Analysis of Preferences for Wooden Panels with Different Visual Homogeneities
– Examination by Implementation of Individual Classification according to Evaluation Tendency –

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Abstract: Wooden panels that are made of glueing elements with various appearances, involve numerous visual combinations. Although craftsmen believe that homogeneous patterns are desirable, it is helpful to clarify the acceptability of heterogeneous patterns from the perspective of sustainability. This study classified individuals based on their evaluation tendencies and examined their preferences. We performed a subjective evaluation of 17 sample images of 109 participants using an online survey. Consequently, it was found that patterns evaluated as “even” are generally more preferred. However, the classified clusters showed differences in their evaluation tendencies. For instance, the general consumer group confirmed only “heterogeneity” and the expert group felt “naturalness” from all samples. Additionally, there was a cluster that might have derived additional value from more homogeneous patterns. We conclude that an even appearance is desired, and additional information illustrating the characters of the wooden panel is needed to release unique patterns.

Keywords: Wooden furniture, Online survey, Cluster analysis

1. INTRODUCTION

Because wood is a nature-derived material, its size is limited. Therefore, several pieces of wood are combined when applied to plane components such as a tabletop. However, the number of patterns created by combining individuals with different appearances has increased significantly. In the furniture industry, the pattern created by combining lumber is considered desirable to have a uniform appearance, and furniture makers coordinate the colors and patterns to avoid any irregularity [1]. On the other hand, consumer preferences have diversified, and there is a possibility that not only uniform-looking top boards, such as the traditional style, but also tops with visual heterogeneity will be accepted in the market. While it is necessary to continue addressing the issues of meticulous selection of wood and the inheritance of craftsmen’s skills to continue the supply of homogeneous panels, if the supply of uneven tops is also achievable, it would be beneficial to address both the diversity of consumers and sustainable manufacturing. Manuel et al. [2] showed that consumers perceived different impressions for different clusters of similar appearance patterns by conducting a web-based survey using softwood flooring samples with various appearances. In addition, they suggested the effectiveness of the design and marketing of suitable combination patterns according to consumers’ expectations. Therefore, we focused on the preferences for various combination patterns of hardwood.

In addition to Manuel et al.’s study [2], several other studies have evaluated the appearance of wood combinations, and it has been pointed out that a unified impression, such as harmony and homogeneity, is important [3-5]. Although these studies mainly focused on softwoods, Yamaguchi et al. [1] indicated that alignment of the contrast of adjacent individuals is also a critical concern in the pattern matching of hardwoods used for furniture. Peterson et al. [6] conducted visual, tactile, and visual-tactile impression evaluations of samples containing both softwood and hardwood on Japanese and Swedish subjects to examine which samples were preferred by each subject group. The results suggest that Japanese prefer wood with a homogeneous appearance, whereas Swedish accepts wood with complex textures. There have been other reports of such differential evaluations of objects depending on the attributes and sense of value of the participants [7-10]. Matsumoto et al. [11, 12] focused on the context in which the objects were applied and investigated the impression of wooden wall panels with different amounts of knots within each room type. The results showed that while panels with fewer knots were preferred, panels with more knots were acceptable in the interiors of public buildings. These findings suggest that while a homogeneous appearance in wooden top
boards made of hardwoods is preferred, a heterogeneous appearance is also acceptable, depending on the individual and context. Nevertheless, no studies have been conducted to investigate the impressions of matched patterns with various visual homogeneities for furniture made of hardwoods.

Therefore, we performed an experiment to evaluate the appearance of wooden top boards of different homogeneities by focusing on individual differences. The purpose of this study was to categorize people who have a similar evaluation tendency for wooden top boards, and to discuss the characteristics of each group. Because it was technically difficult to present many patterns to the participants using real panels, a web-based survey was employed to evaluate the images of the samples.

2. METHODS

2.1 Sample images

In this study, 17 patterns selected from 60 patterns obtained in previous studies [1] were used as samples, considering variation. These patterns were collected from an experiment that instructed participants to select five of the 15 red oak (Quercus rubra) elements (edge grain) and arrange them in the width direction to create the desired pattern. One element was 400 mm long and 42 mm wide, and the size of the panel with a collection of five elements was 400 × 210 mm. Surface images of the sample were obtained under the same illumination environment, and 24-bit full-color images of 3,500 × 1,850 pixels (approximately 396 × 209 mm) were used as the target image for the analysis.

