

ORIGINAL ARTICLE

# Specification of Individuality in Causal Relationships among Texture-related Attributes, Emotions, and Preferences

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**Abstract:** To effectively design tactile textures of product surfaces, it is essential to specify the semantically multilayered and multi-dimensional structure of human perceptual, emotional, and preferential expressions pertaining to touching materials. We implemented a method to identify individual differences in the structure of these expressions, based on subjective reports of the mutual impacts among 29 adjective dyads used to describe tactile experiences of material samples. Results showed that the 11 university students who responded to 46 types of flat materials were clustered into three statistically different groups. The structures were largely composed of three layers of expressions: psychophysical (bottom), emotional or material attributes (middle), and preferential (top). All groups selected the same adjective dyads encompassed in the bottom layer, relating to percepts of physical quantities, which indicates the similarity of psychophysical percepts among the participants; however, the middle and top layers significantly differed across individuals. These results indicate that under the tested conditions, there are individual differences in the semantic structures of emotional and preferential experiences; however, such differences in psychophysical expressions are relatively minor.

**Keywords:** *Tactile perception, Texture, Perceptual model, Individual difference, Perceptual layer*

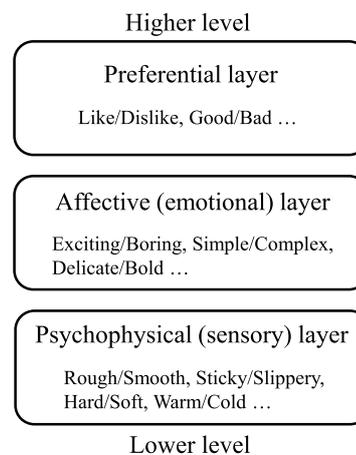
## 1. INTRODUCTION

Touching surfaces produces diverse types of subjective experiences. Primitive experiences comprise psychophysical transformation to perceptual quantities, from physical percepts such as surface roughness and thermal properties. Emotional and affective experiences are described in terms of feelings, comprising simple-complex and exciting-boring. Most personal experiences relate to preferences, such as like-dislike and good-bad. In order to effectively design surface textures of products, it is crucial to understand the causal relationships among these different types of texture-related experiences. Especially because emotional and personal experiences significantly influence the value of a product, many studies have investigated experiences of pleasantness, comfort, and preference for product design purposes [1-5].

Experiences pertaining to touch are sometimes categorized into semantically different layers [6-8], as shown in Fig. 1. The bottom layer, tentatively named the psychophysical layer, corresponds to percepts of the physical properties of materials. The dimensionality of this layer has attracted the interest of many researchers [9, 10], and is typically composed of factors related to perceived fine and coarse (i.e., macroscopic) roughness, softness (or hardness), warmth (or coldness), and friction. The middle layer comprises emotional and cognitive experiences.

Chen et al. [6] suggested that this layer encompasses two sublayers, which is also consistent with the report of Nagano et al. [8], and indicates the complexity of human affective perception. The top, or preferential, layer indicates personal preferences about the item. It is semantically located above the other layers, and these preferences are considered to be determined based on the physical and affective attributes of the product.

Thus far, few research groups have attempted to specify the layered structure of tactile perception. Chen et al. [6]



**Figure 1:** Semantically layered structures of touch-related adjective dyads.

The words in each layer were selected from the literature [6-8]. The structure of the lower level layer varies less across people, whereas that of the higher layer is more dependent on individual perceptions.

mapped discrete layers of sensory and affective adjectives used to describe textures, based on correlations among the scores assigned to the adjectives in a sensory evaluation experiment. Nagano et al. [8] developed a method to establish the semantically layered model of psychophysical, affective, and preferential adjectives, on the basis of impact relationships among the words. Guest et al. [7] and Ackerley et al. [11] projected textures into both psychophysical and emotional spaces, with each space being described by at least three individual dimensions. The specified emotional space appears to correspond to classical emotion models [12,13], in which human emotions are expressed in the two- or three-dimensional spaces. In summary, words relating to textures are semantically layered, and each layer is multi-dimensional.

