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Contrastive Analysis of Sensory-relevance of Factors Affecting Aesthetic Impressions[1]

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The semantic differential (SD) technique has been often used for measuring aesthetic impressions. The present study proposed a new utilization of the results obtained by the SD technique. The sensory-relevance of each adjective pair was derived by the probability that the participants chose one of the five sensory modalities when they were asked to select the most related modality for each adjective pair, relying on their general understanding. The sensory-relevance score for each factor is defined as the sum of these probabilities multiplied by the squared factor loadings. The sensory-relevance score can represent how the factor is related to sensory modalities. We applied this method to the results of three researches that used the SD technique. As a result, we found that the sensory-relevance score enables us to analyze the factors affecting aesthetic impressions in close relation to human sensory modalities.

Key words: impressions, sensory-relevance, multimodality, semantic differential, factor analysis

Introduction

The semantic differential technique and its problems in practical usage

The semantic differential (SD) technique developed by Osgood (1952) has been found very useful for measuring impressions. Using the SD technique, we can analyze affective meanings that people feel about various things. Nowadays the SD technique is widely used not only for analyzing the meanings of concepts, but also for the measurement of the impressions and images about various things such as colors, sounds and pictures (Oyama, Takimoto, and Iwasawa, 1993; Jingu, 1996; Nakamura, 2000). This technique has been also utilized for the measurement of the impressions concerning the various industrial products in the domain of the *Kansei* (aesthetic) engineering (Osawa, 2000; Nagamachi, 1988).

In the SD technique, participants rate various stimuli on adjective scales. Then, the factor analysis is conducted on the data in order to extract factors that structure the impressions. In most cases three factors are extracted. These are the evaluation factor, the activity factor, and the potency factor. However, it is often pointed out that the semantic differential technique contains some difficulties in practical usage since the extracted factors are too abstract to capture the concrete or practical meanings especially in the field of applied psychology and aesthetic

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1. This research was partially based on our paper that will appear in *Japanese Journal of Psychology* and the reports presented in IEICE Technical Report (HIP2001-6) and in the proceedings of the 17th Congress of International Association of Empirical Aesthetics,
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engineering (Osawa, 2000; Nagamachi, 1988). Also, we can not easily find the uniqueness of the results obtained by the SD technique because the factorial structures are fairly common and stable across versatile stimuli.

Sensory-relevance of adjective pairs

The adjectives play a very important role in the SD technique. It is well known as synesthetic expressions that an adjective relevant to one modality modify a noun denoting other modality. For example, in "soft color", the tactile adjective "soft" modifies the visual none "color". There is a possibility that each adjective has sensory-relevance properties based on these synesthetic expressions.

Following our previous study (Suzuki & Gyoba, in press), we quantitatively measured how adjective pairs are related to sensory modalities (visual, auditory, tactile, gustatory, or olfactory modality) as "sensory relevance coefficients". The coefficients are derived from the probabilities that the participants (N = 174) chose the sensory modalities when they were asked to select the most related modality for each adjective pair (see, Table1, 2, 3, 4). When the participants could not find any proper modality for a given adjective pair, they were instructed to respond with "Other". For example, in Table 1, the sensory-relevance coefficients of "beautiful-ugly" indicate the 78% participants selected tactile modality, the 9% gustatory, the 9% visual modality, and the 3% selected "Other". Combining these coefficients with the results of factor analysis, Suzuki & Gyoba (in press) have proposed a new index of measuring of the impressions, called "sensory-relevance score."

The definition of sensory relevance score and the purpose of the present study

Sensory-relevance score represents how each factor obtained by the SD techigue is related to sensory modalities (visual, auditory, tactile, gustatory, or olfactory modality). These scores corresponded to the sums of values that are obtained with multiplying the squared factor loadings by the sensory-relevance coefficients for each modality. For example, if a factor has high factor loadings for adjective pairs having high sensory-relevance coefficients on tactile modality, the sensory-relevance score of the factor for tactile modality becomes high value. In each factor, the sum of sensory-relevance scores for five modalities (including the score for "Other") coincides with the factor contribution.

In the present study, we applied the sensory-relevance score to the results of three researches that analyzed the impressions of drawings and words, room atmospheres, and perfume bottles by the SD technique in order to show the validity and the effectiveness of the newly developed score.