2.2 Web-based survey

We employed the semantic differential method [13] to evaluate the impressions of the samples. Four evaluation terms included “even/uneven (kin-itsu/fu-kin-itsu)” that directly evaluates the homogeneity of the pattern, “natural/artificial (shizen/jinko-teki)” and “expensive/cheap (taka-sou/yasu-sou),” which are considered important factors in the evaluation of wood products, and “like/dislike (suki/kirai)” that evaluates preference. Each evaluation term was rated using a seven-grade scale, and each scale was converted into a value from +3 to −3 in the analysis (e.g., +3: extremely even (hijo-ni kin-itsu), +2: even (kin-itsu), +1: slightly even (yaya kin-itsu), 0: neither (dohira-demo-nai), −1: slightly uneven (yaya fu-kin-itsu), −2: uneven (fu-kin-itsu), and −3: extremely even (hijo-ni fu-kin-itsu).

On the evaluation web page, one sample image that was scaled down to 900 × 475 pixels, which was supposed as a reasonable resolution for a web page, was displayed at the top, and the instructional text and each evaluation term were shown below the image. The text was “Observe the image above (actual size: approximately 40 × 20 cm) and answer how you feel about its appearance as a wooden top board.” Seventeen evaluation pages were prepared for each sample image, and participants were presented with 17 pages in random order, following a homepage that asked for their agreement to participate and their attributes. In addition to the four evaluation scores for each sample, we collected the following data: name, gender, age, occupation (five choices: wood-related workers, general workers, wood-related students, general students, and others), and residential area, which were provided by the participants, and response time and window size were obtained from the participants’ access information.

The survey forms were published on the Internet, and we requested answers from university students and wood-related workers. The study period was 15 days, from February 16, 2021 to March 2, 2021.

2.3 Screening of valid answers

A total of 139 records were received, and valid answers were screened according to the following procedure.

(1) Records that did not match the number of evaluations with the samples

Based on the number of ratings contained in one answer, the record that did not seem to complete the evaluation of all 17 samples × four terms or that seemed to do the overlapping evaluation was removed. Nineteen cases belonged to this category.

(2) Records of the participants who rejoined

Based on the attribute data (i.e., name), we excluded records of participants who decided to appear multiple times for evaluation. Five cases belonged to this category.

(3) Records with a long screen time

To avoid bias in the display time between samples, four records with a total response time of over 20 min were excluded.

(4) Records with small window sizes

If the window size was smaller than the full size of the image, the entire image might not have been visible. Two cases were excluded because of this issue.

Using the above operations, 109 records that had completed the evaluation of 17 samples were defined as valid answers. Table 1 shows the attributes of 109 participants who submitted their records.
2.4 Analysis
First, we carried out a one-way ANOVA (paired data) for the even/uneven evaluation scores of all participants to confirm whether the 17 samples offered different visual homogeneities. In addition, we defined the average score, calculated from an even/uneven score of 109 answers, as the index of subjective homogeneity and named it DoSH (degree of subjective homogeneity). Next, k-means cluster analysis was performed to categorize participants with similar evaluation tendencies. The parameters were 17 samples × four items scores (a total of 68 dimensions), and 109 participants were classified into six clusters. To interpret the characteristics of each cluster, the attributes of the participants were compared between clusters. ANOVA and multiple comparisons with Bonferroni correction were applied to test age, whereas the χ² test and residual analysis were applied to test other attributes. Pearson correlation coefficients (r) between terms in the whole cluster and each cluster were calculated, and no correlation tests were performed to examine the evaluation trends of each cluster.

Finally, to consider the whole and individual cluster preferences for each sample, like/dislike scores for each cluster were provided for the ANOVA. In addition, we defined the sample whose average score of like/dislike was more than zero, that is, better than neither, as an acceptable pattern, and considered the relationship between DoSH and the average score of like/dislike.

