereas saturation plays the smallest role. The influences of gloss and texture were relatively similar, both greater than saturation but smaller than hue.

Next, correlation analysis was conducted to find the relation between color and gloss or texture. The results of the correlation analysis in Table 7 showed that there was a positive correlation between gloss and *flamboyant*, *elegant*, and *clear,* respectively, and a negative correlation between gloss and *soft*. This means that surfaces with high gloss enhance *flamboyant*, *elegant*, and *clear* emotions, and surfaces with low gloss stimulate s*oft* sentiments. In the case of texture, there was a strong negative correlation with all of emotional characteristics. In other words, smooth texture effectively maximizes all four emotional factors.

6 Implications for Design Practice

6.1 Color Design Guideline for White-Based Products

A color design guideline was developed that proposes a list of product emotions and the corresponding color, gloss, and texture for portraying those emotions. As shown in Table 8, there are 16 categories of product emotions based on which emotional characteristics are desired. For each emotion, the most suitable color, gloss, and texture are suggested. For example, to highlight the *flamboyant* emotion, highly saturated red white with high gloss and smooth texture is recommended. Blank spaces indicate that there are no applicable conditions to express those emotions because there are contradictions between the combination of emotional characteristics and

Table 8 Color design guideline for white-based products

Emotional characteristics				Color	Gloss	Texture
Flamboyant	*Elegant*	*Clear*	*Soft*			
+	−	−	−	Highly saturated red white	High	Smooth
−	+	−	−	–	High	Smooth
−	−	+	−	Highly saturated blue green white Highly saturated blue white Medium saturated blue white	High	Smooth
−	−	−	+	Low saturated yellow red white Low saturated yellow white Low saturated green yellow white Low saturated green white	Low	Smooth
+	+	−	−	Low saturated red blue white	High	Smooth
+	−	+	−	–	High	Smooth
+	−	−	+	Highly saturated yellow red white	–	Smooth
−	+	+	−	–	High	Smooth
−	+	−	+	Medium saturated red white Low saturated red White	–	Smooth
−	−	+	+	Highly saturated yellow white Highly saturated green yellow white Medium saturated green yellow white Medium saturated green white Medium saturated yellow white Medium saturated blue green white	–	Smooth
+	+	+	−	–	High	Smooth
+	+	−	+	Medium saturated red blue white Medium saturated yellow red white	–	Smooth
+	−	+	+	–	–	Smooth
−	+	+	+	–	–	Smooth
+	+	+	+	Highly saturated red blue white	–	Smooth
−	−	−	−	Neutral white Low saturated blue green white	–	Rough

the emotions emphasized by a particular color. In these situations, using additional solutions, such as color combinations or patterns, is recommended.

6.2 Color Emotion Equation

Color emotion equation was proposed to allow designers to identify the emotional characteristics of selected colors. For example, there are two different shades of white. White A has yellow nuance, and white B is tinged with blue, as shown in Table 9. The emotional response of each color can be predicted by substituting the respective color values into a color emotion equation. In this case, the scores of *elegant* and *soft* factors are similar. The output of the equation suggests that white A is preferable over white B for *flamboyant*. Finally, in terms of *clear*, white B has

Table 9 Score of four emotional characteristics of white A and white B (color table online)

Color	Color name	Color value			Score of the emotional characteristics (scale: 1–7)			
		L	a	b	*Flamboyant*	*Elegant*	*Clear*	*Soft*
	white A	90.91	3.07	5.37	3.12	4.16	2.93	5.04
	white B	93.28	−1.49	−1.13	1.01	4.18	6.04	4.57

a noticeably higher score. It means that if a designer wants to render an impression of clarity and softness to product, white B is the more appropriate choice.

Through the use of the two color design applications, designers can select appropriate white colors on the type of emotion they wish to evoke with objective validation backing up their choice of product color. The suggested design applications were based on the collective opinion of the general majority. Hence, referring to the guidelines can provide an advantage compared to making a color design based on the designers' own subjective opinions.

7 Conclusions

In this study, the emotional characteristics of various whites in different shades were investigated. Through the results, four emotional factors—*flamboyant, elegant, clear,* and *soft*—were extracted. By assessing white under the criteria of these factors, it was determined that each white has its own respective emotional characteristic that is affected by hue, saturation, and brightness. With this, it is worthwhile to carefully consider the *elegant* factor of whites. In comparison with other colors, white was discovered to be the most elegant. Therefore, though some whites have relatively low scores for the *elegant* factor derived from the color emotion equation, it should be duly noted these low-valued whites are still comparatively more elegant than other non-white colors. Accordingly, whites with high *elegant* factor scores should exude an exceptional level of elegance.

Additionally, the effect of the CMF element on white-based products was also identified. For example, products with a high gloss maximize flamboyant, elegant, and clear emotions but reduce the sense of softness. However, hue was identified as the element that plays the most decisive role in expressing product emotions, followed by gloss and texture, both with similar effects. Saturation, on the other hand, appeared to play a relatively minor role. Nevertheless, gloss, texture, and saturation are still influential variables and should be considered as good alternatives to hue for generating a change in the emotional characteristics of products. This result will be more applicable to practical product design than was possible—previous studies because it considers not only the emotion induced by colors but also the influence of gloss and texture, which are really important elements when producing actual products.

By assembling the collection of results from the experiments, a color design guideline and a color emotion equation were developed. These applications can be usefully employed during the product design process when designers experience difficulty in deciding the color, gloss and texture of their products. Moreover, it is efficient in both time saving and resources saving in the process of product throughout reducing the trial and error numbers in the color selection of the product. This study represents an underlying yet essential effort toward drafting a product color design guideline.

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The Influence of Skincare Routines on Skin Physiology Parameters and Affective Values

Yuet Sim Chan, Yukiko Tamura, Misako Kuroda and Takao Someya

Abstract Hydration is an essential process in skincare treatments. Low water content in the skin can lead to skin problems, including reduction in skin elasticity and an increase in skin ripples or wrinkles. Consumers use skincare products to reduce age- and environment-related skin changes. Based on our company beauty theory, we proposed a unique skincare routine coupled with a specially formulated moisturizer that improves skin complexion and has the potential to enhance our customer affection, thus generating an overall high customer satisfaction. By using a scientific approach as well as Nagamachi (Applied Ergon 33:289–294, 2002) [1], the differences in skin physiology parameters and affective values, attributed to the various skincare routines, were assessed in the study subjects who underwent a home-use test.

Keywords Skincare routine • Moisturizer treatment in advance • Skin physiology parameter • Affective value

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_21,

1 Introduction

There are numerous skincare products available on the market today. Products such as cleansing oils and facial cleansers are used for facial cleansing. Other products, including lotions, moisturizers, serums, and creams are primarily used to provide nutrition, moisture, and emollients to the skin. In general, all skincare products aim to maintain the skin in its best condition and make the skin look young, healthy, and beautiful.

In addition to various types of skincare products, cosmetics manufacturers recommend various skincare routines that suggest the amount of product and method for use to obtain optimum product efficacy. The commonly recommended skincare routines involve the application of lotion immediately after facial washing, followed by the application of a moisturizer or cream.