Naturally, these tactile experiences differ from person to person. For example, Soufflet et al. [14] reported that those working in the clothing industry and those who do not, use different terminology when assessing fabrics. Similarly, students majoring in fashion use adjectives that are different from those of nonfashion majors [15]. Such individuality is also observed in the level of the percepts of physical stimuli. For example, Hollins and Bensmaïa [16] found that the dimensionality of perceptual space varies among people, and concluded that the prominence of friction properties in texture perception depends on individuals. According to Klöcker et al. [17], pleasantness experienced by touching materials is affected by the humidity of the finger pad, which may pertain to the individuality in importance of friction percept when assessing textural dimensions. As found in these studies, the perceptions and feelings caused by touching materials depend on individuals. In principle, the layered structures of texture-related experiences should also exhibit individual differences; however, the explicit establishment of such structures has begun only recently [6,8], so individuality in the structure has yet to be reported thus far.

In this study, we computationally specified individual differences in the structure of texture-related adjective dyads. We constructed the layered structures of these adjective dyads based on Nagano et al.'s method and data [8]. However, where Nagano et al. [8] analyzed the average results across all participants, we focused on individual differences. In this study, the participants were clustered into statistically different groups to show how their layered structures vary. This method will help us to understand, for example, differences in customer values held for products.

## 2. METHOD

The following experiment was originally conducted by Nagano et al. [8] with the approval of the ethical committee of the Engineering School at Nagoya University.

### 2.1 Participants

The experimental participants were 11 university students who were recruited through an open advertisement. They were free of self-reported neural and tactile disabilities.

### 2.2 Tasks

The rating task was not conducted for each material sample, as is typical in the sensory evaluation task. Instead, the causalities between each pair of adjectives were comprehensively judged based on the set of specimens.

Using only one hand, the participants freely touched each of the 46 types of materials, which were randomly lined up behind a curtain, such that they could not see the materials or their hands. They were instructed not to lift the materials, and were not informed of the type of materials used. On the basis of the material textures, participants then rated the causality between two adjective word dyads from among 29 dyad options. They judged the causalities for all permutations made by the 29 dyads in random order. For example, they rated the impact from rough–smooth to delicate–bold using 6-grade scales that ranged from 0 (no effect) to 5 (highly influential).

The adjective dyads were rough–smooth, uneven–flat, hard–soft, warm–cold, sticky–slippery, wet–dry, simple–complex, regular–irregular, delicate–bold, sharp–dull, strange–usual, clean–dirty, clear–vague, concrete–abstract, dangerous–safe, beautiful–ugly, interesting–uninteresting, exciting–boring, rich–poor, comfortable–uncomfortable, good–bad, significant–insignificant, itchy–not itchy, modern–classic, natural–artificial, friendly–unfriendly, general–special, like–dislike, and happy–sad. These adjectives were selected from among a pool of adjectives used in earlier studies on tactile sensory evaluation, with semantically overlapping words excluded. Some may consider that the adjective dyad beautiful–ugly is largely based on visual sensations; however, tactile or haptic aesthetics are also recognized in this context [18].

### 2.3 Stimuli: Material specimens

As listed in Table 1, we used 46 types of material specimens, which were cut into square forms (15 × 15 cm), including wood, cloth, fur, paper, fake leather, ceramic tile, and machined metal plates. Thin materials, such as paper or cloth, were pasted to a 15 cm square plate made

**Table 1:** The 46 materials used for sensory evaluation

Magnolia wood	Oak wood	Sapelli wood
Cork board	Fine woven straw	Coarse woven straw
Woven linen	Woven rush grass	Soft fake fur
Short hair fake fur	Long hair fake fur	Fake boa
Fake cowhide	Fake alligator hide	Fake woven leather
Fake suede	Felt	Towel
Satin	Pyramid rubber matting	Mirror plate
Iridescent sheet	Aluminum foil cloth	Mosaic tile
Glossy vinyl sheet	Glossless vinyl sheet	Cotton cloth
Denim	Fine Japanese paper	Crumped paper
Corrugated paper	Wall paper	Artificial grass
Sponge	Perforated aluminum	Woven wire mesh
Glass beads (7 mm)	Glass beads (5 mm)	Glass beads (3.5 mm)
Glass beads (1.5 mm)	Cotton	Goose feathers
Steel wool	Stainless steel scrubber	Urethane resin
Tile		

of hard plastic. We attempted to prepare for a variety of materials that are common in our daily lives, as opposed to specific products or categories of materials. However, due to difficulties with controlling conditions among the trials, we excluded fresh materials, such as vegetables and leaves, and oily and sticky materials. Some adjective dyads may not be applicable to some materials. For example, soft metal plates do not exist, and softness percepts do not influence affective experiences for metal plates, even though the participants could not visually recognize the type of materials they touched. Hence, to acquire a structure model specified for a certain material category, only the

specimens belonging to that category should be used. In this experiment, we acquired a more comprehensive model of average human responses toward various types of materials.