The significance level for ρ-value was defined as 5%, and we assessed the case with ρ-value less than 10% as marginally significant. The degree of each effect size was interpreted in three levels: small, medium, and large, based on the literature [14]. The strength of correlations was defined as absolute r of 0–0.2: no correlation, 0.2–0.4: weak correlation, 0.4–0.7: correlated, and 0.7–1.0: strong correlation.

The analyses were conducted using the statistical analysis software (Social Survey Research Information Co., Ltd., BellCurve for Excel 3.21).

3. RESULTS

3.1 Subjective homogeneity of each sample
Figure 1 shows the average scores of the even/uneven overall. The main effect of the difference between the samples was significant (Greenhouse–Geisser correction, F(11.3,1225) = 95.9, ρ < .001, η² = .352). Based on the correspondence between DoSH and the evaluation scale, L-31 to L-24 showed an uneven pattern, L-12 to L-30 showed a slightly uneven pattern, L-4 to L-2 showed a moderate pattern, and L-29 to L-23 showed a slightly even pattern.

3.2 Classification of participants
Figure 1 and table 1 show the centroids (average score for each evaluation) and participants’ attributes for each cluster respectively. Because some cases had an expected value of frequency distribution of less than five, the results of the χ² test and post hoc test were used as references. Each cluster was named CL1-CL6 in the order of size. CL1 was characterized by a smaller number of wood-

### Table 1: Participants’ attributes for the whole and each cluster
(numbers in brackets mean expected values [cells with less than five are highlighted], †: ρ < .10, *: ρ < .05, **: ρ < .01)

|          | whole | CL1 | CL2 | CL3 | CL4 | CL5 | CL6 |
|----------|-------|-----|-----|-----|-----|-----|-----|
| n        | 109   | 27  | 25  | 23  | 18  | 10  | 6   |
| mean     | 48.5  | 38.0| 32.5| 41.0| 47.5| 38.0|     |
| S.D.     | 15.1  | 14.5| 11.5| 11.3| 16.9| 11.2|     |
| male     | 81    | 22  | 17  | 16  | 13  | 9   | 4   |
| female   | 28    | 5   | 8   | 7   | 5   | 1   | 2   |
| worker wood |       | 44  | 17  | 16  | 13  | 9   | 4   |
| worker general |       | 11  | 11  | 8   | 5   | 5   | 4   |
| student wood |       | 33  | 10  | 7   | 6   | 1   | 2   |
| student general |       | 35  | 8   | 8   | 5   | 5   | 2   |
| other    | 15    | 1   | 11  | 11  | 10  | 6   | 4   |
| PC       | 6     | 21  | 14  | 17  | 13  | 7   | 5   |
| Phone    | 28    | 6   | 11  | 17  | 14  | 1   | 2   |

ANOVA (η²) | χ² test (Cramer’s V) | residual analysis
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.003 * |          |          
.645 n.s. |          |          
.093 † |          |          
.120 n.s. |          |          
.156 Large |          |          
.167 Small |          |          
.257 Small |          |          
.283 Small |          |          

Bonferroni

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Figure 1: Sample images and average scores for the whole and each cluster

(DoSH [degree of subjective homogeneity]: average score of even/uneven for the whole)
related professionals and students, and a larger number of general workers. The mean age of the patients with CL1 was significantly higher than that of the patients with CL3. Although there were no clear features in the attributes, CL2 seemed to have slightly more participants who used the smartphone. CL3 included a large number of wood-related students. This cluster also had the lowest mean age, significantly lower than that of CL1. CL4 included more wood-related professionals, with only one each from the general workers and students. A small number of participants were assigned to CL5 and CL6 (10 and 6, respectively).