However, during facial washing, in addition to removing sebum, makeup, and skin impurities, moisturizer factors and skin components are also removed. Therefore, we believe that it is necessary to supply the skin with a moisturizer element immediately after facial washing. Thus, we introduce an original beauty theory called the "4-step routine with moisturizer treatment in advance." This theory proposes the application of our specially formulated moisturizer before applying any other skincare products. Our specially formulated moisturizer contains the optimum balance of moisture, oil, and natural moisturizing factor (NMF) suitable for use immediately after facial washing (Fig. 1).

This original 4-step routine has three main characteristics that primarily focus on the use of the specially formulated moisturizer. First, the moisturizer is applied after facial washing to create an optimum moisture balance in the corneal layer and to make the skin supple. Second, a facial cotton pad is used to apply the moisturizer evenly for instant absorption and to aid in skin softening. Third, one teaspoon of moisturizer is used to thoroughly deliver the moisturizing ingredients to the corneal layer (Fig. 2).

The quality of the cosmetics affects the customers' attitude during their judgment of the value of the product. These qualities create affective values based on changes in the affection of a user [2–4]. We at Albion, owing to our status as a luxury cosmetics manufacturer, promote our products to our customers through counseling services instead of mass media advertising. We believe that through counseling, we can provide a high level of customer service while selling our high-quality products. Therefore, our original 4-step routine has successfully helped us upgrade our products' affective value and our brand image over the years.

We have previously studied the efficacy and quality of the 4-step routine and various skincare products through customer feedback, customer interviews, and sales counseling. Through all of these years, our original 4-step routine has enjoyed good customer reviews. In this study, a home-use test was used to evaluate the efficacy of the "4-step routine with moisturizer treatment in advance" and our skincare products by using a scientific approach and affective engineering.

Before beginning this study, we referred to other published reviews that focused on obtaining an in-depth understanding of affective values of cosmetics

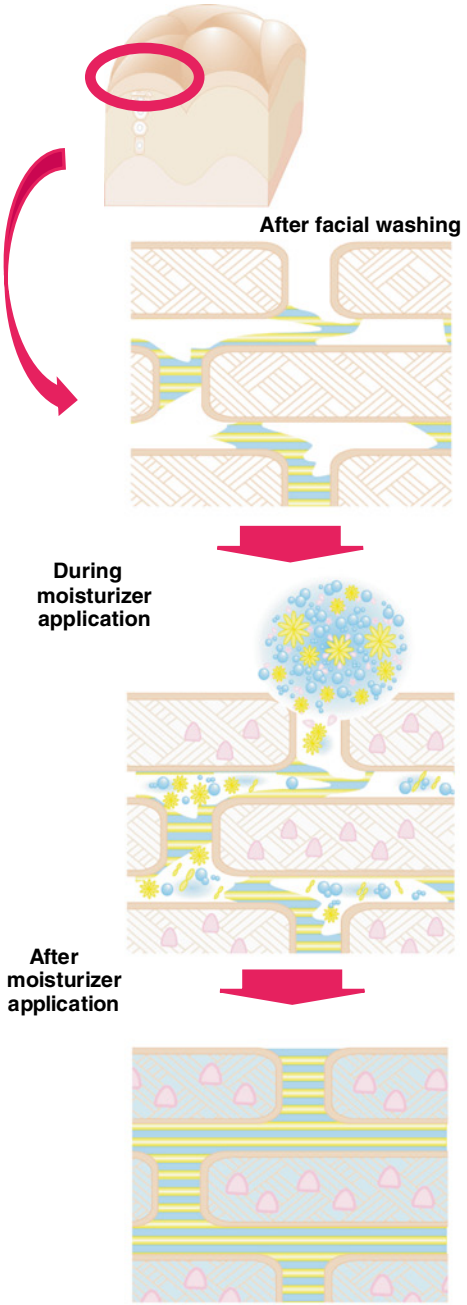

Fig. 1 Schematic of condition of the skin, from the beginning of facial washing to after completion of moisturizer application

products and feelings of luxury. We gained a great deal of inspiration and many ideas about the methodology from the reviews surveyed. For example, by applying 2 methods "magnitude estimation" for furnishing quantitative data and "protocol

Fig. 2 Applying moisturizer with a facial cotton pad

analysis" for qualitative data, the changes in the emotions of a user who uses a facial cleanser, lotion, and emulsion in a specific sequence can be traced and evaluated both qualitatively and quantitatively [5, 6]. These emotional changes, considered as changes in the affective values of the individual, have great importance in the development of skincare products [7].

Additionally, there are many studies being conducted to examine the effects of the application methods of skincare products. For example, a 2-week study focusing on subjects who apply lotion by hand compared with those who apply it with a facial cotton pad showed a significant difference in the amount of moisture of the skin [8]. In addition, subjects that applied lotion by padding with a facial cotton pad were also shown to gain better satisfaction in terms of the lifting-up effect, improvement in the blood circulation, and the pore minimization effect. Together, these proved that differences in the method of application of a skincare product affect the user's affective value, based on the mean result of sensory evaluations, consequently leading to better customer satisfaction.

In this study, we launched a 4-week home-use test that provided a better understanding of the efficacy and influence of skincare routines on their users by evaluating skin physiology parameters and affective values.

2 Methods

Forty female adults who committed all of the conditions shown in Fig. 3 were selected to join this home-use test study. The selected subjects were then divided into 4 groups. Each group used a series of test items (skincare products) twice daily for 4 weeks continuously. The skincare products consisted of cleansing oil, facial foam, moisturizer, lotion, and serum. Although the same products were used, each group followed a different skincare routine as shown in Table 1.

Skincare routine A is a model of the "4-step routine with moisturizer treatment in advance" introduced by our company. Skincare routines B and C are modified versions

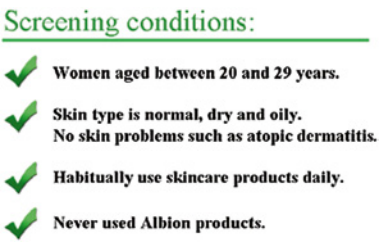

Fig. 3 Screening conditions for the selection of home-use test subjects

Table 1 Details of the skincare routine used by each group

Group	Skincare routine
A	1 > 2 > 3 > 4
B	1 > 2 > 3 > 4
C	1 > 2 > 3 > 4
D	1 > 3 > 2 > 4

4-step skincare routine that consists of
(1) Cleansing and face wash; (2) Moisturizer; (3) Lotion; (4) Serum

Table 2 Details of the application method and amount needed for moisturizer application for each group

	Moisturizer	
Group	Application method	Amount
A	Facial cotton pad	3 pumps
B	Facial cotton pad	1 pump
C	Hands	1 pump
D	Hands	1 pump

of skincare routine A. We designed these routines to study the effect of the application method and moisturizer amount on skin rehydration and affective values. Skincare routine D is the generic skincare routine that is commonly used by consumers.

As shown in Table 2, the order, method, and amount used for each application of moisturizer vary slightly between the groups. For Group A, 3 pumps of the dispenser, approximately 1 teaspoon was used while applying the moisturizer. Our company believes that this is the precise amount needed for applying the moisturizer with a facial cotton pad. In contrast, 1 pump of the dispenser is the amount that is commonly recommended by other cosmetics manufacturers while using hands to apply the moisturizer, as in Groups C and D.

Figure 4 shows the amount of the moisturizer dispensed from 3 pumps compared with the amount from 1 pump. Although the order of application of lotion in the skincare routine was different for each group, we asked the subjects to apply the lotion with a facial cotton pad by padding it firmly onto the face. Next, serum was applied by spreading it gently over the face by hands.