### 3. ANALYSIS

#### 3.1 Construction of the layered structure of adjective dyads

Here, we briefly review the method used by Nagano et al. [8] to establish causal relationships among adjectives. They used effect matrices [19,20] to specify these causalities, given difficulties associated with using correlations among ratings assigned to words, namely, covariance matrices or correlation matrices.

The procedure of computation is shown in Fig. 2, with example values. For participant  $k$ , the causality rating from adjective dyad  $i$  to another adjective dyad  $j$  was defined as

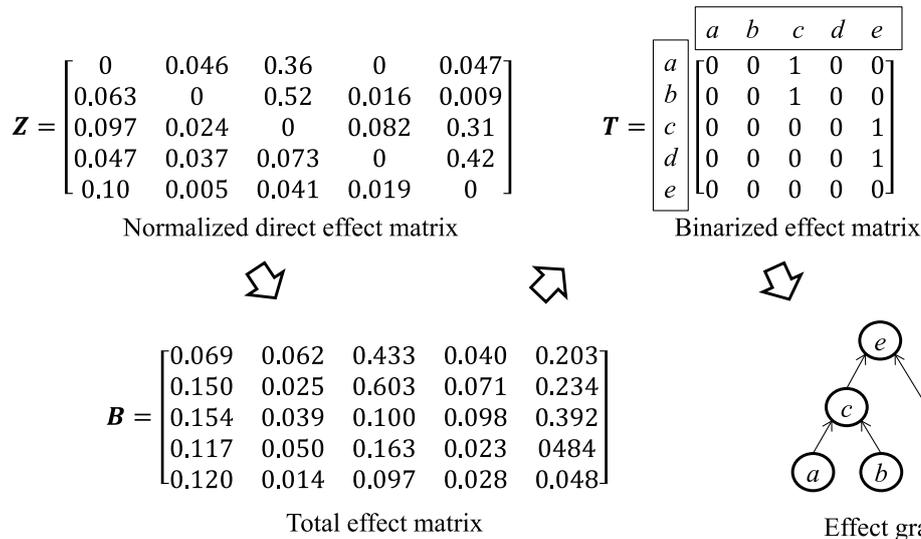
$$x_{ij}^{(k)} \quad (i, j = 1, 2, \dots, m, i \neq j) \quad (1)$$

and was assigned a decimal value from 0 to 5 according to the participant's answer. To acquire the direct effect matrix  $Z^{(k)}$ , the matrix  $X^{(k)}$  of  $x_{ij}^{(k)}$  was normalized for each participant by the formula

$$Z^{(k)} = \frac{X^{(k)}}{s^{(k)}} \quad (2)$$

$$s^{(k)} = \max \left( \sum_i x_{ij}^{(k)}, \sum_j x_{ij}^{(k)} \right) \quad (i, j = 1, 2, \dots, m) \quad (3)$$

where  $s^{(k)}$  was the maximum value of column and row sums of  $X^{(k)}$ . The total effect matrix of  $Z$  was defined by



**Figure 2:** Example of the computation process to produce the effect graph from the effect matrix.  $Z$  and  $B$  correspond to (2) and (4), respectively.  $T$  is the binarized matrix of  $B$  with the threshold value being 0.3, as an example.

the formula

$$\mathbf{B}^{(k)} = \mathbf{Z}^{(k)} + \mathbf{Z}^{(k)2} + \mathbf{Z}^{(k)3} \dots = \mathbf{Z}^{(k)}(\mathbf{I} - \mathbf{Z}^{(k)})^{-1} \quad (4)$$

An element of  $\mathbf{Z}^{(k)}$  indicates the indirect effect from one adjective dyad to another adjective dyad by way of other  $l-1$  adjective dyads. Next, the causality graph was drawn based on  $\mathbf{B}$ , with the adjective dyads being nodes. If  $b_{ij}^{(k)}$ , an element of  $\mathbf{B}$ , is higher than a certain threshold value, a directional arc is produced from  $i$  to  $j$ , which indicates that  $i$  has an impact on  $j$ . The smaller threshold values produce relatively detailed structures, while the higher values can simplify the graph for visual clarity. The acquired graph may include multiple paths from one node to another. By removing such redundant paths between nodes while remaining the reachability between arbitrary two nodes [8], a layered structure of adjectives was established.