3.3 Correlations between terms

Table 2 shows the values of $r$ between four evaluation terms. The values of the whole were calculated from scores of all $109 \times 17$ samples, and the values of each cluster were calculated from scores of $n \times 17$ samples. The result shows an $r$ of more than positive 0.2 for all combinations of four terms. The null hypothesis (populational $r$ is zero) was also denied on all pairs, as shown in table 2 ($p<.01$). However, the strength of the correlations varied between clusters. In CL1, correlations were weak between even/uneven and expensive/cheap, and between even/uneven and like/dislike, whereas in CL3, all correlations were strong. The correlation between even/uneven and natural/artificial was weak for CL4 and CL5, whereas the correlation between expensive/cheap and like/dislike was strong for CL6.

| natural/artificial | expensive/cheap | like/dislike |
|-------------------|----------------|-------------|
| whole 109×17      | whole .656    | whole .645  |
| CL1 .447          | CL1 .387 w    | CL1 .378 w  |
| CL2 .712 s        | CL2 .590      | CL2 .519    |
| CL3 .885 s        | CL3 .817 s    | CL3 .826 s  |
| CL4 .385 w        | CL4 .572      | CL4 .630    |
| CL5 .357 w        | CL5 .515      | CL5 .506    |
| CL6 .471 w        | CL6 .403      | CL6 .628    |

3.4 Acceptable samples for each cluster

Figure 2 shows the relationship between the average score of like/dislike and DoSH for the whole cluster and each cluster. The ANOVA results for like/dislike showed significant effects of differences in the samples for the whole and each cluster. The results for CL5 and CL6 were omitted because of the small number of classified participants.

For the whole cluster, the number of acceptable samples with an average score of like/dislike more than zero was eight (L-3 to L-23). The numbers for each cluster were as follows: seven (L1, N-7 to L23) for CL1, 13 (L-16 to L-23) for CL2, five (N-7, L-29 to L-23) for CL3, and nine (L-4, L-3 to L-23) for CL4.

| Natural/artificial | Expensive/cheap | Like/dislike |
|-------------------|----------------|-------------|
| whole 109×17      | whole .746 s   |              |
| CL1 27×17         | CL1 .562       |              |
| CL2 25×17         | CL2 .676       |              |
| CL3 18×17         | CL3 .836 s     |              |
| CL4 16×17         | CL4 .692       |              |
| CL5 10×17         | CL5 .613       |              |
| CL6 6×17          | CL6 .731 s     |              |

Figure 2: Relationship between DoSH and preferences (tests: paired ANOVA for like/dislike, GGC: Greenhouse-Geisser correction, †: $p<.10$, *: $p<.05$, **: $p<.01$)
4. DISCUSSION

4.1 Whole evaluation trends

The correlations between the terms in Table 2 are all positive. Thus, for the samples and conditions used in this study, it is suggested that all four evaluation terms were evaluated in the same way. Using the hypothesized model whose sensitivity evaluation depends on a hierarchical structure consisting of a physical layer, an impression layer, and a value layer [15-17], it can be assumed that the evaluation terms in this study are physical layers for even/uneven, impression layers for natural/artificial, and value layers for expensive/cheap. Therefore, it is concluded through the evaluation tendency that the patterns with more visual homogeneity will give a more natural impression, and thus will be preferred as a comprehensive trend.

Focusing on the relationship between DoSH and preference for the whole (Figure 2), it can be assumed that more homogeneous samples are preferred. In particular, the average preference score exceeded zero for the samples from L-3 (DoSH: -0.09) or higher. Therefore, it is considered that a pattern that is evaluated as even (kin-itsu) than neither (dochira-demo-nai) is generally preferred when edge-glued wooden panels are evaluated in terms of even/uneven (kin-itsu/fu-kin-itsu).

4.2 Evaluation tendency for each cluster

CL1 is considered to be a cluster closer to the elderly general consumer owing to the smaller size of wood-related participants and higher mean age. Regarding preferences, samples on the heterogeneous side of the DoSH, from L-31 to L-30, were evaluated as dislike-side, whereas samples on the more homogeneous side of the DoSH, from L-4 to L-23, were not preferred. Additionally, r values in CL1 were low compared to the whole and other clusters. Therefore, it can be concluded that CL1 evaluates patterns that are perceived as heterogeneous as “uneven (fu-kin-itsu),” but does not explicitly evaluate other samples and evaluation terms. This is because CL1 is close to general consumers and lacks extensive knowledge or experience with wood. Therefore, CL1’s evaluation tendency is interpreted as a “heterogeneous confirmation type,” focusing on whether or not it can be clearly identified as heterogeneity. It is also considered that people with this evaluation tendency dislike heterogeneous patterns, whereas patterns with more than a certain homogeneity do not differ in their preferences.