Lastly, because all skincare products used for the test were already marketed, we prepared blind samples for our test subjects to prevent any bias for or against the products. We rebottled the contents of each product into a simple translucent

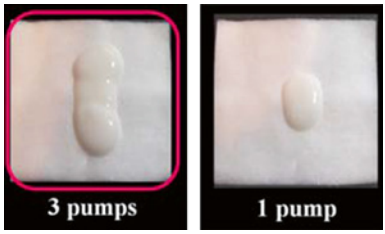

Fig. 4 Comparison on the amount of moisturizer being taken for 3 pumps and 1 pump of the dispenser

container without any label or design. However, to ensure the accuracy of the moisturizer amount taken from every pump of the dispenser, we used the same moisturizer container as the marketed product, but without any printed information.

2.1 Evaluation of Skin Physiology Parameters

Each subject's basic skin physiology parameters were evaluated before the use of the test items (Day 0) and after using the skincare products for 4 weeks (Day 29). Measurements were taken after the subjects had stayed in the environmental test laboratory, with controlled temperature and humidity (22 °C, 55 %), for 20 min. Figure 5 shows the test areas where each measurement was taken.

1. The water content of the corneal layer was measured using a Skicon-200 (I.B.S. Co. Ltd.), and the mean value of 7 measurements was recorded.
2. The trans-epidermal water loss (TEWL) was measured using a Vapometer (Keystone Scientific Co. Ltd), and the mean value of 3 measurements was recorded.

2.2 Evaluation of Affective Values

All subjects answered a questionnaire at home after the first application of moisturizer. A similar questionnaire was answered by the subjects on the last day of the test after the final application of the moisturizer. The questionnaire focused primarily on the evaluation of the product characteristics listed below (which are considered during the development of a new product).

1. Moisturizing feeling of the moisturizer.
2. Sticky feeling of the moisturizer.
3. Sense of luxury in using the moisturizer.

We modified the semantic differential method into a 5-point rating system, as shown in Fig. 6, for subjects to choose when answering the questionnaire.

Additionally, we also prepared a daily comment record sheet for our subjects to keep record each day of any changes in skin condition they feel and to make

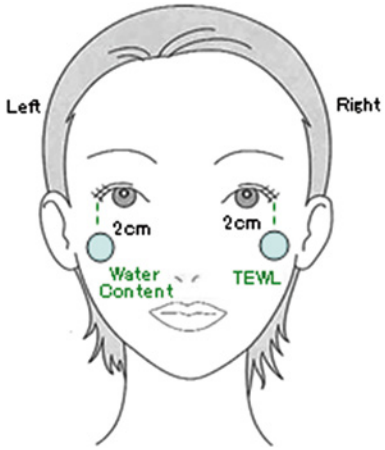

Fig. 5 Test areas for measuring skin physiology parameter

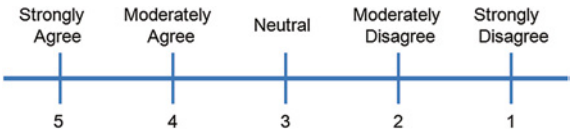

Fig. 6 The model of 5-point rating system used in the questionnaire

free comments about the home-use test [4]. A test-mining method was applied to analyze the contents of the daily comment records, allowing us to select only the targeted keywords from the bulk of the sentences. We also qualitatively and quantitatively evaluated differences in Affective Value among the groups.

In this study, we put greater effort into analyzing the keywords related to changes in skin condition and effects on make-up, which were together interpreted as the affective value.

Lastly, correspondence analysis was applied to obtain a better insight into the relationship between each group after the subjects followed the directed skincare routine for 4 weeks.

3 Results

3.1 Changes in Skin Physiology Parameters

3.1.1 Changes in the Water Content of the Corneal Layer

The water content of the corneal layer can be determined by measuring electrical conductivity. If the skin is in good hydrated condition, the value of electrical conductivity will become higher. Figure 7 shows the skin conductivity data obtained on Day 0 and Day 29, while Fig. 8 shows the rate of change of the conductance value (water content) with respect to Day 0.

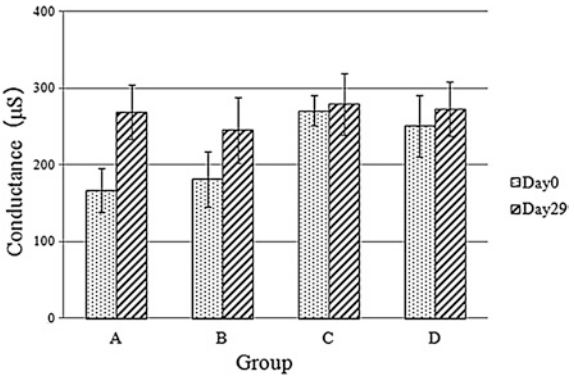

Fig. 7 Values of water content measured on Day 0 and Day 29

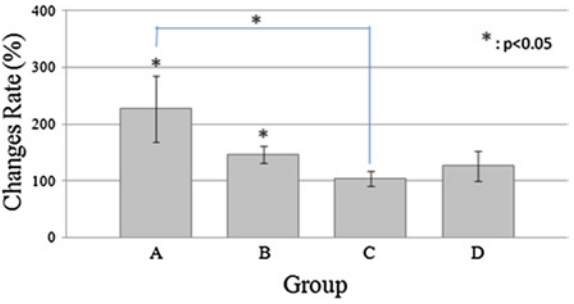

Fig. 8 The rate of change of water content after 4 weeks

These results indicate that Group A showed the most remarkable changes during the experimental period. Although all 4 groups used the same test items, only Group A showed a significant increase in the water content. Thus, the skincare routine A is the most effective skin rehydration method.

In addition, the groups that used a facial cotton pad to apply the moisturizer, Group A and Group B, showed higher skin hydration on Day 29 than Group C and Group D, wherein the subjects used their hands for application. These data suggest that the method of applying the moisturizer can also influence product efficacy, especially in terms of increasing skin hydration.

3.1.2 Changes in Trans-Epidermal Water Loss (TEWL)

Measurement of TEWL is useful for evaluating the barrier function of the epidermal layer of the skin. The value of TEWL is low if the transpiration rate of water from the epidermis is low. Thus, a low TEWL value indicates that the skin has a higher potential for keeping itself hydrated all day. The TEWL value is normally maintained at the same level with negligible changes. A decrease in the TEWL value indicates improvement in the condition of the epidermis and in the hydration

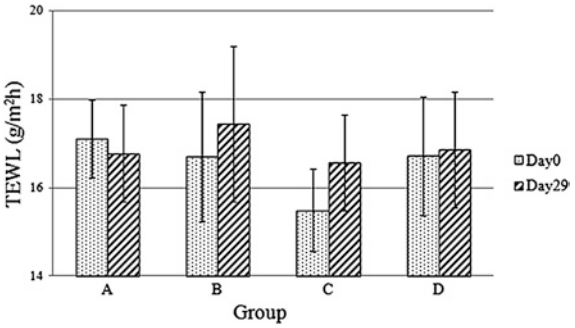

Fig. 9 The rate of change of water content after 4 weeks

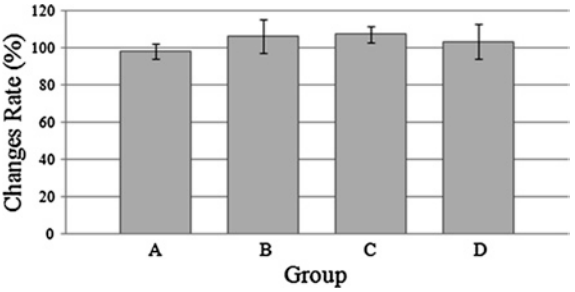

Fig. 10 The rate of change of TEWL after 4 weeks

potential of the skin. The TEWL value of Group A decreased after following skincare routine A for 4 weeks (Fig. 9). This means that there is a marked change in the skin barrier function of these subjects.