### 3.2 Cluster analysis of individual layered structures

We wanted to group the participants with substantially similar structures of adjectives; however, thus far, no researchers have discussed the qualitative differences in the structures even though some factors are apparently qualitatively important, such as the number of layers and types of adjectives in single layers. Hence, we classified the participants in a quantitative manner using statistical tests. We clustered the total effect matrices ( $\mathbf{B}^{(k)}$ ,  $k = 1, 2, \dots, 11$ ) of all participants using Ward's method [21]. The distance between two matrices of participants  $k'$  and  $k''$ ,  $\mathbf{B}^{(k')}$  and  $\mathbf{B}^{(k'')}$ , was defined by the formula

$$\text{dist}(\mathbf{B}^{(k')}, \mathbf{B}^{(k'')}) = \|\mathbf{b}^{(k')} - \mathbf{b}^{(k'')}\| \quad (5)$$

where  $\mathbf{b}^{(k)} \in \mathbf{R}^{841}$  was the vector that contained all elements in  $\mathbf{B}^{(k)}$ . The distance can be also written as follows

$$\text{tr}((\mathbf{B}^{(k')} - \mathbf{B}^{(k'')})^T (\mathbf{B}^{(k')} - \mathbf{B}^{(k'')}))^{1/2} \quad (6)$$

Figure 3 illustrates the results of the clustering analysis. In order to build statistically valid clusters, we tested the following two clusters: For each element in two clusters of  $\mathbf{P} = \{\mathbf{b}^{(p1)}, \mathbf{b}^{(p2)}, \dots, \mathbf{b}^{(pr)}\}$  and  $\mathbf{Q} = \{\mathbf{b}^{(q1)}, \mathbf{b}^{(q2)}, \dots, \mathbf{b}^{(qs)}\}$  where  $r$  and  $s$  are, respectively, the number of participants belonging to clusters  $\mathbf{P}$  and  $\mathbf{Q}$ , we computed the distance from the center of  $\mathbf{P}$ . The sets of distances are denoted as  $\mathbf{p}$  and  $\mathbf{q}$

$$\mathbf{p} = \{\|\mathbf{b}^{(k_p)} - \mathbf{b}_p\| : \mathbf{b}^{(k_p)} \in \mathbf{P}\} \quad (7)$$

$$\mathbf{q} = \{\|\mathbf{b}^{(k_q)} - \mathbf{b}_p\| : \mathbf{b}^{(k_q)} \in \mathbf{Q}\} \quad (8)$$

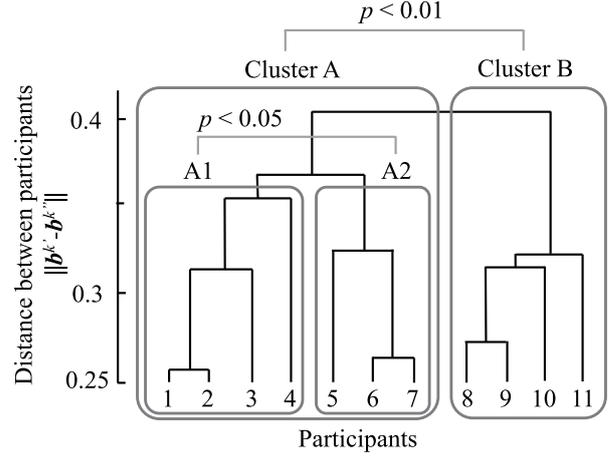


Figure 3: Participant clusters in terms of similarities of effect matrices.

where  $\mathbf{b}_p$  is the center vector of  $\mathbf{P}$ .  $\mathbf{b}_p$  is determined by

$$\mathbf{b}_p = \frac{\sum_{i=1}^r \mathbf{b}^{(p_i)}}{r} \quad (9)$$

We then compared  $\mathbf{p}$  and  $\mathbf{q}$  using Welch's  $t$ -test. As a result, clusters A and B ( $t_0(9) = 3.67$ ,  $p < 0.01$ ) were judged as statistically different. Further, two subclusters of A1 and A2 ( $t_0(5) = 3.95$ ,  $p < 0.05$ ) were different. Clusters A and B were composed of participants 1–7 and 8–11, respectively, while clusters A1 and A2 were composed of participants 1–4 and 5–7, respectively.

