Quantification of Human Sensitivity Affected By Surface Color Tone of Plating

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Abstract

Recently, it is very important for us to design engineering products from the viewpoint of user friendliness. We aimed to quantify the effect of surface tone of plating on human sensibility, using SD method. We sent out questionnaires about six kinds of specimens to many test subjects and investigated their images and feelings about the specimens. And then, we calculated coefficient of correlation based on Pearson's equation. By factor analysis, we tried to quantify human's images about surface tones. Finally, we made semantic plane and derived two available factors and could quantify the human's image and feeling successfully.

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1. INTRODUCTION

Recently, user-friendliness has been taken into account for materials design. When engineers are going to commercialize materials into products, they should investigate closely in advance how the surface color tone would affect the human emotion. For the purpose, SD (Semantic Differential) method has been often utilized to evaluate human sensation quantitatively[(1), (2)]. However, such a study still belongs to the frontier. In this paper, we tried to evaluate the human sensation affected by the surface color tone quantitatively, using SD method.

2. EXPERIMENTAL

SD method is one of the psychological measurements. For the impressions which human beings hold for a certain materials surface, the questionnaires composed of adjective couples such as a “like-dislike” are provided to trial subjects. Fig.1 shows the flow chart of procedure for SD method.

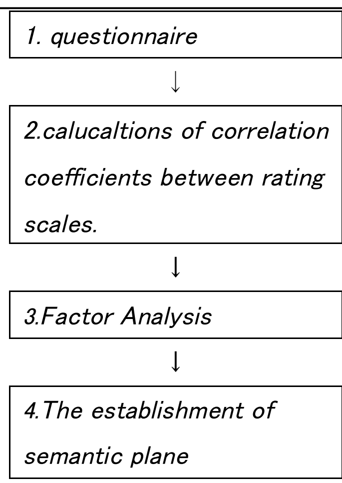

Fig.1 The procedure of SD Method

There were six sample specimens (Concepts) for this experiment. The specimens were made visionary, by using computer graphics. The colors were grey(#1), black(#2), red(#3), dark brown(#4), green(#5) and aqua(#6). For the colors as specimens surface, 10 kinds of adjective couples were provided to 77 trial subjects totally. The results were summarized and their averages and variances were calculated. The procedure was repeated in quite the same way for all Concepts. Then they were compared with each other and the top 5 concepts having higher variances were chosen as rating scale. They were #1: conspicuous - not conspicuous, #2: quiet – not quiet,

#3: refreshing – not refreshing, #4: tripping – not tripping, #5: bright – not bright. The corresponded variances were 4.78, 5.30, 4.79, 5.28 and 5.15, respectively.

Correlation coefficients between any two rating scales were calculated by using Pearson's equation (1).

$$r_{l,l+1} = \{ \Sigma_k(X_{kl}-X_l)(X_{k(l+1)}-X_{l+1}) / K \} / \{\{ \Sigma_k(X_{kl}-X_l)^2\} / K \}^{1/2} \times \{ \Sigma_k(X_{k(l+1)}-X_{l+1})^2 / K \}^{1/2} \quad (1)$$

X_{kl}: the score for concept k on rating scale 1

X_l: the average of all scores for concept k on the rating scale 1

k: the number of concepts (K=6)

Using the equation mentioned above, all correlation coefficients were calculated. Then the correlation matrix composed of correlation coefficient as elements was established. After the matrix was established, a factor analysis based on Centroid Method was carried out. From the correlation matrix, R_1, the modified matrix, ${}_zR_1$, was made by substituting zero into the diagonal elements of each line. On the other hand, another modified matrix, h^2R_1, was made, by substituting the element of the largest absolute value for each line into the diagonal. And in addition, the column vector, ${}_cV_{[\pm1]}$, was made by multiplying ${}_zR_1$ with a certain column vector composed of +1 or -1. Using the following equation (2), the first factor was calculated.

$$a_1 = h^2R_1 \cdot {}_cV_{[\pm1]} / ({}_cV'_{[\pm1]} \cdot h^2R_1 \cdot {}_cV_{[\pm1]}) \quad (2)$$

When the square of the first factor (a_1) would have proceeded over 1, the process should have be ended. However, the value was smaller than 1, the process was continued and the residual matrix was calculated by the equation (3).

$$R_2 = h^2R_1 - C_1 \qquad (C_1 = a_1 \times a_1') \quad (3)$$

Then, the second factor was calculated from the residual matrix, R_2, by the same process. Since h^2 ($h^2 = a_1^2 + a_2^2$) was smaller than 1, the process was still continued to the next step. The contributing extent (Σa^2) was % of C were calculated.

$$\%ofC = \Sigma a / \Sigma h^2 \qquad (4)$$

Another residual matrix, R_3, was calculated in the same way and the third factor was obtained. Even though $h^2(=a_1^2 + a_2^2 + a_3^2)$ didn't exceed over 1, % of C was pretty low (3.7%). It suggests that the third factor didn't have so significant meaning and also that the first and second factors were significant enough.