Groups B, C, and D showed an increase in TEWL, which indicates deterioration in the barrier function of the skin (Fig. 10). These changes may be a consequence of the change in season. In Japan, during the changing of season from winter to spring, the barrier function of the skin commonly deteriorated. The results show that the skincare routines of groups B, C, and D did not effectively preserve skin functions that are required to cope with the seasonal environmental change. This again shows that skincare routine A was the only routine that was successful at preventing skin damage induced by seasonal climatic changes.

3.2 Changes in Affective Values

3.2.1 Evaluation of Moisturized Feeling

The average score of the moisturized feeling for Groups A and D after the first application was higher than those of the other groups. For Group A, the score increased

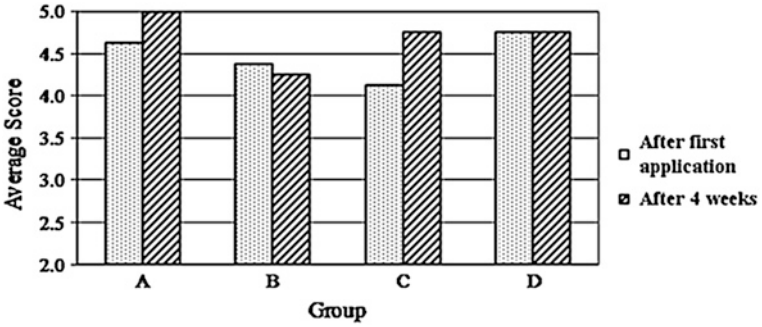

Fig. 11 Scores of moisturized feeling recorded after the first application and after 4 weeks

and reached the maximum score of 5 over the 4 weeks, showing that every subject in this group achieved a better moisturized feeling (Fig. 11).

In contrast, the scores of Group D did not change over the 4 weeks. Although the subjects in Group D used the lotion in the first step, followed by the moisturizer, the scores of Group D were lower than those of Group A, which indicated that subjects in Group A had a better moisturized feeling than those in Group D.

Moreover, comparing the moisturized feeling scores of Groups B and C to that of Group A also shows that the amount of moisturizer used and the method of application can affect the moisturized feeling.

The data in Figs. 7 and 8 indicate that Group A had higher water content in the corneal layer, which in turn suggests that the skincare routine of Group A may be the most effective method for increasing the skin hydration levels as well as for achieving the fully moisturized feeling.

3.2.2 Evaluation of Sticky Feeling

The average sticky feeling scores for Groups A, B, and D showed a declining trend after using it for 4 weeks (Fig. 12). The texture of the moisturizer as well as the method of application may have mediated the reduction in sticky feeling over the home-use test period.

Although the amount of moisturizer used by Group A is 3 times that of Group B, the sticky feeling score of Group A was lower than that of Group B. This implies that 3 pumps of the dispenser (moisturizer) are the optimum amount for facial cotton pad usage. Because the skin is quite uneven due to the pores and furrows on its surface, application of 3 pumps of moisturizer by using a facial cotton pad may be useful to help deliver the moisturizer components evenly with faster absorption.

Some of the daily comments record of subjects in Group B stated that the lack of the required amount of moisturizer has caused friction while sweeping

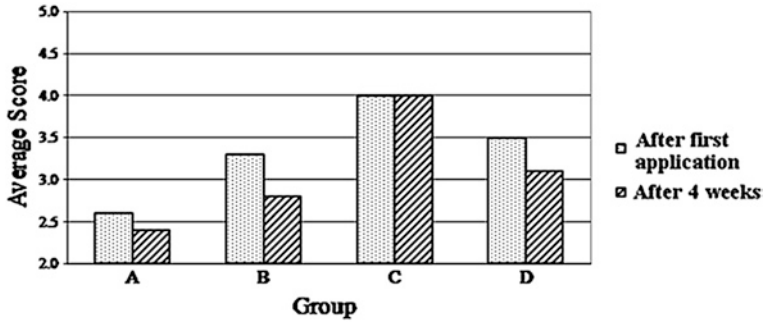

Fig. 12 Scores of sticky feeling recorded after the first application and after 4 weeks

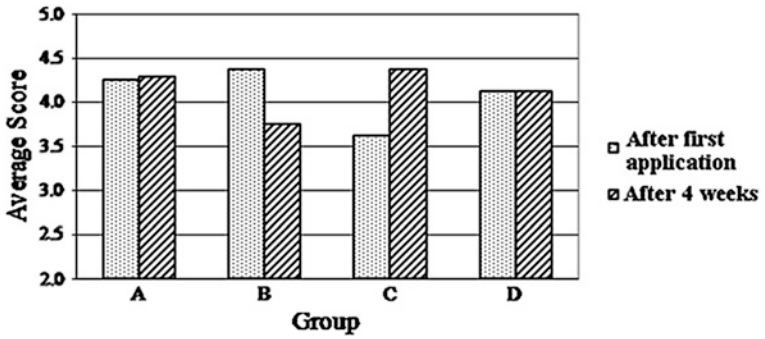

Fig. 13 Scores of the sense of luxury recorded after the first application and after 4 weeks

the facial cotton pad over the face. This unfavorable feeling made them quit the sweeping motion even though the moisturizer was not penetrating fully into the skin yet. We believe that this action in turn may have lead to a higher sticky feeling score for Group B compared with Group A.

The other 2 groups (Groups C and D) that applied moisturizer by hands had higher sticky feeling scores, which are probably caused by the increased contact with the moisturizer owing to the absence of facial cotton pad usage.

3.2.3 Evaluation of the Sense of Luxury

All groups used the same skincare products during the home-use test. As expected, there was no significant difference in the "sense of luxury" scores of Groups A and D after the first application or after 4 weeks of application (Fig. 13). However, a comparison between Groups B and C showed differences in scores, which may be attributed to the method of moisturizer application: Group B subjects used a facial cotton

pad, and Group C subjects used their hands for the application. Taken together, the sticky feeling and sense of luxury data indicate that the sense of luxury may be correlated with the sticky feeling, especially for the score after first application.

After 4 weeks of application, the sense of luxury score of Group B decreased because of the amounts of moisturizer used (1 pump of the dispenser), which was insufficient for application with a facial cotton pad. We postulate that the insufficient amounts of moisturizer may have resulted in a lower moisturized feeling score. In contrast, after using the moisturizer for 4 weeks, Group C subjects were habituated to the sticky feeling. These results indicated that the evaluation of the product characteristics, such as sense of luxury, changed over the home-use test period.

Lastly, the data indicate that not only the quality of the moisturizer itself but also the method of product application will be taken into consideration for the evaluation of product efficacy.