Application 1: The sensory-relevance scores of the factors affecting the impressions of words and drawings

Outline of the previous studies

Takahashi (1995) examined the impressions of words and drawings by the SD technique.

As a result of factor analysis, the factorial structure of the word impressions was similar to the drawing impressions, especially in respect to the evaluation factor and the activity factor. In contrast, the adjective pairs characterizing the potency factor were different between drawings and words. For the words, the adjective pairs such as heavy-light, plain-fancy, simple-complex, flexible-rigid, and stable-unstable had high factor loadings, while for the drawings, the pairs, for instance, rounded-angular, soft-hard, blunt-sharp, relaxed-tense, and smooth-rough structured the potency factor. Consequently, Takahashi (1995) proposed that the meaning of words seem to be more connotative in nature, whereas the impressions of drawings are mainly judged in terms of sensory-relevant concepts, especially tactile-relevant concepts.

However, this suggestion has not been quantitatively investigated. From the viewpoints of empirical aesthetics, we examine the quantitative differences of impressions for words and drawings with the sensory-relevance score that represent how each factor is related to sensory modalities (Suzuki & Gyoba, in press).

Participants and Design

The participants were 182 college students. They were divided into three independent groups, 59 (29 males, 30 females) for the word (W) condition, 61 (32 males, 29 females) for the drawing (D) condition, and 62 (32 males, 30 females) for the drawing and word (DW) condition. In these conditions, the participants were asked to rate the impressions of the words, the drawings, or the pairs of word and drawing, respectively.

Stimuli

Eight words and drawings were selected from those used by Takahashi (1995). These stimuli were preliminary confirmed to represent the same concepts (*joy*, *depression*, *human energy*, *femininity*, *tranquility*, *hysteric*, *anxiety*, *and anger*) in Japanese. These stimuli also had considerable agreement among the participants (107 males, 95 females) when they were asked to choose the most suitable drawing for each word concept (Figure.1).

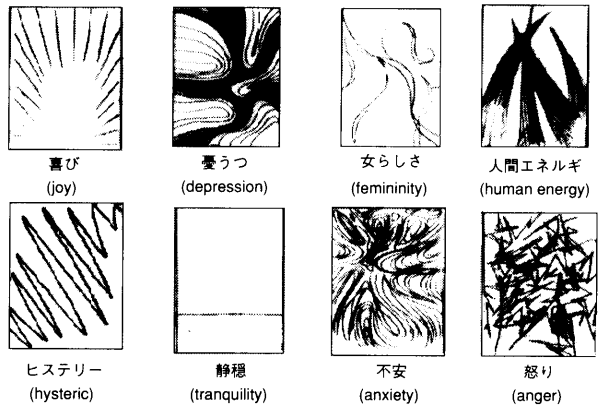

Figure 1. Drawings and words used in the study of Suzuki and Gyoba (in press). These stimuli were selected from those used in the study of Takahashi (1995). Each pair was confirmed to represent the same concept.

Selection of adjective pairs

Out of 36 adjective pairs that were used in Takahashi (1995) and Inoue & Kobayashi (1985), the appropriate pairs were selected based on the factor loadings and communalities revealed by the pilot tactor analysis. After the pilot analysis some pairs representing sensory impressions (for example "hot-cold") were added, while some pairs containing high relevance to gustatory or olfactory sensation was excluded, because in the pilot examination, we found that the factor analyses of the words or the drawings showed fairly low loadings on the gustatory- or olfactory-relevant adjectives. The pairs having low communality were also excluded. After all, 20 adjective pairs were selected and used as the SD scales (see Table 1).

Table 1. Sensory-relevance coefficients and factor loadings for each adjective pair (see text for details). The adjective pairs are listed in the order that represents the simple factor structure extracted in the drawing (D) condition. The factor loadings in the word (W) and the drawing and word (DW) condition are also shown in the table. The symbols, V, A, T, G, O, and Other signify visual, auditory, tactile, gustatory, olfactory, and the other modalities respectively.

