Analyses and Discussion of Human Sensation / Reaction to Glossy Surfaces

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We have developed a unique psychological method, using the Semantic Differential technique, to determine the human factor for use in the glossy plating design process. The test subjects saw various specimens of glossy plated materials and answered many questions composed of epithet pairs for each sample. They marked their impressions about the specimens, using scales with seven choices including the epithets of opposite meanings at each end. The Data were analyzed mathematically by using software, in terms of participants' nationalities, geological locations, and female versus male choices. Also the meanings of the results were discussed and applied to surface treatment engineering.

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INTRODUCTION

Materials were originally designed to maximize specific functions effectively. However, these materials were lacking in terms of user-friendliness. Therefore a society surrounded by such high functioning materials would be stressed. Particularly, Japan is becoming an aging society at a rapid rate, and many other advanced countries have the same situation. In such a country, user-friendliness will be a very important concept in regards to material design. Surface treatment processes including electroplating will be critical and a key process to give materials user-friendliness, since the material surface is always the interface between materials themselves and the human environment. In this study, we tried to apply the semantic differential method(1) to the plated specimens(2)-(5), when a number of values had to be dealt with in a short time. The subjects were selected in US and Japan, and were composed of many males and females. The results were discussed from the viewpoint of differences between genders and nationalities.

EXPERIMENTAL

Six kinds of specimens were prepared in advance. All of them were bright chromium plating specimens. In this paper, they were called tentatively as follows: “Pearl Bright Chrome”, “Hex Bright Chrome”, Trivalent Bright Chrome”, “Bright Black”, “Satin Chrome” and “Smokey Chrome”. The color tone for the specimens, based on L-a-b system was measured and described in the previous paper (5). For all of these specimens, 33 epithet pairs were prepared and provided to all trial subjects, composed of 21 people older than 21 years old for each author’s group. Totally, the number of trial subjects was 63. (However, some of the results were removed because of missing and/or incomplete data.) The epithet pairs were shown to the trial subjects by seven step rating bars, as provided below.

------------------ 33 scales composed of opposite epithet pairs -----------------

stable -: -: -: -: -: -: - not stable

uniform -: -: -: -: -: -: - not uniform

visible -: -: -: -: -: -: - invisible

elegant -: -: -: -: -: -: - not elegant

warm -: -: -: -: -: -: - not warm

comfortable -: -: -: -: -: -: - not comfortable
massive -: -: -: -: -: -: - not massive
bold -: -: -: -: -: -: - not bold
calm -: -: -: -: -: -: - not calm
round -: -: -: -: -: -: - not round
cozy -: -: -: -: -: -: - not cozy
refreshing -: -: -: -: -: -: - not refreshing
bright -: -: -: -: -: -: - not bright
sophisticated -: -: -: -: -: -: - not sophisticated
metallic -: -: -: -: -: -: - not metallic
shiny -: -: -: -: -: -: - dull
smooth -: -: -: -: -: -: -: rough
soft -: -: -: -: -: -: - hard
clear -: -: -: -: -: -: - fuzzy
beautiful -: -: -: -: -: -: - ugly
cool -: -: -: -: -: -: - warm
thick -: -: -: -: -: -: - thin
flexible -: -: -: -: -: -: - rigid
transparent -: -: -: -: -: -: - reflective
sharp -: -: -: -: -: -: - dull
wide -: -: -: -: -: -: - narrow
light -: -: -: -: -: -: - dark
full -: -: -: -: -: -: - empty
fresh -: -: -: -: -: -: - stale
strong -: -: -: -: -: -: - weak
clean -: -: -: -: -: -: - dirty
new -: -: -: -: -: -: - old
expensive -: -: -: -: -: -: - cheap

According to their impressions, subjects marked their suitable places on a certain bar. For example, they wrote down the mark on the left end bar of the scale, when their impression was very true for the left epithet. On the other hand, they marked above the right one, when their impressions were very true for the right hand epithet. Each scale has 7 steps between both edges. The checks were also rated as 7 steps, according to the extent of the subjects' impressions. When their impressions corresponded to the high order end, the rates were 7 point, while the opposite was one point.