CL2 was not significantly characterized by attributes, but a reasonably high number of participants used the smartphone. Thus, it is possible that the sample images were displayed and evaluated on a smaller screen. CL2 has a wide evaluation range of even/uneven among all samples, as shown in Figure 1, which is assumed to be because of the small display size of the evaluation image, making it easy to evaluate homogeneity as a whole view. Therefore, the evaluation tendency of CL2 can be interpreted as a “homogeneity-sensitive type” with a wide evaluation range for homogeneity, and this type would be related to people who observe on small screens. Regarding preferences, CL2 was the cluster that accepted the largest number of samples, and it is considered that people of this type are more tolerant of heterogeneity patterns.

CL3 was the youngest cluster as per mean age, and was assumed to be a cluster close to a younger group. CL3 showed the strongest positive correlation between evaluation terms, and linear-shaped cluster centroids tended to shift to positive/negative depending on the samples. A study [18] that investigated differences in the Kansei space according to the age of participants suggested the possibility that the meanings and concepts of words are clearer in mature people than in young people. Similarly, in this study, younger participants did not differentiate between each term and evaluated all terms in the same manner, implying that the correlation between the terms became stronger. Accordingly, the evaluation tendency of CL3 was interpreted as an “inter-terms-linear type,” in which the correlation between evaluation terms was strong, and it was estimated that young people tend to use this type. Regarding preferences, figure 2 shows that the acceptable sample size for CL3 is limited to five. This implies that homogeneity directly influences preference, and only limited patterns with high homogeneity are preferred.

Because CL4 included many wood-related participants, it was considered to be close to people with rich knowledge and experience with wood. The shape of the cluster centroid shows that all samples tend to be evaluated as “natural”. In other words, it can be assumed that participants who were interested in wood evaluated “it’s natural because it’s wood” regardless of the visual pattern of the panels. Therefore, the evaluation tendency of CL4 was interpreted as a “naturalness-enhanced type,” and it was considered that this type is more common among craftspeople and consumers who are interested in wood products than general consumers. On the other hand, basically, a correspondence between DoSH and preferences was observed in Figure 2, and the correlation between even/uneven and like/dislike was not too low. In other words, it is considered that people with this evaluation type perceive any pattern of wooden panels as “natural,” but believe the preferable pattern is an evenly
aligned one. CL5 and CL6 were the groups that evaluated high or low scores to almost all, but it cannot be dismissed that attitude toward participating in the questionnaire might have influenced their evaluations in both groups. This implies that CL5 had a high motivation to participate in the questionnaire and might have given consistently high scores to any term in any sample, whereas CL6 had the opposite effect. Nevertheless, the number of participants in these two groups was smaller than that in the other clusters.

4.3 Possibility of consumer acceptance of wooden panels in varying homogeneity

First, based on the overall trend, it can be concluded that wooden panels with evenly matched colors and patterns are more acceptable to the consumers. Preferences for each cluster also tended to increase with increasing DoSH, but the details suggested differences.

Because CL1 was characterized by a difficult-to-increase preference despite elevated DoSH, it is assumed that general elderly consumers may accept the panels; otherwise, their visual patterns are not extremely heterogeneous, and it is not cost-effective to deliver the different patterns individually.

CL2 is a cluster that is tolerant of heterogeneous patterns and fully accepts wooden panels that have more than a certain level of homogeneity. CL2 also tended to further increase in preference as DoSH increased, even for samples with an average like/dislike score of 0 or higher. Therefore, for the “homogeneity-sensitive type” consumer group that observes products using smartphones, a wooden top board with more aggressively matched colors and grain patterns may be accepted as a value-added product.

Because CL3 was considered to prefer only limited samples with high visual homogeneity, it can be suggested that wooden panels with a unique appearance are not suitable for younger consumers who tend to evaluate “inter-terms-linear type,” and that as much evenly matched colors and patterns as possible is necessary.