	Sensory-relevance coefficients						Factor loadings obtained in each condition							
	Modality						Word		Drawing			Drawing + Word		
Adjective pairs	V	A	T	G	O	Other	Fac.1	Fac.2	Fac.1	Fac.2	Fac.3	Fac.1	Fac.2	Fac.3
beautiful-ugly	.95	.01	.02	.00	.00	.02	.82	.19	.86	−.14	−.13	.84	.14	−.18
pleasant-unpleasant	.10	.23	.10	.01	.22	.33	.89	−.07	.81	−.09	−.13	.87	.07	−.14
likable-repugnant	.14	.06	.01	.26	.10	.43	.89	−.01	.79	−.04	−.16	.85	.05	−.20
clear-cloudy	.86	.07	.01	.02	.02	.02	.80	.06	.78	−.28	−.06	.85	.25	.03
light-heavy	.05	.05	.70	.03	.01	.17	.64	−.14	.63	−.14	−.11	.77	.12	−.08
cheerful-gloomy	.46	.15	.02	.00	.01	.37	.68	−.39	.62	.21	.17	.78	−.18	−.02
stable-unstable	.29	.11	.09	.01	.00	.50	.76	.14	.55	−.40	.07	.73	.28	.03
wet-dry	.01	.00	.91	.01	.03	.03	.31	−.24	.43	.00	.41	.50	−.14	.38
living-quiet	.13	.83	.01	.00	.01	.03	−.07	.82	−.18	.79	.31	.07	.81	−.20
dynamic-static	.67	.15	.05	.01	.00	.13	.04	.89	−.14	.78	.09	.15	.80	−.13
gay-sober	.99	.01	.00	.00	.00	.01	−.11	.81	−.05	.73	.31	−.06	.79	−.15
powerful-feeble	.55	.26	.01	.05	.00	.14	.11	.74	−.14	.61	.32	.18	.62	−.19
excited-calm	.26	.41	.03	.00	.02	.27	.47	.73	−.33	.59	.56	.42	.69	−.33
active-passive	.24	.03	.08	.01	.01	.64	−.20	.80	.11	.56	.44	−.20	.69	−.35
strong-week	.20	.11	.11	.01	.14	.44	−.02	.76	−.15	.52	.44	.09	.71	−.25
soft-hard	.01	.00	.96	.02	.00	.01	.62	.29	−.07	.10	.85	−.16	−.35	.79
smooth-rough	.09	.00	.78	.09	.00	.03	.73	.44	−.13	.34	.78	−.29	−.48	.72
blunt-sharp	.27	.17	.28	.02	.06	.20	.12	.50	.20	.33	.71	.23	−.43	.60
relaxed-tense	.28	.12	.16	.00	.00	.45	.65	.08	−.17	.26	.60	−.36	−.35	.54
delicate-rugged	.30	.02	.49	.06	.00	.13	.29	.69	−.38	.31	.43	−.35	−.53	.36
Factor contribution							6.17	5.7	4.33	3.79	3.64	5.58	4.93	2.58
Percentage of variance							30.8	28.5	21.7	19.0	18.2	27.9	24.6	12.9
Cumulative %variance							30.8	59.3	21.7	40.6	58.8	27.9	52.6	65.5

Procedure

A booklet of 17 pages was prepared. On the first page of the booklet, instruction and an example appeared. On the remaining pages, a word (in the W condition), a drawing (in the D condition), or a set of word and drawing (in the DW condition) was printed on the top of each page with ten adjective pairs below. The participants rated each of eight concepts on 20 SD scales in separate two pages in order to relieve the load of the rating task.

Factor analysis

On the basis of the scale values (8 concepts × N of participants), intercorrelations (Pearson's *r*s) were computed among the 20 scales. The principal factor analysis was applied to this 20 × 20 correlation matrix. The factors whose Eigenvalues exceeded 1.0 were rotated by the varimax method. This procedure was conducted independently for the data obtained in the W, D, and DW condition. Additionally, the same analysis was applied to the total samples including the data of the three conditions.

Results and Discussion

In the W condition, two factors were extracted. By contrast, three factors were extracted in the D and the DW condition. In all three conditions, the first factor can be regarded as an evaluation factor because adjective pairs such as likable-repugnant, pleasure-unpleasure, and beautiful-ugly have high factor loadings. The second factor corresponds to an activity factor since dynamic- static, noisy-silent, and gay-sober contain high factor loadings. The third factor in the D condition and the DW condition can be viewed as a potency factor so as to be represented by pairs such as hard- soft, smooth-rough, and blunt-sharp.