The scores for all of these scales were input on the data view sheet of SPSS ver.16.0J for Windows (SPSS Inc.). Then factor analysis was carried out by using software[6]. Before beginning the factor analysis, all scales were checked in advance, to see if any of them would have a ceiling or effect or floor effect. If some scales would have corresponded to these cases, then they would have been removed for the following analysis. However, in fact, there were no scales for these cases. The factor analysis was composed of two steps. At the first step, all factors were extracted without any rotations, according to principal axis factoring. The number of factors were decided based on initial eigen values and the scree plot. Then the second factor analysis by the same principal axis factoring was carried out with oblique (promax) rotation. For it was very natural for the 33 scales to be correlated with each other to some extent. According to the communalities and the pattern matrices after the rotation, the scales were grouped into their appropriate factors. Finally, the score for each specimen was averaged and plotted in some graphs. The correlation and differences for the impression characteristics between male and female, and between the US and Japan were analyzed and discussed.

RESULTS AND DISCUSSION

The first factor analysis

All scores for 33 scales were recorded and input into the data view of SPSS and the averages and standard deviations were calculated for all 33 scales used in this study. The results were shown in Table 1.

Table 1 Average and standard deviation for all 33 scales.

	frequency	minimum	maximum	average	standard deviation
stable - not stable	219	1	7	4.3835616	2.047353205

uniform - not uniform	219	1	7	4.4063927	1.998659012
visible – invisible	219	1	7	4.8219178	1.827484854
elegant - not elegant	219	1	7	4.1461187	2.001518003
warm - not warm	219	1	7	3.8812785	1.959349782
comfortable - not comfortable	219	1	7	4.2465753	1.889960113
massive - not massive	219	1	7	4.0958904	1.803394228
bold - not bold	219	1	7	4.2739726	1.957766987
calm - not calm	219	1	7	4.3926941	1.891832167
round - not round	219	1	7	3.4885845	1.923683228
cozy - not cozy	219	1	7	4.1004566	2.018026507
refreshing - not refreshing	219	1	7	4.1278539	1.932840391
bright - not bright	219	1	7	4.2191781	2.183633295
sophisticated - not sophisticated	219	1	7	4.2328767	2.021811441
metallic - not metallic	219	1	7	4.5068493	2.025909838
shiny – dull	219	1	7	4.1050228	2.159451675
smooth – rough	219	1	7	4.7579909	1.855037174
soft – hard	219	1	7	4.1141553	1.903818132
clear – fuzzy	219	1	7	4.173516	2.11959663
beautiful – ugly	219	1	7	4.5844749	1.912281905
cool – warm	219	1	7	4.4977169	1.863149226
thick – thin	219	1	7	3.9360731	1.785652584
flexible – rigid	219	1	7	4.0547945	1.868795503
transparent – reflective	219	1	7	3.4885845	2.028152163
sharp – dull	219	1	7	4.2922374	2.051288254
wide – narrow	219	1	7	4.173516	1.709936413
dark – light	219	1	7	3.8538813	1.955144004
full – empty	219	1	7	4.6757991	1.622634814
fresh – stale	219	1	7	4.2237443	1.94893117
strong – weak	219	1	7	4.6757991	1.827393159
clean – dirty	219	1	7	4.5936073	1.949865968
new – old	219	1	7	4.4703196	1.935374555
expensive – cheap	219	1	7	4.369863	1.924064286

The floor and ceiling effect in the data were checked before the factor analysis. The criteria were as follows, respectively:

Ceiling effect $\text{average} + \text{standard deviation} \leq 7$ (1)

Floor effect $\text{average} - \text{standard deviation} \geq 1$ (2)

All data were satisfied with the two criteria. Therefore, no scales were removed from the list mentioned in Table 1.