3.2.4 Evaluation on Text Data

Text mining method was applied to analyze the daily comment records, allowing us to concentrate solely on targeted keywords of interest. The content of these daily comment records can be divided into 4 categories.

First are the comments evaluating the usability and touch of skincare products, for example, “Easy to make bubble from the facial cleanser” and “The texture of the moisturizer is creamy.” Second are the records of the actual practice or the method of application, for example, “Spending more time on skincare routine than make-up” and “Handle with more care while applying cleansing oil to the skin.”

Third are emotional expressions mainly focused on the evaluation of the skincare routine in general, for example, “Feel relaxed after having finished applying the skincare product at night” and “Very happy when praised by friend saying that my face color tone is getting better.” Fourth are comments regarding the efficacy and the realization of changes in the skin condition because of the application of the directed skincare routine, for example, “Feel hydrated all day” and “Make-up became more long lasting than before.” Table 3 shows the summary of keywords for each category among the groups.

Since we were more interested in finding out the difference in efficacy and influence brought about by the skincare routine, we analyzed the keywords regarding the evaluation of efficacy and skin condition changes in more detail. The comments in this category can be divided into 2 sub-categories: effect on skin and effect on make-up. Figure 14 shows the accumulation of keywords for each group over 4 weeks.

From Fig. 14, we were the most impressed by finding that the subjects of Group A, who applied the moisturizer in advance with facial cotton pad, show faster realization of efficacy compared with the other groups after 2 weeks. In addition, the observation that Group A had the largest total accumulated number of keywords also indicated that subjects in Group A experienced better efficacy of the skincare products compared with the other groups that apply it using a different method.

Table 3 Summary of keywords for each category after 4 weeks

Group	Evaluation of usability and touch		Record of the method of application	Emotional expression		Evaluation of efficacy and skin condition changes		Total
	Positive image	Negative image		Positive image	Negative image	Positive image	Negative image	
A	39	18	9	49	23	138	40	316
B	40	13	6	70	27	123	39	318
C	50	12	4	19	40	115	29	269
D	86	25	16	59	66	119	36	407
Total	215	68	35	197	156	495	144	1,310

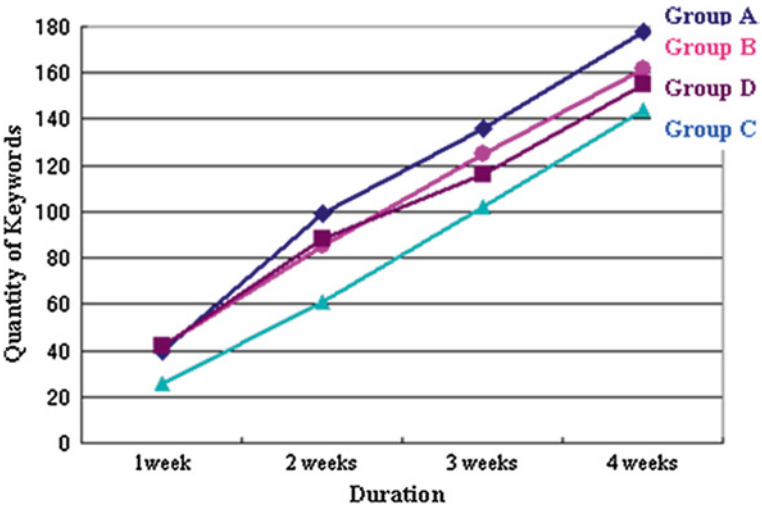

Fig. 14 Accumulation of keywords for the evaluation of efficacy and changes in the skin condition for each group

Next, we applied correspondence analysis to the data showed in Table 3 to find out the co-relationship of each skincare routine after the subjects used it for 4 weeks. We obtained 6 dimensions of sample scores and the cumulative contribution ratio was 0.947 (Fig. 15). The data of first and second dimension (component) were used to draw the positioning map, and by referring to the position of the spot on the map, we can easily visualize the characteristics and co-relationship of each skincare routine.

Although all subjects used the same series of skincare products, the positioning map that reflects the contents of daily comment in a visualized image clearly showed that subjects in Group A experienced a more effective skincare routine in terms of positive image of emotional expression, effect on skin, and effect on make-up compared with other groups. Moreover, we can also noticed that

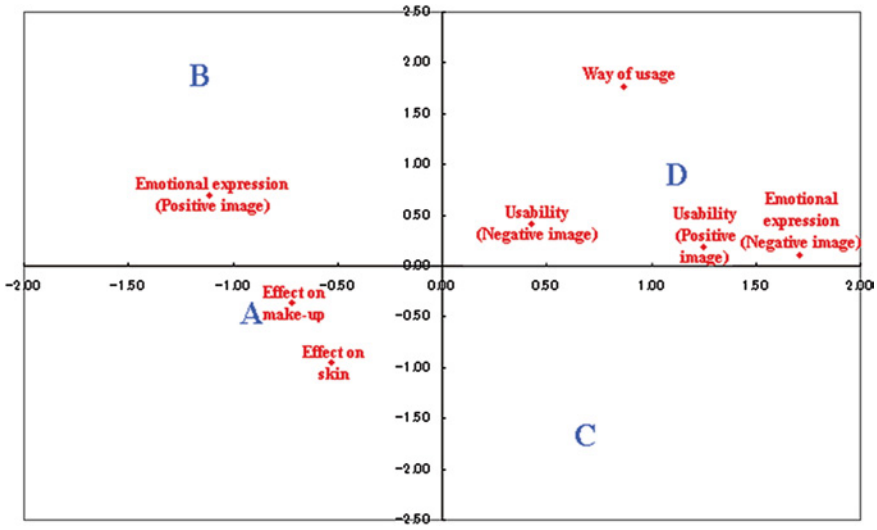

Fig. 15 Positioning map of the correspondence analysis of daily comments records. [single capital letter (*A*, *B*, *C*, and *D*) represents the location of each group; phrases with spot represent the location of each category stated in Table 3]

Groups B and C who applied moisturizer in advance as Group A, but different in the terms of amount and method (by hands or by using facial cotton pad), showed a different way in realization of products efficacies. From these data, we can conclude that method application (skincare routine) did play a key role in affecting the evaluation of affective values of the subjects.

4 Conclusions

We have concluded that different methods and orders of products caused different changes in skin physiology parameters.

The greatest improvement, as indicated by the increased water content in the corneal layer of the skin, was shown in Group A, which used skincare routine "A." Moreover, the decrease in the TEWL value also corroborated these findings. In addition, using a facial cotton pad instead of the hands for moisturizer application was found to be more effective. Moreover, by using the semantic differential method, we found that even though the same skincare products were used, the amount, the order, and the method of applying the product affected the affective values, particularly in terms of moisturized feeling, sticky feeling, and sense of luxury. Finally, by using the correspondence analysis to analyze the contents of daily comments, we successfully confirmed that subjects who applied skincare routine "A" experienced more positive effects on both skin condition and make-up compared with other groups.

The products used in this study are specially formulated to suit skincare routine "A"; therefore, we observed that the subjects of Group A showed greater improvement in skin condition than other groups. Moreover, skincare routine "A" was shown to have a higher potential for enhancing the user's affection by providing a pleasant and enjoyable skincare experience.