We calculated sensory-relevance scores for these factors in each condition (Figure 2). In all three conditions, the evaluation factors reveal high sensory-relevance scores for visual modality

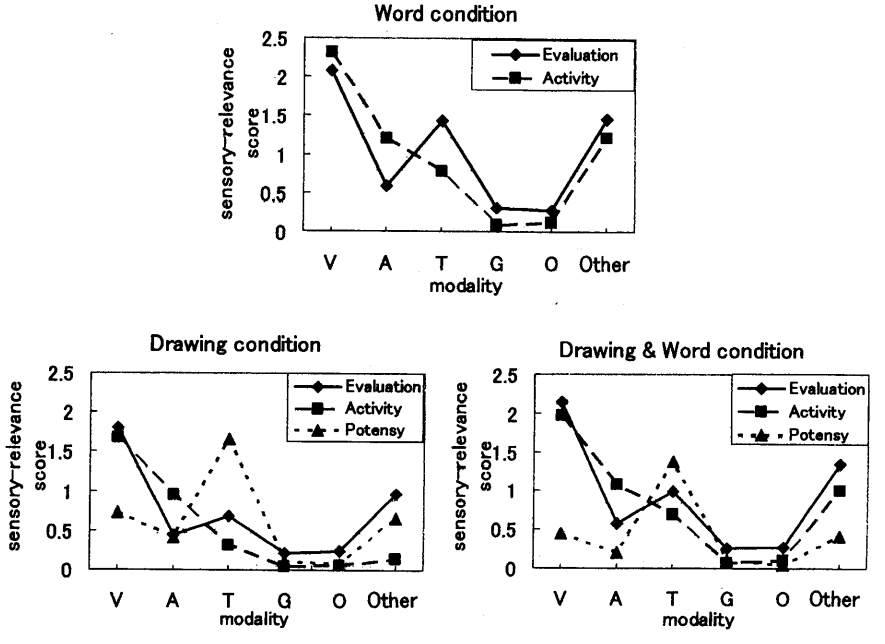

Figure 2. Sensory-relevance scores of each factor in each condition. These scores represent the sums of the squared factor loadings multiplied by the sensory-relevance coefficients for each sensory modality (for details, see Table 1). The symbols, V, A, T, G, O, and Other signify visual, auditory, tactile, gustatory, olfactory, and the other modalities respectively. In these figures, the horizontal scales are nominal ones, but we use line graphs for easy comparisons of the patterns of sensory-relevance scores.

and also for tactile modality. The activity factors indicate high scores for auditory modality besides visual modality. The more interesting result in Figure 2 is that both in the D and the DW condition, the extracted potency factors contain high sensory-relevance scores exclusively for tactile modality. By contrast, such tactile-specific factors cannot be found in the W condition. These results quantitatively support the suggestion of Takahashi (1995) indicating that the drawings arouse tactile sensations and their impressions are largely affected by tactile sensory-relevant concepts.

Then why can we find no factor specific to tactile modality in the word condition? Why do the drawings arouse especially tactile sensations though it is plausible that impressions of drawings contain various impressions related to the other modalities? The possible answers for these questions may be as follows. There are many studies about the intermodal interaction between vision and touch, and it has been suggested that there is a close relation between the two modalities. For example, Gregory (1998) pointed out that visual processing developed from tactile sensation that contains essentially simpler processing and provides immediate and significant information. Perceptual transfer from vision to touch or touch to vision has been shown in infants aged 2 month under certain conditions (Streri & Molin, 1993). Furthermore, in syneasthetic expressions, it is known that the adjectives denoting lower-modal qualities modify the nouns representing higher-modal contents (for example, soft sound, sweet mood, or bright memory), and that tactile adjectives often modify visual nouns, for example warm color (Kusumi, 1988). Taking these facts into consideration, tactile impressions seem to be more concrete and direct in nature, while visual impressions being relatively abstract and indirect. Furthermore, the word impressions are most symbolic and abstract, including highly compressed information. In short, we can regard the relation of these impressions as a kind of information pyramid. The word impressions can be assumed to reside in the top of the pyramid, the visual impressions in the intermediate level, and the tactile impressions in the bottom. According to the information pyramid model, the word impressions can evoke visual impressions that locate just below the word level, but hardly arouse tactile impressions that reside in the lowest level. By contrast, it seems highly likely that the tactile impressions can be automatically evoked when the drawings are presented, because the visual level has direct links to the tactile level in the pyramid.