Then the first factor analysis was carried out. At that time, the analysis did not involve any factor rotation, since the purpose was to get the initial eigen values for factor matrices. The scree plot for the results is shown in Fig.1. The numbers on the horizontal axes correspond to the factor number and those on vertical axes to eigen values for factor matrices. The eigen values for the first factor were very large. The second one was much smaller than the first one. The eigen values decreased with the increase of the factor numbers gradually. However, when one observes the small gradual change after the second factor very cautiously, a relatively remarkable change is found between the third factor and the fourth (The red line in the Fig.1). Therefore, we could estimate the number of factors from the analysis as 3, provisionally.

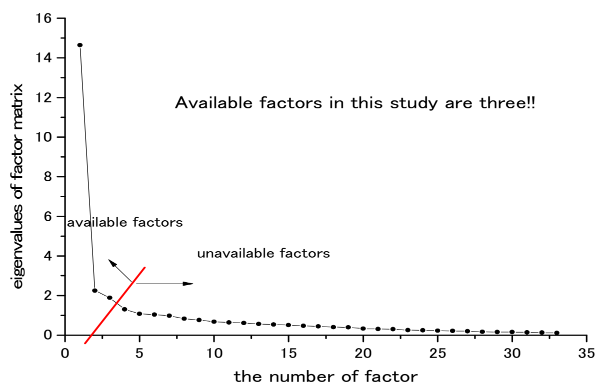

Fig.1 Scree plot for 33 scales in this study.

The second factor analysis

The second factor analysis involved the oblique factor rotation (promax rotation) and the factor analysis continued until the third factor was extracted.

Table 2. Communality for the 33 scales at the second factor analysis

	initial	after the 2nd factor analysis
stable - not stable	0.7606502	0.622932495
uniform - not uniform	0.707665	0.583795898
visible – invisible	0.5293899	0.347304971
elegant - not elegant	0.7483794	0.68140572
warm - not warm	0.602615	0.58421993
comfortable - not comfortable	0.7366962	0.648697922
massive - not massive	0.6120416	0.598927608
bold - not bold	0.6579132	0.573925352
calm - not calm	0.5260396	0.497638209
round - not round	0.4273452	0.317951237
cozy - not cozy	0.6238066	0.573981024
refreshing – not refreshing	0.7934961	0.723673458
bright - not bright	0.7605536	0.685320708
sophisticated - not sophisticated	0.7402777	0.678844812
metallic - not metallic	0.4904407	0.385515223
shiny – dull	0.7782238	0.732522382
smooth – rough	0.6443933	0.470992109
soft – hard	0.4598031	0.340927097
clear – fuzzy	0.7692407	0.673284086
beautiful – ugly	0.8173843	0.778242234
cool – warm	0.3616747	0.169208744
thick – thin	0.2818193	0.203503195
flexible – rigid	0.4663962	0.315632366
transparent - reflective	0.4313899	0.242995423
sharp – dull	0.7748422	0.668936248
wide – narrow	0.4648017	0.319619201

dark – light	0.4200306	0.372887423
full – empty	0.3793584	0.328915386
fresh – stale	0.7578267	0.695434675
strong – weak	0.6004597	0.544609323
clean – dirty	0.7390213	0.630774949
new – old	0.7779221	0.658230211
expensive - cheap	0.7390144	0.61447108

Table 2 shows the communality. If the communality for some scales would have been smaller than 0.16, they should have been removed and the factor analysis should have continued further more. However, all communalities shown in Table 2 were larger than the criterion value. Therefore, all scales could be used for the analysis. According to the results of the pattern correlation matrices, the scales were classified into three groups shown in Fig.2. The following 22 scales which have the highest factor loadings for their fast factors were grouped into "factor 1" as "Surface Tone Factor".

shiny-dull, bright-not bright, sharp-dull, clear - fuzzy, dark - light, refreshing – not refreshing, fresh - stale, clean - dirty, beautiful - ugly, new - old, elegant - not elegant, uniform - not uniform, expensive - cheap, sophisticated -not sophisticated, stable - not stable, bold - not bold, visible - invisible, comfortable – not comfortable, smooth -rough, transparent - reflective, cool - warm, metallic -not metallic