At the next step, the semantic plane where the horizontal axis corresponded to a_1 and the vertical one to a_2 was formed. When the each value for a_1 and a_2 was plotted in the semantic plane, there were many discrete points away from the axes. To fix which factor affected the impressions more effectively, the axes were rotated to 45 degrees in the counterclockwise direction. The new plots were calculated in the following equation (5).

$$\begin{bmatrix} X1, Y1 \\ X2, Y2 \\ X3, Y3 \\ X4, Y4 \\ X5, Y5 \end{bmatrix} = \begin{bmatrix} x1, y1 \\ x2, y2 \\ x3, y3 \\ x4, y4 \\ x5, y5 \end{bmatrix} \times \begin{bmatrix} \cos\theta, -\sin\theta \\ \sin\theta, \cos\theta \end{bmatrix} \qquad (5)$$

Here Xn corresponds to a renewed point, while xn to the original point. θ corresponds to the rotating angle (45 degrees in this case.).

3. RESULTS AND DISCUSSION

3.1 Results for questionnaires

Table 1 shows the average values, variances for the top 5 high variances rating scales.

Table 2 Averages and variances for the concepts

	#1: conspicuous - not conspicuous	#2: quiet - not quiet	#3: refreshing - not refreshing	#4: tripping - not tripping	#5: bright - not bright
No.1 average	3.07	6.80	3.70	4.17	3.67
No.1 variance	3.82	5.04	5.50	7.60	6.12
No.2 average	5.56	5.80	2.52	1.81	1.79
No.2 variance	7.81	6.85	3.43	2.57	3.55
No.3 average	9.15	1.95	2.96	3.10	7.41
No.3 variance	2.61	3.23	5.59	3.87	5.95
No.4 average	3.38	6.52	4.25	4.54	4.15
No.4 variance	3.72	5.98	3.89	5.60	4.83
No.5 average	5.52	6.46	6.85	6.37	6.35
No.5 variance	5.68	5.20	4.48	4.98	4.35
No.6 average	5.25	6.95	7.16	6.68	6.35
No.6 variance	5.03	5.50	5.83	7.04	6.09

And according to Pearson's equation, the correlation coefficients were calculated as follows.

$r_{1,2}$ = -0.042842, $r_{1,3}$ = 0.1971512, $r_{1,4}$ = 0.250457, $r_{1,5}$ = 0.3759597, $r_{2,3}$ = 0.2978334, $r_{2,4}$ = 0.261736, $r_{2,5}$ = 0.1717351, $r_{3,4}$ = 0.6465471, $r_{3,5}$ = 0.5227041, $r_{4,5}$ = 0.5933291.

3.2 Factor Analysis

From these correlation coefficients, the starting matrix, R_1, was established.

$$R_1 = \begin{bmatrix} 1.00 & -0.04 & 0.20 & 0.25 & 0.38 \\ -0.04 & 1.00 & 0.30 & 0.26 & 0.17 \\ 0.20 & 0.30 & 1.00 & 0.65 & 0.52 \\ 0.25 & 0.26 & 0.65 & 1.00 & 0.59 \\ 0.38 & 0.17 & 0.52 & 0.59 & 1.00 \end{bmatrix} \qquad (6)$$

And ${}_zR_1$, h^2R_1 and the column vector, ${}_cV_{[\pm 1]}$, were established as follows.

$${}_zR_1 = \begin{bmatrix} 0 & -0.04 & 0.20 & 0.25 & 0.38 \\ -0.04 & 0 & 0.30 & 0.26 & 0.17 \\ 0.20 & 0.30 & 0 & 0.65 & 0.52 \\ 0.25 & 0.26 & 0.65 & 0 & 0.59 \\ 0.38 & 0.17 & 0.52 & 0.59 & 0 \end{bmatrix} \qquad (7)$$

$$h^2R_1 = \begin{bmatrix} 0.38 & -0.04 & 0.20 & 0.25 & 0.38 \\ -0.04 & 0.30 & 0.30 & 0.26 & 0.17 \\ 0.20 & 0.30 & 0.65 & 0.65 & 0.52 \\ 0.25 & 0.26 & 0.65 & 0.65 & 0.59 \\ 0.38 & 0.17 & 0.52 & 0.59 & 0.59 \end{bmatrix} \qquad (8)$$

$$ {}_{c}V_{[\pm 1]} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ 1 \\ 1 \end{bmatrix} \qquad (9) $$

From the equation (2), the first factor was calculated as follows:

$$ a_1 = \begin{bmatrix} 0.38 \\ 0.32 \\ 0.76 \\ 0.79 \\ 0.74 \end{bmatrix} \qquad (10) $$

In the same way, the second and the third factors were also calculated. The results were shown in Table 3.