Anyway, the present study clearly shows that we can precisely analyze the close relationship between visual and tactile impressions produced by drawings in terms of the sensory-relevance score

Application 2: The sensory-relevance scores of the factors affecting impressions of rooms

Outline of the previous studies and analyses by the sensory-relevance scores

Kunishima and Yanase (1984, 1985) conducted two experiments to investigate the effects of physical factors for room atmospheres. They used miniatures which reproduced various types of living rooms and conducted two experiments. The experiment 1 was carried out to investigate

the effects of fundamental materials. The participants were asked to rate the impressions of rooms consisted of various kinds of wall colors, light source locations, illumination levels, and textures of wall materials. The experiment 2 was on the effects of elemental materials. The participants were asked to rate the impressions of rooms containing various types of lights, curtains, furniture, and carpets.

They conducted factor analyses and extracted three factors in both studies (Kunishima and Yanase, 1984, 1985). In the experiment 1, these factors were activity (Fac.1), evaluation (Fac.2), and roughness (Fac.3), respectively (Table 2). In the experiment 2, those were gorgeousness (Fac.1), evaluation (Fac.2), and activity (Fac.3), respectively (Table 3). We calculated the sensory-relevance sores using the factor loadings and the sensory-relevance coefficients of the adjective pairs. The derivation procedures of sensory-relevance coefficients and sensory-relevance scores were the same as Application 1.

Table 2. Sensory-relevance coefficients and factor loadings for each adjective pair (see text for details) that was used for investigating the impressions of rooms with various kinds of fundamental materials.

	Sensory-relevance coefficients						Factor loadings		
	Modality								
Adjective pairs	V	A	T	G	O	Other	Fac.1	Fac.2	Fac.3
light-dark	.53	.16	.06	.01	.02	.22	.99	.09	-.01
open-exclusive	.60	.04	.06	.00	.02	.27	.98	-.04	.03
light-gloomy	.23	.35	.13	.03	.02	.24	.98	-.11	.23
vivid-drab	.97	.00	.01	.01	.00	.01	.97	.08	-.12
active-calm	.48	.19	.04	.01	.00	.28	.95	.27	-.01
cheerful-gloomy	.46	.15	.02	.00	.01	.37	.94	.31	.01
placid-fidgety	.58	.20	.05	.00	.01	.16	-.86	-.19	-.13
living-quiet	.13	.83	.01	.00	.01	.03	.77	.62	-.01
familiar-unfamiliar	.38	.01	.08	.05	.07	.41	.73	.29	-.15
clear-cloudy	.86	.07	.01	.02	.02	.02	.71	-.61	.05
warm-cool	.04	.00	.79	.00	.01	.16	.20	.94	.78
gorgeous-poor	.85	.01	.01	.07	.00	.05	.16	.86	-.27
tumescent-non tumescent	.25	.23	.02	.00	.02	.48	.22	.84	-.24
neat-heavily	.60	.00	.11	.26	.00	.02	.12	-.84	.31
soft-hard	.01	.00	.96	.02	.00	.01	.48	.83	.01
sufficient-insufficient	.13	.02	.06	.22	.00	.57	.01	.80	-.41
sleek-sandy	.01	.01	.98	.01	.00	.01	.13	-.26	.93
fine-coars	.29	.00	.69	.01	.00	.01	-.09	-.26	.90
Factor contribution							9.29	5.28	1.50
Percentage of variance							51.6	29.3	8.30
Cumulative %variance							51.6	80.9	89.2

Table 3. Sensory-relevance coefficients and factor loadings for each adjective pair (see text for details) that was used for investigating the impressions of rooms with various kinds of elemental materials.