As for the following 6 scales which have the highest factor loadings at their second factors, the group was named as "Sensation Factor". For the scales seemed to be related to human sensations rather than the physical surface attribution.

warm - not warm, soft - hard, flexible - rigid, calm - not calm,
round - not round, cozy - not cozy

The other 5 scales which have the highest factor loadings at their third factors

scale	factor 1	factor 2	factor 3
shiny – dull	1.079	−0.189	−0.225
bright – not bright	1.02	−0.084	−0.261
sharp – dull	0.951	−0.155	−0.083
clear – fuzzy	0.918	0.019	−0.181
dark – light	−0.819	0.025	0.454
refreshing – not refreshing	0.769	0.078	0.048
fresh – stale	0.759	0.043	0.07
clean – dirty	0.735	0.126	−0.032
beautiful – ugly	0.726	0.135	0.097
new – old	0.685	0.111	0.078
elegant – not elegant	0.635	0.312	−0.047
uniform – not uniform	0.621	0.115	0.096
expensive – cheap	0.596	0.077	0.189
sophisticated – not sophisticated	0.583	0.058	0.269
stable – not stable	0.574	0.071	0.226
bold – not bold	0.558	−0.188	0.38
visible – invisible	0.508	−0.032	0.139
comfortable – not comfortable	0.505	0.336	0.072
smooth – rough	0.499	0.112	0.153
transparent – reflective	0.451	0.133	−0.074
cool – warm	0.411	−0.334	0.149
metallic – not metallic	0.349	−0.024	0.348
warm – not warm	−0.082	0.699	0.192
soft – hard	−0.091	0.693	−0.166
flexible – rigid	−0.028	0.65	−0.187
calm – not calm	−0.137	0.604	0.287
round – not round	0.06	0.571	−0.087
cozy – not cozy	0.307	0.505	0.043
full – empty	−0.224	0.005	0.695
massive – not massive	0.255	−0.2	0.683
thick – thin	−0.266	0.005	0.579
strong – weak	0.368	−0.211	0.555
wide – narrow	0.238	0.122	0.291

factor 1 "surface tone factor"

shiny–dull, bright–not bright, sharp–dull, clear – fuzzy, dark – light, refreshing – not refreshing, fresh – stale, clean – dirty, beautiful – ugly, new – old, elegant – not elegant, uniform – not uniform, expensive – cheap, sophisticated – not sophisticated, stable – not stable, bold – not bold, visible – invisible, comfortable – not comfortable, smooth – rough, transparent – reflective, cool – warm, metallic – not metallic

factor 2 "sensation factor"

warm – not warm, soft – hard, flexible – rigid, calm – not calm, round – not round, cozy – not cozy

factor 3 "space factor"

full –empy, massive – not massive, thick – thin, strong – weak, wide – narrow

Fig.2 The results of 2nd factor analysis and classification of 33 scales

were named as "Space Factor", since the scales relates mostly to the sense of space. The following scales belong to the group.

full -empty, massive - not massive, thick - thin, strong - weak, wide - narrow

The factor groups were named after the attribution of the scales in the group, even though some of them were not always appropriate for the naming perfectly. However, most of them seemed to be matched with the concept of the naming.

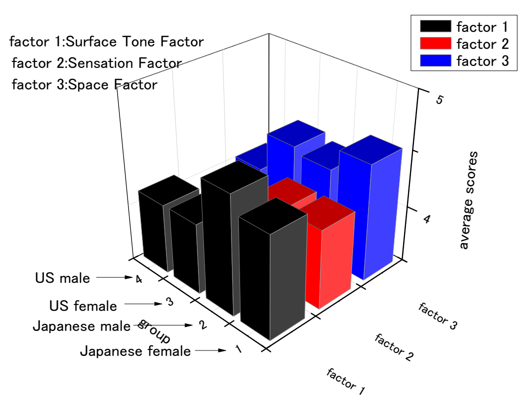

Fig.3 Averages of scores for all three factors and their differences among subjects' groups.