In conclusion, our study showed that it is important to follow the skincare routine recommended by the cosmetics manufacturer as specific skincare routines might be essential for obtaining the optimum performance of skincare products.

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Understanding Product Features Using a Hybrid Machine Learning Model

Manjeevan Seera, Chee Peng Lim and Junzo Watada

Abstract In accordance with advancement in society, consumers' psychological feelings constitute an important factor whereby manufacturers need to consider when designing or improving various services and/or products in order to gain a competitive edge in global market. In this study, a hybrid model combining the fuzzy min–max (FMM) neural network and the classification and regression tree (CART) is applied to extract useful information from databases pertaining to products and/or services. The hybrid model, known as FMM–CART, exploits the advantages of both FMM and CART in undertaking data classification and knowledge discovery problems. It is able to categorize products/services into different classes (through FMM) and, at the same time, to provide useful information of the product/service features in each class (through CART). To demonstrate the usefulness of FMM–CART in affective engineering (AE) applications, two publicly available data sets related to the automobile industry are utilized. The experimental outcome positively indicates the potential of FMM–CART in classifying products and/or services and elucidating useful knowledge and information pertaining to the classification process.

Keywords Fuzzy min–max neural network • Classification and regression tree • Database • Knowledge discovery • Affective engineering

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_22,

1 Introduction

In this knowledge economy era, the industry sector is constantly facing various challenges, and each company needs to adapt to rapid changes and dynamic environments in its operations. It is necessary to develop new products swiftly to meet customer needs [1]. An important factor influencing consumer purchases is the way a product looks [2]. As such, various systematic product design studies are conducted to solicit a better understanding of consumers' perceptions [2]. One of the most notable studies is that of affective engineering (AE), or known as Kansei engineering [3]. Indeed, affective computing is coming into prominence as a branch of human–computer interaction, with the aim of closing the communication gap between humans and machine [4]. According to Picard [4, 5]:

> Computers do not need affective abilities for the fanciful goal of becoming humanoids, they need them for a meeker and more practical goal: to function with intelligence and sensitivity towards humans.

Machine learning and complementary techniques have been utilized in mining useful information from databases in order to have a better understanding of a specific product, its performance, and characteristics. In this aspect, it would be interesting to investigate how machine learning techniques could be useful in the AE domain. As an example, AE has been applied to mobile phone design [1, 2, 6]. The techniques used include an expert system comprising support vector regression and multi-objective genetic algorithm [6], a multi-objective genetic algorithm-based rule mining method [1], and factor analysis and Procrustes analysis [2] for mobile phone design. In [7], a real-time affect detector is used in detecting the emotional impact of a video clip by identifying emotional events in video streams. In [8], participants assessed their agreement or disagreement on short videos with correct and incorrect tags.

Other applications include human factors assessment on car and truck designers for studying the Citarasa analysis system, with validation by thirteen original equipment manufacturer (OEM) vehicle designers [9]. The support vector machine is used to classify psycho-physiological responses from users in an attempt to develop adaptive environments that respond to real-time changes in user affect, cognition, and motivation [10]. A facial emotion recognition and multimodal fusion model for affective information to analyze different subjects by their sex, age, ethnicity using statistical evaluation strategy and Kalman filtering is proposed [11]. A human emotion model with respect to social networks is proposed [12]. The user's emotion, personality, and mood are built by analyzing their activities in social networks, with the aim to provide more elaborate services to them [12]. Computer satisfaction measurement using an annotated emotion corpus, which compares the linguistic characteristics of emotional expressions of positive and negative attitudes, has also been investigated [13].

Hybrid systems consist of a combination of two or more models. The aim is to capitalize on the advantages of the each model by integrating them into a common framework [14]. In this study, a hybrid system comprising the fuzzy min–max

(FMM) [15] neural network and the classification and regression tree (CART) [16] is described. While FMM has the advantages of one-pass training with online learning capabilities, it does not have the capability of producing rules to explain its predictions. On the other hand, while CART is able to explain its prediction, it is less flexible in terms of online learning from data samples. The resulting hybrid system, known as FMM–CART [17], overcomes the limitations of both FMM and CART by formulating an intelligent learning system that is able to learn from data samples and to provide explanation for its predictions on an online learning setting.

We have previously examined the effectiveness of FMM–CART in tackling fault detection and diagnosis problems [17]. In this study, we further extend the applicability of FMM–CART to AE-related tasks. Specifically, two publicly available data sets which are to the automobile industry are considered. The key objective is to examine how FMM–CART can be employed to extract useful information pertaining to a product or service, so that customers can have a better understanding of the product or service from different viewpoints.

The organization of this chapter is as follows. In Sect. 2, FMM–CART is described. An experimental study is presented in Sect. 3. The results from FMM, CART, and FMM–CART are analyzed and discussed. Finally, conclusions and suggestions for further work are given in Sect. 4.

2 The FMM–CART Model

The supervised classification network of FMM introduced in [15] has several advantages. It is able to learn and adapt to new classes online, while refining the existing classes quickly [15]. It is also simple and easy to use, and the training time is short as it requires only one-pass learning through the data samples. FMM [15] is formed using the hyperbox fuzzy sets, where the hyperbox size is controlled by an expansion coefficient, that is, $\theta \in [0, 1]$. When θ increases from a small to a large value, the number of hyperboxes created is reduced. The membership function is determined with respect to the minimum and maximum points of the hyperbox, and to the extent to which a pattern fits in the hyperbox. Further details of FMM can be found in [15].

The hyperboxes generated from FMM training serve as CART's inputs [16]. CART has the advantages of handling both numerical and categorical variables that are highly skewed. The training of CART consists of tree building and tree pruning. In tree building, it begins at the root node where the entire training set is included. No further decision to the partition is made if all data samples belong to the same class. Otherwise, CART finds the best possible variable to split the node into two leaf nodes. This process is repeated for each new leaf node until a completely distinguishable tree is obtained [18]. The CART algorithm utilizes the Gini impurity index as a measure of how often a randomly chosen element from the set would be incorrectly labeled if it were randomly labeled according to the

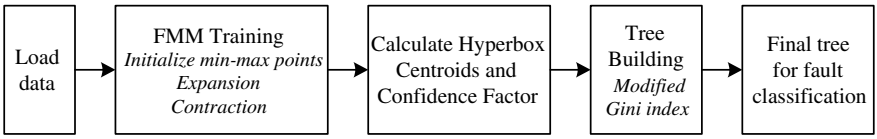

Fig. 1 The FMM–CART training procedure

distribution of labels in the subset. Further details on CART can be found in [16]. A block diagram of the training procedure of FMM–CART is shown in Fig. 1.

3 A Case Study

To demonstrate how FMM–CART can be utilized to extract useful information from data samples so as to provide further information pertaining to a product or service a case study using two automobile-related data sets was conducted. For performance comparison, FMM and CART were also implemented. Note that the prediction error estimated from a small data set could vary from one run to another, and the presence of outliers could affect the estimated prediction error considerably [19]. In this case, the *k*-fold cross-validation method could provide a good estimate of the prediction error [19]. To further ascertain the effectiveness of FMM–CART, the bootstrap method [20] was used to compute the performance statistics. The bootstrap method is a statistical method that does not rely on the assumption that data samples must be drawn from a normal distribution. In [21], it was suggested that using 1,000 bootstrap samples generally could provide accurate results. In a sampling variability study [22], the prediction error reduced from 0.0071 to 0.0014 when the number of bootstrap samples was increased from 200 to 5,000. In this study, the results (average accuracy) were computed using 5,000 re-samplings. Using an Intel Core i5 2.50 GHz processor with 4 GB RAM and with MATLAB® R2011a, the computational time consumed by one run of the cross-validation experiment was also recorded. The details are as follows.