	Sensory-relevance coefficients						Factor loadings		
	Modality								
Adjective pairs	V	A	T	G	O	Other	Fac.1	Fac.2	Fac.3
neat-heavily	.60	.00	.11	.26	.00	.02	-.94	-.14	.02
luxurious-reserved	.64	.03	.01	.11	.00	.21	.89	.32	.21
gorgeous-poor	.85	.01	.01	.07	.00	.05	.83	.41	.25
wide-cramped	.74	.02	.11	.00	.01	.11	-.85	-.33	.17
sufficient-insufficient	.13	.02	.06	.22	.00	.57	.78	.56	.20
monotonous-varied	.38	.38	.01	.13	.00	.11	.78	.40	.41
gay-sober	.99	.01	.00	.00	.00	.01	.74	.35	.53
living-quiet	.13	.83	.01	.00	.01	.03	.67	.24	.63
tumescent-non tumescent	.25	.23	.02	.00	.02	.48	.66	.64	.35
sophisticated-common	.51	.09	.00	.18	.00	.22	.64	.61	.39
placid-fidgety	.58	.20	.05	.00	.01	.16	.35	.88	.19
comfortable-uncomfortable	.08	.03	.31	.00	.06	.51	.32	.87	.34
relax-tense	.17	.11	.14	.00	.01	.57	.30	.83	.39
happy-unhappy	.34	.17	.06	.04	.00	.39	.39	.79	.40
soft-hard	.01	.00	.96	.02	.00	.01	.28	.71	.54
active-calm	.48	.19	.04	.01	.00	.28	.33	.24	.85
light-gloomy	.23	.35	.13	.03	.02	.24	-.52	.08	.78
light-dark	.53	.16	.06	.01	.02	.22	.29	.46	.77
open-exclusive	.60	.04	.06	.00	.02	.27	-.07	.33	.76
vivid-drab	.97	.00	.01	.01	.00	.01	.42	.44	.72
cheerful-gloomy	.46	.15	.02	.00	.01	.37	.40	.55	.70
Factor contribution							14.7	3.20	1.20
Percentage of variance							70.1	15.3	5.50
Cumulative %variance							70.1	85.4	90.9

Results and Discussion

In Figure 3A, the activity factor (Fac.1) reveals a high sensory-relevance score for visual modality, the evaluation factor (Fac.2) for visual and tactile modalities, and the roughness factor (Fac.3) exclusively for tactile modality. By contrast, all factors reveal fairly similar patterns of sensory-relevance scores in Figure 3B. These results suggest that while the fundamental materials such as wall color and light source locations can evoke the variation in the sensory-relevance scores, the elemental materials (ex. curtain, furniture, and light) produce little deviation in the sensory relevance scores. As can be seen from Figure 3A, the evaluation factor (Fac.2) and the roughness factor (Fac.3) indicate a high sensory-relevance score for tactile modality. Therefore, the tactile impressions may be evoked from the fundamental materials of room. On the other hand, it is likely that the elemental materials mainly produce visual impressions, since all factors indicate high sensory-relevance scores only for visual modality (Figure 3B).

However, it is necessary to consider that these results were obtained in the limited situation in which the participants were only allowed to observe the miniatures of rooms. Therefore, if we investigate the impressions of real rooms with various materials, there is a possibility that the sensory-relevance scores will show rather different patterns.

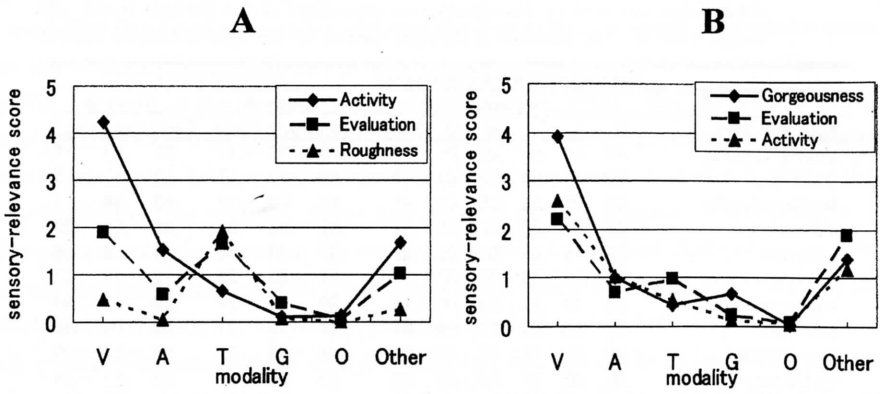

Figure 3. Sensory-relevance scores of factors underlying the impressions of rooms with various kinds of fundamental materials (A) and elemental materials (B). For the meanings of symbols, see the caption of Figure 2.

Application 3: The sensory-relevance scores of the factors affecting the impressions of bottles for perfume

Outline of the previous studies and analyses by the sensory-relevance scores

In a variation of the SD method, a number of participants rate only one object and factors are extracted based on the correlation matrix calculated from the collected data.