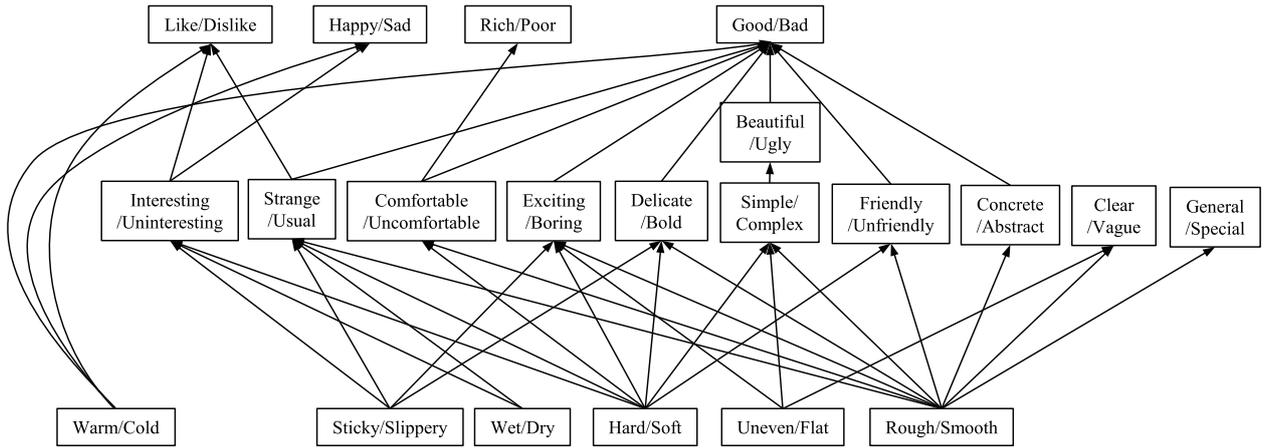
## 4. RESULTS

### 4.1 Similarities and differences among the three clusters

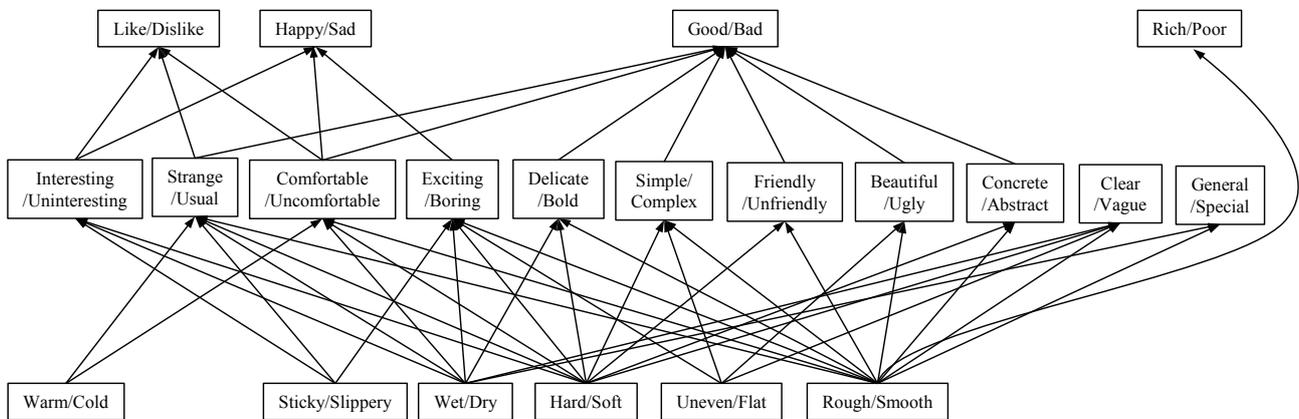
For each of the three statistically valid clusters described in the previous section, we constructed the layered structure of adjective words as shown in Figs. 4 (group A1), 5 (group A2), and 6 (group B) by applying the method described in Section 3.1 above. The threshold value was set at 0.050. In general, larger threshold values reduce the number of apparent paths in the graph and yield a more visually understandable graph; however, the graph should not be simplified too much. We adopted the value of 0.050 because the number of nodes in the graph plummeted when the threshold value was set above 0.051. Further, within the range of 0.036–0.050, the number of nodes in each layer did not change.