3.1 Automobile Data Set

The automobile data set is downloaded from the UCI Machine Learning Repository [23]. The data set contains three main entities, that is, the characteristics of an automobile, the assigned insurance risk rating, and the normalized losses as compared with other cars [23]. The characteristics of an automobile comprise a number of specifications, as shown in Table 1.

In terms of risk rating, a car is assigned a risk factor based on its price. Its risk factor varies according to a scale from safe to risky. Then, its risk factor is adjusted either up or down the scale, in accordance with the process of “symboling” [23].

Table 1 Input features and values of automobile data set [23]

Input features	Values
Fuel type	Diesel and gas
Aspiration	Std and turbo
Number of doors	Four and two
Body style	Hardtop, wagon, sedan, hatchback, and convertible
Drive wheels	4wd, fwd, and rwd
Engine location	Front and rear
Wheel base	Continuous from 86.6 to 120.9
Length	Continuous from 141.1 to 208.1
Width	Continuous from 60.3 to 72.3
Height	Continuous from 47.8 to 59.8
Curb weight	Continuous from 1,488 to 4,066
Engine type	dohc, dohcv, l, ohc, ohcf, ohcv, and rotor
Number of cylinders	Eight, five, four, six, three, twelve, and two
Engine size	Continuous from 61 to 326
Fuel system	1bbl, 2bbl, 4bbl, idi, mfi, mpfi, spdi, and spfi
Bore	Continuous from 2.54 to 3.94
Stroke	Continuous from 2.07 to 4.17
Compression ratio	Continuous from 7 to 23
Horsepower	Continuous from 48 to 288
Peak rpm	Continuous from 4,150 to 6,600
City mpg	Continuous from 13 to 49
Highway mpg	Continuous from 16 to 54
Price	Continuous from 5,118 to 45,400

The relative average loss payment per insured vehicle year is normalized for automobiles based on its size classification [23].

In this experimental study, the "normalized losses" factor is not used. The rationale is to investigate how FMM–CART can be used as a tool to reveal the relationship between the automobile characteristics and the insurance risk rating scores from the symboling process. The risk ratings are grouped into three classes, that is, negative scores (-3, -2, -1) are labeled as "risky," 0 as "neutral," and positive scores (1, 2, 3) as "safe." The automobile characteristics shown in Table 1 are used as the input features. In the experiment, the vehicles were segregated into two main categories, one from Japanese manufacturers (i.e., Honda, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, and Toyota) and another from all other manufacturers (i.e., Alfa Romeo, Audi, BMW, Chevrolet, Dodge, Jaguar, Mercedes-Benz, Mercury, Peugeot, Plymouth, Porsche, Renault, Saab, Volkswagen, and Volvo). The results are as follows.

3.1.1 Automobiles from Japanese Manufacturers

The results from the Japanese manufacturers are shown in Table 2. FMM and CART produced accuracy rates of 82.46 and 79.62 %, respectively while

Table 2 Results of FMM, CART, and FMM–CART for Japanese manufacturers

Network	Accuracy (%)	Std Dev	Complexity	Time (sec)
FMM	82.46	3.28	35 hyperboxes	0.06
CART	79.62	2.19	8 leafs	0.39
FMM–CART	94.84	0.38	6 leafs	0.54

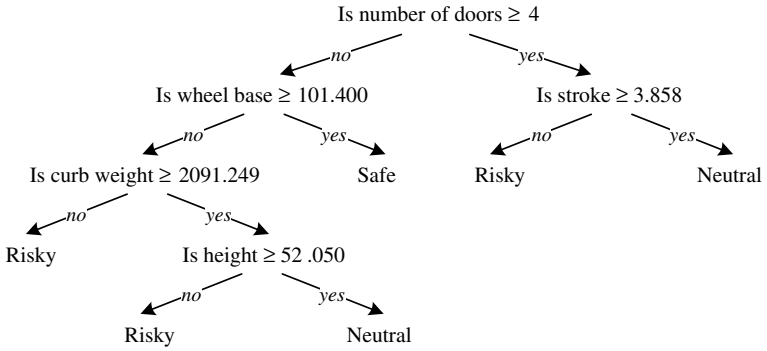

Fig. 2 FMM–CART decision tree for Japanese manufacturers

FMM–CART yielded the highest accuracy rate at 94.84 %. The FMM model was the most complex, with 35 hyperboxes, while CART and FMM–CART only created 8 and 6 leafs, respectively. FMM consumed the shortest computational time while the computational time of FMM–CART was the longest.

In addition to producing good performance, the most important feature of FMM–CART is the extraction of a useful decision for explaining its learned knowledge. Figure 2 shows the knowledge tree of FMM–CART, which is interpreted as follows.

The tree starts by splitting the feature of "number of doors." When the value is ≥4, the tree checks whether the feature of "stroke" is ≥3.858. If yes, the input is categorized into the "neutral" class. Otherwise, it is considered in the "risky" class. If "number of doors" is <4, splitting occurs based on the feature of "wheel base." If "wheel base" is ≥101.400, FMM–CART classifies the input as "safe." Otherwise, splitting occurs again using the feature of "curb weight." When "curb weight" is <2,091.249, the input is categorized as "risky." Otherwise, splitting occurs again. When the feature of "height" is ≥52.050, the input is classified as "neutral," otherwise as "risky."

3.1.2 Automobiles from Non-Japanese Manufacturers

The results from non-Japanese manufacturers are shown in Table 3. FMM and CART produced accuracy rates of 72.37 and 74.80 %, respectively. Again, FMM–CART exhibited the highest accuracy rate at 87.77 %. Similar to the previous experiment, the model complexity of FMM was the highest, with 35 hyperboxes.

Table 3 Results of FMM, CART, and FMM–CART for non-Japanese manufacturers

Network	Accuracy (%)	Std Dev	Complexity	Time (sec)
FMM	72.37	1.09	35 hyperboxes	0.07
CART	74.80	1.29	8 leafs	0.35
FMM–CART	87.77	0.35	6 leafs	0.49

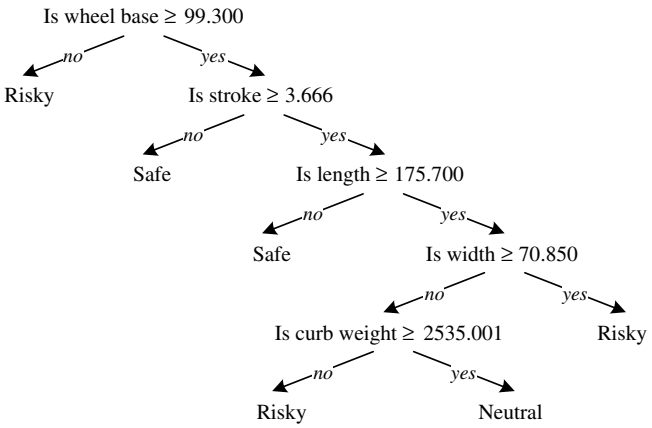

Fig. 3 FMM–CART decision tree for non-Japanese manufacturers

FMM–CART only produced 6 leafs. The computational time of FMM was the shortest, while FMM–CART's was the longest. As shown in Fig. 3, the decision tree produced by FMM–CART can be interpreted as follows.