As an example of such application, Jingu (1996) introduced a research in the field of product designing. For a newly developed perfume, the impressions of two perfume bottles (Figure 4) were investigated separately with the same twelve adjective pairs such as "dark-bright", "heavy-right" "feminine-manly" "dignified-light" and so on. As the results of factor analysis, three factors were extracted for both designs (Table 4).

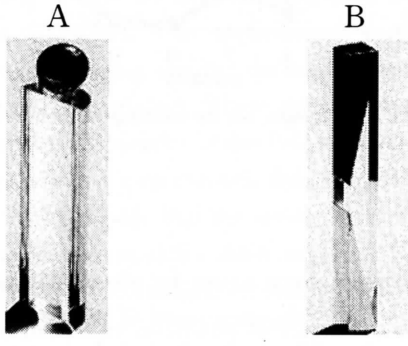

Figure 4. Designs of perfume bottles. The design A has a rounded form, while the design B has a rectangular form.

[Cited from Jingu (1996)]

For the design A, the factor 1 was regarded as "lightness factor", the factor 2 as "calmness factor", and the factor 3 as "coldness factor". For the design B, the factor 1 was considered as

Table 4. Sensory-relevance coefficients and factor loadings for each adjective pair (see text for details) that was used for investigating the impressions of two perfume bottles (the design A and B). The meanings of the other symbols are the same as those of Table 2.

	Sensory-relevance coefficients						Factor loadings					
	Modality						Design A			Design B		
Adjective pairs	V	A	T	G	O	Other	Fac.1	Fac.2	Fac.3	Fac.1	Fac.2	Fac.3
gloomy–cheerful	.46	.15	.02	.00	.01	.37	.85	.17	−.22	.89	.28	.11
grave–airy	.36	.34	.08	.02	.02	.17	.69	.27	.07	.57	.17	.16
familia–unfamilia	.38	.01	.08	.05	.07	.41	.65	.08	−.13	.63	.38	−.11
old–youthful	.81	.01	.05	.02	.01	.09	.62	−.24	.08	.82	.02	−.03
light–dark	.53	.16	.06	.01	.02	.22	.57	.30	−.33	.70	.18	.06
feminine–manly	.76	.01	.03	.00	.03	.17	−.21	−.80	.09	−.10	−.17	.32
weekly–powerful	.38	.19	.23	.03	.00	.18	−.09	−.79	−.28	.28	.33	.90
soft–hard	.01	.00	.96	.02	.00	.01	.41	.76	−.21	−.03	.03	−.40
clear–cloudy	.86	.07	.01	.02	.02	.02	.14	−.33	.19	.69	−.57	−.20
cold–warm	.01	.00	.91	.05	.00	.03	.59	.26	−.70	.58	.61	−.34
passionate–rational	.31	.24	.01	.02	.01	.41	−.15	−.32	.69	−.12	−.70	.03
lively–quiet	.61	.08	.02	.00	.00	.28	.01	.23	.48	−.45	−.59	−.02
Factor contribution							4.98	4.53	3.46	3.78	1.96	1.28
Percentage of variance							24.4	20.1	12.9	31.5	16.3	10.6
Cumulative %variance							24.4	44.5	57.4	31.2	47.8	58.5

"lightness factor", the factor 2 as "calmness & warmth factor", and the factor 3 as "strength factor". We calculated the sensory-relevance sores using the factor loadings obtained from those analyses (Figure 5) and compared the impressions of the two bottles in relation to sensory modality.

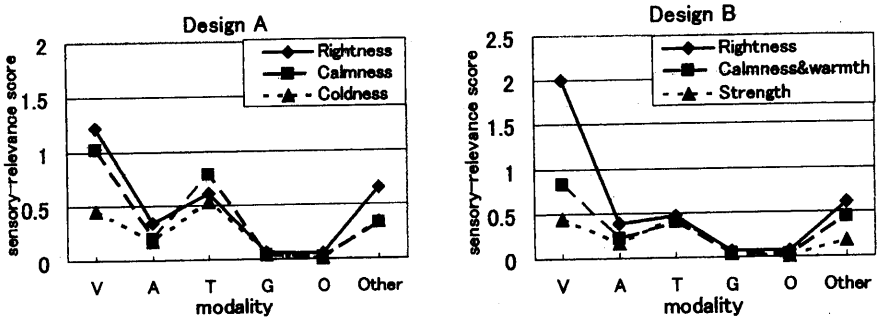

Figure 5. Sensory-relevance scores of each factor for the two bottle designs. For the meanings of symbols, see the caption of Figure 2.