The nodes in the highest layer (like–dislike, happy–sad, rich–poor, and good–bad) and those in the bottom layer (warm–cold, sticky–slippery, wet–dry, uneven–flat, and rough–smooth) were the same across all three groups. The nodes in the highest layer were largely related to personal

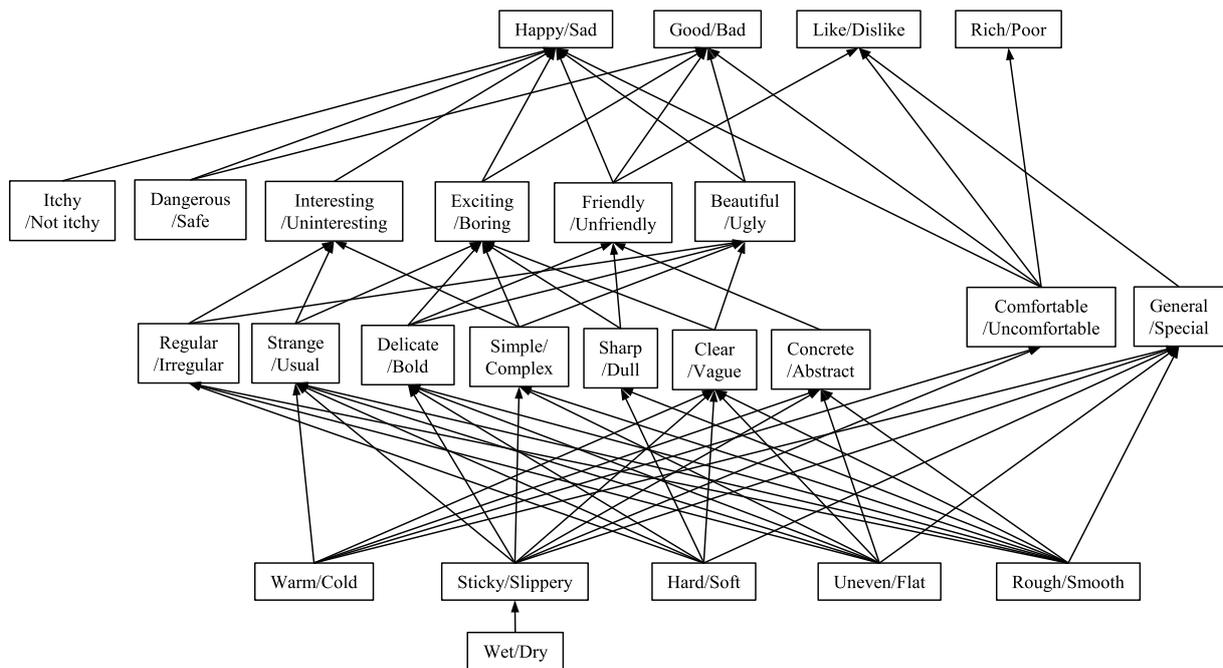
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**Figure 4:** Effect graph built from group A1.  
This is nearly three layered except for the beautiful-ugly dyad.



**Figure 5:** Effect graph built from group A2.  
This has a three-layered structure.  
The rich-poor node cannot be judged in relation to whether it belongs to the middle or top layer.



**Figure 6:** Effect graph built from group B.  
This has a four-layered structure with a complicated middle layer.  
The dangerous-safe and itchy-not itchy nodes were not strongly influenced by the bottom, psychophysical layer.

preference, and those in the bottom layer pertained to psychophysical percepts. The middle layer was composed of attributes of materials, such as clear–vague, general–special, and simple–complex, and emotional properties including comfortable–uncomfortable, interesting–uninteresting, and exciting–boring.

In Figs. 4, 5, and 6, although the bottom and highest layers in all groups have the same or very similar nodes, the structures of the middle layer varied between groups A and B. In short, the middle layer in group B clearly included an additional sublayer, whereas that in group A was a single layer. The distinctions between groups A1 and A2 were relatively minor in terms of the types of nodes in the layer. In the structure of group A1, the beautiful–ugly node was located above the other nodes in the middle layer, while the middle layer in group A2 was completely flat. Nonetheless, most of the differences between groups A1 and A2 lay in the paths spanning the nodes. For example, in the structure of group A1, happy–sad was influenced by interesting–uninteresting and warm–cold nodes, whereas in structure A2, it was directly influenced by interesting–uninteresting, comfortable–uncomfortable, and exciting–boring nodes. Some participants appeared distant from the others belonging to the same group for example, participants 6 or 7 and participant 5 although the topological differences in their layered structures were minuscule.