The tree starts by considering the feature of "wheel base." When its value is <99.300, FMM–CART classifies the input as "risky." Otherwise, splitting occurs by considering the feature of "stroke." When its value is <3.666, FMM–CART classifies the input as "safe." Otherwise, splitting occurs again by considering the feature of "length." When its value is <175.700, the input is considered as "safe." Otherwise, the feature of "width" is considered. When its value is ≥70.850, the input is classified as "risky." Otherwise, splitting occurs by considering the feature of "curb weight." When its value is ≥2,535.001, the input is classified as "neutral," otherwise as "risky."

Based on the decision trees from the Japanese and non-Japanese manufacturers, the features of "wheel base," "stroke," and "curb weight" are deemed important. The features of "number of doors" and "height" are unique to Japanese manufacturers while "length" and "width" are associated with non-Japanese manufacturers only. The decision tree pertaining to Japanese manufacturers starts with "number of doors," and is followed by "wheel base" and "stroke" at the second level. In the decision tree of non-Japanese manufacturers, "wheel base" is the top priority. This is followed by "stroke" at the second level, which is similar to that of the Japanese manufacturers.

Table 4 Input features and values of car evaluation data set [24]

Input features	Values
Buying	Vhigh, high, med, and low
Maint	Vhigh, high, med, and low
Doors	2, 3, 4, 5, and more
Persons	2, 4, and more
Lug boot	Small, med, and big
Safety	Low, med, and high

Table 5 Results of FMM, CART, and FMM–CART for car evaluation

Network	Accuracy (%)	Std Dev	Complexity	Time (sec)
FMM	80.24	5.92	661 hyperboxes	1.53
CART	92.37	2.43	15 leafs	0.44
FMM–CART	94.90	1.44	9 leafs	3.52

3.2 Car Evaluation Data Set

The car evaluation data set is also downloaded from UCI Machine Learning Repository [24]. The task is to evaluate the acceptability of a car based on price (buying price and maintenance price) as well as technical and comfort specifications (number of doors, capacity in terms of passengers, size of the luggage boot, and safety of the car). These six input features are shown in Table 4. There are four evaluation outcomes (target classes), that is, "unacceptable," "acceptable," "good," and "very good." It should be noted that the data set is useful for evaluating constructive induction and structure discovery methods [24].

The results are shown in Table 5. Again, FMM–CART produced the best accuracy rate (slightly under 95 %), while FMM and CART yielded 80.24 and 92.37 % accuracy, respectively. The most complex model was FMM, with 661 hyperboxes, while FMM–CART created only 9 leafs. CART used the shortest computational time (less than half a second). The computational time of FMM–CART was the longest, that is, about 4 s. As compared with the previous experiment, the computational time of this experiment was longer. This is within expectation as the computational time is in proportion to training data sizes.

The decision tree extracted from FMM–CART is shown in Fig. 4. The tree starts splitting by considering the feature of "safety." When this feature is < low, FMM–CART classifies the input as "unacceptable." Otherwise, splitting occurs by considering the feature of "person." If "person" is <2, the input is classified as "unacceptable," otherwise the tree encounters a major junction. The feature of "buying" is ≥ high, and it needs to be scrutinized again. If "buying" is now < very high, FMM–CART classifies the input as "very good." Otherwise splitting occurs by considering the feature of "maintenance." If "maintenance" is < medium, the input is classified as "good." Otherwise, splitting occurs by considering "lug boot." When "lug boot" is ≥ medium, FMM–CART classifies the input as "acceptable,"

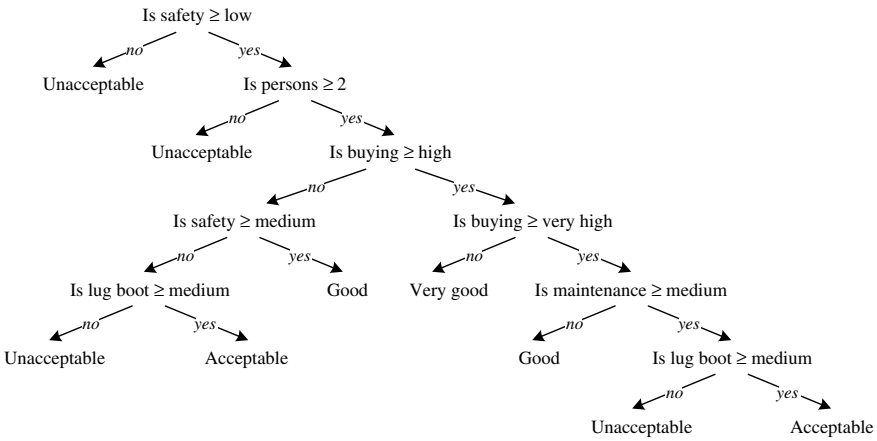

Fig. 4 FMM–CART decision tree for car evaluation

otherwise as "unacceptable." Going back to the previous major junction, when "buying" is < high, splitting occurs by considering the feature of "safety." If "safety" is ≥ medium, the input is classified as "good." Otherwise splitting occurs by considering the "lug boot" feature again. When "lug boot" is ≥ medium, the input is classified as "acceptable," otherwise as "unacceptable."

Based on the decision tree, it can be observed that "safety" is the main priority in the evaluation, and it appears twice in the tree. Indeed, it appears at the top of the tree whereby if "safety" is worse than "low," this leads to an immediate evaluation outcome of "unacceptable." Another important feature is the number of passengers that can be carried by the car. It is deemed "unacceptable" of the car is meant for only one passenger. Next, the buying price is taken into consideration. If the car price is between "high" and "very high," it is evaluated as "very good." Next, the maintenance price is considered, whereby the evaluation is "good" if the maintenance price is low. Therefore, it can be observed that safety, practicality (number of passengers), and price (both buying and maintenance) are the main three factors in car evaluation. The luggage size is also considered, but at a lower priority. The details are depicted in Fig. 4.

4 Conclusions

In this study, the applicability of FMM–CART to data classification and knowledge discovery from databases has been empirically demonstrated. Its usefulness in analyzing two automobile-related tasks has been described, that is, the automobile and car evaluation data sets from the UCI Machine Learning Repository. The automobile data samples were further split into two based on either Japanese and non-Japanese manufacturers. The accuracy rates attained by FMM–CART are high, that is, about 95 % for automobile (Japanese manufacturers) and car

evaluation, and 88 % for automobile (non-Japanese manufacturers). Comparing with its constituents (FMM and CART), FMM–CART is able to achieve higher accuracy rates with less complex model structure. More importantly, it is possible to extract useful information from the data sets in order to elucidate more information pertaining to a product or service, which is in line with AE principles. The resulting decision trees have been analyzed and discussed.

Further work will focus on collecting real data samples from various sources, which include the banking industry and fashion industry, to further evaluate the potential of FMM–CART in different applications. In addition, it would be interesting to validate the knowledge discovered from FMM–CART with domain experts. This enables the provision of useful opinions and feedbacks pertaining to a product/service to the relevant industries for product and service improvements.

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0,