Results and discussion

In the design A, all factors indicate high sensory-relevance scores for visual and tactile modality. On the other hand, in the design B, the sensory-relevance score of the factor 1 is extremely high for only visual modality, while the factor 2 and 3 contain relatively low scores but the similar patterns for visual and tactile modalities as those in the design A .

Therefore, the design A seems to evoke visual and tactile impressions more strongly in

comparison with the design B since all factors showed high sensory relevance scores to visual and tactile modality. By contrast, it can be said that the design B arose visual impressions more keenly because the principal factor indicates a high score for visual modality in particular.

In the research on the perfume bottle design (Jingu, 1996), the impressions of the newly produced perfume which should have been put into one of the bottles were also investigated with the same SD method. The factorial structure of the perfume was very similar to that of the design A, so the bottle with the rounded shape was adopted for the container of the perfume.

The present analyses based on the sensory-relevance scores show that the design A can more richly evoke not only visual but also tactile impressions, while the design B has sensory relevance exclusively to visual modality. Generally, perfume should be related not only to olfactory, but also to tactile modality because we put it on our skin. In addition, tactile factor in designing perfume bottles may be also important since users directly touch the bottles when they wear perfume. Taking these facts into consideration, the sensory-relevance scores of the design A can be considered to fit more nicely actual feelings of perfume usage.

Thus using the sensory-relevance score, we can more precisely investigate the interaction between the impressions of products and human sensations when they use the products. The sensory relevance score may become an important index in the field of product development and usability research, especially in the domain of the *Kansei* (aesthetic) engineering.

General discussion

In the present study, we developed the sensory-relevance score as a new index for evaluating aesthetic impressions in close relation to human sensory modalities, and introduced some applications of the score. In the application 1, we could quantitatively confirm the phenomenon on the impressions of words and drawings qualitatively reported by Takahashi (1995). In the application 2, the sensory-relevance scores revealed the differences between the impressions of rooms with various kinds of fundamental or elemental materials. Thus we found that the score is useful to analyze the impressions having similar factorial structures and also helpful for naming the extracted factors. In the application 3, we demonstrated the effectiveness of the sensory-relevance score in analyzing whether the newly developed product evokes impressions which fit the actual usage of the product. These applications show that the sensory-relevance score enables the researchers especially in the field of *Kansei* engineering to analyze the extracted factors more concretely and quantitatively from the viewpoint of human sensory-modality.

It is plausible that the sensory-relevance coefficients of adjective pairs may vary when an adjective pair modifies different nouns. For example, in the description like "warm cloth", "warm" is related to tactile modality, while in the description such as "warm color", "warm" may be related more intimately to visual modality. At the modality-selection task for each adjective pair, we didn't specify concepts which should be modified by these adjective pairs. Therefore, it can be considered that each coefficient represents an average of values when each adjective pair modifies various concepts. Moreover, in analyzing impressions by the SD method, the factor

loadings change depending on what concepts we use. For example, if we investigate impressions of cloth, the factor loadings will be higher on the adjective pairs which have high sensory-relevance coefficients for tactile modality, while for the impressions of colors, the factor loadings are likely to be higher on the adjective pairs which contain high sensory-relevance coefficients for visual modality. The resulting sensory-relevance scores vary depending not only on the sensory-relevance coefficients for each adjective pair but also on the factor loadings which are different with the relevant concepts. In other words, we assume that the sensory-relevance scores can absorb the variations in the sensory-relevance of adjective pairs in terms of the changes of factor loadings.

Most of the sensory-relevance coefficients indicate large values for visual, auditory, and tactile modalities, not for gustatory and olfactory modalities. Therefore, the sensory-relevance scores are found to be higher especially for visual modality in all applications. The well-known visual dominance phenomenon might be responsible for this tendency, while it is also likely that it may be an effect due to the limited adjective samples. We are now planning to measure sensory-relevance coefficients for various adjective pairs as much as possible, and to create a database which can be available for other researchers.

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