#### 4.2 Comparison of the layered structures with those in a related study

The abovementioned general features were also observed by Chen et al. [6], who built the structure based on the correlation coefficients among ratings assigned to adjectives. Further, to the best of our knowledge, their study is the sole example of the structure of texture-related adjectives with more than three layers. In spite of several differences between their method and ours, profound similarities were observed in these two studies. Chen et al.'s stimuli were 15 flat wrapping papers and films used for food packages, which were cut into 50 × 80 mm pieces. Forty women aged 10–30s rated each specimen in terms of 17 adjectives, using 7-graded scales in a blind condition. Unlike in our experiment, Chen et al.'s participants knew that the materials were used for food packaging. In their structure, the bottom (i.e., psychophysical or sensorial) layer consisted of the following terms: warm, rough, hard, dry, and sticky. These adjectives are very similar to those located in the bottom layers of our Figs. 4, 5, and 6. Some similarities can also be found between Chen et al.'s

study and ours in relation to the middle and upper layers. Their middle layer included delicate and simple adjectives that also appeared in the middle layer of our model. In addition, indulgent and relaxing adjectives in Chen et al.'s model and the friendly–unfriendly and comfortable–uncomfortable nodes in the middle layer of our model may be considerably similar. The highest layer in Chen et al.'s model included exciting, pleasurable, playful, premium, and precious adjectives. Our structures have similar adjectives, i.e., happy–sad, good–bad, and rich–poor located in the highest layer, and exciting–boring in the second highest layer in the structure of group B. Overall, eight of the 17 adjectives (warm, rough, hard, dry, sticky, delicate, simple, and exciting) in Chen et al.'s model are consistent with our model in terms of the literal consistency of words and their locations in the layered structure. Considering the similarities in the meanings of words, an additional five words (relaxing, precious, premium, indulgent, and playful) in Chen et al.'s model are also regarded as consistent with our model. We did not offer the exact adjectives used by Chen et al.; however, these abovementioned analogies suggest that the correlation-based method and our method, based on the effect matrix, would produce very similar semantic structures of texture-related adjectives. These structures were robustly established despite differences in material sets and demographics between the two studies, which supports the general validity of the structures used in these studies.

On the other hand, the natural node was included in the layer above the psychophysical one in Chen et al.'s model, whereas our natural–artificial node was filtered out owing to its weak impacts on the other nodes. This difference in the natural–artificial node may be attributed to differences in the analyses. A correlation-based method, which was used by Chen et al. [6], does not specify the causal relationships among adjectives; hence, adjectives can be coincidentally connected without regard to actual causalities, especially when the number and categories of material samples are limited. In contrast, our method was based on effect matrixes and can be used to establish causality. Further, the material samples were designated as being used for food packaging in Chen et al.'s study [6], whereas the usage of materials was not specified in our study. Thus, Chen et al.'s participants might have judged whether the material samples were natural or artificial for food packaging purposes, whereas such judgment criteria were not provided in our study.

## 5. DISCUSSION

### 5.1 Individuality tends to lie in the middle (attribute/emotion) and higher (preference) layers

It should be noted that our results are based on a small sample group of participants from the same generation and nationality. A larger variety of experimental participants may lead to a larger number of subgroups than the three found in this study. All three groups tested in this study included the same types of nodes in the bottom—or psychophysical—layer, indicating that the variance across people at this basic sensory level is minimal. Nonetheless, as suggested in earlier studies [1, 16, 22], individuality should not be neglected even in this layer. Compared with the bottom layer, the contents of the middle and higher layers varied significantly between groups A and B. The middle layer in group A was flat, and the causal relationships among the nodes within this layer were not clearly shown. In contrast, the middle layer in group B encompassed a larger number of nodes and an additional sublayer, suggesting that some of these nodes influenced others in the middle layer. The types of node in the highest layer were the same in all groups; however, they were very differently affected by the nodes in the lower levels. Therefore, this study computationally demonstrated that individual variations in perceptual experiences tend to apply at the affective and preferential levels, rather than at the psychophysical level.

### 5.2 Graphical structures are based on the relative importance of relationships

The individual differences specified in this study originate from the magnitudes of reported causalities among the 29 adjective dyads. Paths between relatively weakly connected adjectives were filtered out; hence, it is a fallacy that the paths and nodes that did not appear in the graphs were not felt by the participants. In fact, they were just apparently ignored because they were perceived as relatively unimportant.