Table 3 The results for factor analysis.

	The first factor	The second factor	The third factor	h^2
1	0.383	-0.43	0.063	0.334
2	0.327	0.34	-0.2	0.262
3	0.766	0.244	0.149	0.668
4	0.795	0.111	0.157	0.669
5	0.748	-0.22	0.067	0.614
Contributing extent	2.031	0.421	0.095	2.546
%ofC	79.8%	16.5%	3.7%	100%

Table 3 indicates that the % of C for the third factor was very low, corresponding to the low contribution to the result. On the contrary, it can be concluded that the first and the second factors explain the impressions for subjects mostly, since % of C for both were 96.3%.

3.3 Semantic plane

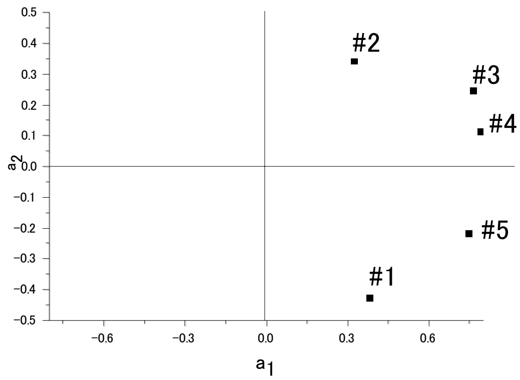

Fig2. Semantic plane obtained by SD method

Fig.2 shows the semantic plane where the horizontal axis is the first factor and the vertical axis the second factor. Since the plotted results were located away from the two axes, the plane was rotated to 45 degrees in the anticlockwise direction. As a result, the modified data were obtained as shown in Table 4.

Table 4.Modified data after rotating to 45 degrees

	a_1'	a_2'	h^2
1	−0.03136	−0.57334	0.329706
2	0.471773	0.00963	0.222663
3	0.713632	−0.36912	0.645519
4	0.640351	−0.48355	0.643875
5	0.370134	−0.68744	0.609576
Contributing extent	1.279873	1.171466	2.451339
%ofC	**52.2%**	**47.8%**	100%

From those data, the modified semantic plane was obtained (Fig.3). From Fig3 and Table 4, the five rating scales were classified into two groups each of which is close to the axes, respectively. The following three scales, a_1', #2:quiet - not quiet, #3: refreshing - not refreshing and #4: tripping - not tripping belong to the scale group close to the modified horizontal axis. On the other hand, another two scales, #1: conspicuous - not conspicuous and #5: bright - not bright belong to that close to the modified vertical axis. The former group was called

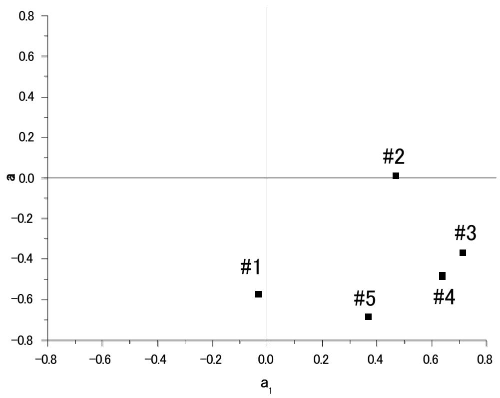

Fig. 3 Modified semantic plane by rotating.

"refreshing factor" totally, and the latter one "clear factor". Then the scores for each concept were averaged in the new factors, respectively and the results are shown in Table 5.

Table 5 Averages of scores for the renamed two factors

No.	1	2	3	4	5	6
Refreshing factor	4.890	3.377	2.671	5.100	6.560	6.933
Clear factor	3.370	3.676	8.280	3.770	5.930	5.800

Table 5 suggests a certain guideline to choose the surface colors in practical application. When the clear image is required, the best choice should be red color. On the other hand, aqua and green colors are desirable when the refreshing image is required.

4. CONCLUSIONS

From SD method and the factor analysis based on centroid method, the two meaningful factors were extracted as a result – refreshing factor and clear factor. The procedure can be applied to the materials surface design in the future.

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