CL4 was considered to be closer to manufacturers than consumers, but even for this group, a homogeneous wooden top board is more acceptable. In contrast, the preference for CL4 may vary, even among samples with DoSHs close to each other, such as L-4 or L-7, which were preferred over the samples around it, as shown in Figure 2. This suggests that factors other than homogeneity also affect preference in CL4, and that a unique appearance may also be valued. It is presumed that the factors include more professional wood-related things such as grain, broad rays (torafu) [19], and the sort order of elements.

From the above, it was suggested that the homogeneous patterns were more likely to be accepted by most consumers, although the possibility that the evaluation focused on factors other than homogeneity was observed for expert/expert-like-consumers such as CL4. Peterson et al. [6] focused on the fact that Japanese building material advertisements often contain images of homogeneous grain patterns, suggesting that Japanese consumers prefer homogeneous grain patterns. In other words, Japanese consumers may be familiar with wooden panels with evenly matched colors and patterns, and may be unfamiliar with uneven appearances. Therefore, when introducing a wooden tabletop with a unique visual pattern that is customized for individuals in the market, it is necessary to promote consumer understanding by presenting additional information, such as the intent of the visual design, details of the grain, and the environmental benefits of using various types of irregular wood.

4.4 Limitations and future endeavors

A limitation of this study is that the sample images were evaluated using a web-based questionnaire, without using actual panels for impression evaluation. In textiles, the difference between the actual product impression and the impression received from a photo is considered problematic [20], and this concern may be especially important in observation environments with small screens, such as smartphones. Therefore, it is desirable to control the display environments or conduct evaluations of actual products in the future.

Furthermore, this study focused on the homogeneity of each sample, which was described using the subjective evaluation score, that is, DoSH. Because each cluster would not necessarily perceive the same homogeneity for the same sample, it would be effective in the future to examine the characteristics of each cluster in terms of homogeneity by mapping this subjective homogeneity to physically measurable values. In previous studies [1,5], attempts were made to explain the apparent irregularity of wood using contrast values between pixels, and it would be useful to apply similar methods in the future to investigate the correspondence between quantified homogeneity and impression evaluation.

It is also interesting to explore appearance characteristics other than homogeneity because it was suggested that even if the DoSH is close, the degree of preference is not necessarily the same; for example, L-1 and E-10, and that an evaluation viewpoint other than homogeneity may be used in combination as in CL4.
5. CONCLUSION

To investigate the preference for wooden panels of different homogeneities, we conducted an impression evaluation of the sample images using a web-based questionnaire. A total of 109 valid answers were classified into six clusters based on the evaluation scores of four evaluation terms and 17 samples, and the characteristics and preferences of each cluster for different wooden panels were discussed. The findings are as follows.

1. Positive correlations were found between all evaluation terms: even/uneven, natural/artificial, expensive/cheap, and like/dislike, suggesting that, as a whole, even samples may give the impression of being natural, expensive, and preferred.

2. The tendencies of the 109 participants in this study were interpreted as follows: a heterogeneous-confirmation type (n=27, 24.8%), a homogeneity-sensitive type (n=25, 22.9%), an inter-terms-linear type (n=23, 21.1%), a naturalness-enhanced type (n=18, 16.5%), an all-positive type (n=10, 9.2%), and an all-negative type (n=6, 5.5%).

3. A heterogeneous-confirmation type was considered to be close to general elderly consumers, an inter-terms-linear type to be close to younger consumers, and a naturalness-enhanced type to be close to experts/expert-like consumers. A homogeneity-sensitive type may use a small display during evaluation.

4. It was concluded that consumers accepted wooden panels with visual homogeneity.

5. It was suggested that the matching of colors and patterns should be done as much as possible for younger consumers, whereas matching more than necessary for the elderly general consumers was not cost effective.

6. It was found that there is a market in which wooden panels with more aggressively matched colors and patterns are added.

7. The results suggest that it is necessary to add additional information, such as the intent of the design and details of the grain pattern, to the unique patterns because wood panels with a heterogeneous appearance are unlikely to be accepted by Japanese consumers at this time.

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