In the graphical modeling with effect matrices, the apparent complexity of a depicted structure change with the threshold value [23]; however, the general trends of each group in this study held true for a wide range of threshold values. Specifically, the types of nodes in each layer did not vary when the value ranged from 0.050 to 0.036, while when the threshold was smaller than 0.035, the middle layer in each group yielded another sublayer. In other words, more detailed structures of the middle layer could be seen by considering minor effects between the nodes. Even with such small threshold values, group B

generally indicated a structure that was more complicated than that of group A.

### 5.3 Caution regarding the use of the specified individualities

The experimental participants touched flat materials cut into square forms, and the established structures of adjective dyads used in this study relied on these material specimens. The higher levels, in particular, may have been more affected by the set of specimens because emotional and preferential layers are determined not only by physical stimuli, but also by prior knowledge about what the participant is touching. For example, the material percepts of wood, ceramic, and metal are definitively identified at the psychophysical level. However, the responses at higher levels depend on the type of product or object. Ceramic dishes are widely used, whereas metal ones are not so common in some cultures. On the other hand, metal spoons and forks are widely familiar, while ceramic versions of these utensils are not. These types of knowledge about products influence the layered structure of adjectives, so the structures acquired in this study may change according to the type of product. To explain such changes in the structure, we need to introduce factors relating to cultural background or properties of items tested in the experiment. In the field of marketing, the dependence of preferences on multiple aspects of human life styles and products is widely acknowledged [24, 25]. Further, it should be noted that the established structures were grounded on the meanings of adjectives. Hence, the structure is semantic and should not be related to the neural processing of touch-related information.

Another problem in the construction of the layered model is the difficulty of its validation because there does not exist a reference model, known as a golden standard, for the purpose of comparison. In general, the validation of the causal model of social and industrial problems is based on agreement and discussion among experts [23]. However, such validation is not the case for the texture-related perception and feelings model, for which experts are unlikely to exist. One effective method to compensate for this absence would be comparison of models established by different approaches. As previously mentioned, the structural model acquired in Chen et al.'s study [6] and our model largely agreed with each other, supporting the validity of the models. Another possible approach is comparison of the models established from the same participants and tasks but with different material sets, which would allow us to test the robustness of the model against the material sets. Further, more direct comparison

between our approach and that of Chen et al., [6] involving the same participants and material sets, would be interesting to further test the characteristics of the layered models based on the two different approaches.

## 6. CONCLUSION

For product design, it is invaluable to specify the causal relationships among the material perception and various customer values, such as affective, emotional, and preferential factors that are experienced by interacting with the material. However, there exist a limited number of reports and methods to build the semantic structure of such intrinsically multilayered and multidimensional human experiences. Furthermore, thus far, individual differences in the structure have not been computationally identified. We extended a method using effect matrices to define the causality between the adjective words, in order to establish the layered structure of touch-related experiences and realized the analysis of individuality. Furthermore, to specify meaningful differences, we clustered the matrices acquired from all the participants into statistically different subgroups. To test these methods, we investigated the layered structures of the 11 university students and classified them into three groups, with adjective words placed into three or four layers. The bottom layer, which is semantically the cause of other personal experiences, was composed of words pertaining to the percepts of physical quantities of materials, such as rough–smooth, uneven–flat, hard–soft, warm–cold, sticky–slippery, and wet–dry. The structure of this layer, which was named the psychophysical layer, was very similar across all participant groups, indicating that relatively little individuality exists in this layer. On the other hand, groups A and B differed substantially in terms of the middle layers, which related to the perceived attributes of material and emotional experiences, as described by dyads such as strange–usual, delicate–bold, simple–complex, general–special, beautiful–ugly, and exciting–boring. The middle layer of one participant group was flatly configured, suggesting that the adjectives in this layer weakly impacted on each other; however, the other group constructed an additional sublayer within the middle layer, meaning that strong causalities between the words exist within this layer. All groups listed the same adjective dyads in the highest, or resultant, layer, as the terminal nodes of the causality graph. They were happy–sad, good–bad, like–dislike, and rich–poor, and were expressions that largely related to personal preference. Although these four dyads were

typically included in the highest layer, they were very differently impacted on by the lower layers between the groups. These results indicate that the middle and top layers yielded individual differences in touch-related experiences across the tested 11 university students. Such differences were computationally specified in this study for the first time. Modeling the personal characteristics of experiences will aid comprehension of diverse responses across people toward the same material, and establishment of marketing strategies for products.

## ACKNOWLEDGEMENTS

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