The Differences among subjects groups

The scores for all scales were averaged and compared for all subject groups. Fig.3 shows the results. The two axes on the basal plane in the figures correspond to factors and subjects groups. The vertical axis shows the average scores for all scales in a certain group. Generally speaking, the scores for the second factor were relatively low. The difference was not so remarkable for Japanese subjects, while it was large in US subjects. It means that US subjects did not show sensation factor for the specimens remarkably. The surface tone factor and sensation factor were more remarkable for Japanese subjects than those for US ones. Generally speaking, space factor was larger for female subjects than that for male ones. The space factor was larger particularly for US female subjects than that for any other subjects groups.

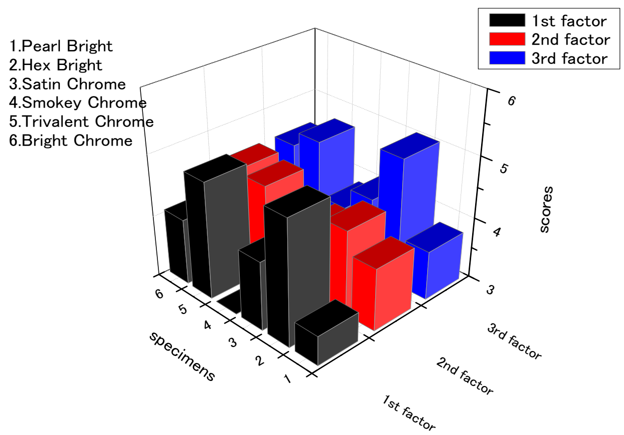

Fig.4 The results of all specimens and factors for US female group

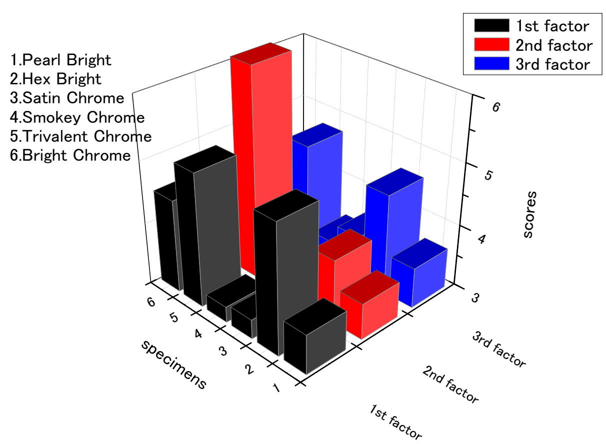

Fig.5 The results of all specimens and factors for US male group

The average scores for the scale groups were calculated for each subject group, respectively.

Fig.4 shows the results of all specimens and factors for US female group. Hex Bright and Trivalent Bright Specimens had high scores for all factors. For US female subjects group, the difference among specimens was remarkable. US female subjects had high scores for Hex and Trivalent Bright specimens relating to space factor. Fig.5 shows the score results for US male subjects group. It was quite the same with other groups" tendency that Hex Bright and Trivalent Chrome had high scores for all factors relatively. Except for the Bright Chrome, scores for the second factor were pretty low for the US male group. It suggests that the sensation factor was relatively low for the US male group. In this group, the difference among specimens was very remarkable. Hex Bright, Trivalent Chrome and Bright Chrome had high score values and the other specimens have relatively low scores.

Fig.6 shows the score results for JP female group. As already described, the sensation factor and space factor were relatively high. For all factors, Hex Bright, Trivalent Chrome had high values which were the common feature for the other subject groups. However, the Bright Chrome specimens had relatively high values for this JP female subject group. By comparison between Fig.4 and 6, the tendency for the scores was very similar for both US and Japanese female subjects.

Fig.7 shows the results of all specimens for JP male group. Also in this case, Hex Bright and Trivalent Chrome had high values for all factors. However, Bright Chrome did not have so high values for surface tone factor and sensation factor. By comparison with US groups, the differences among specimens were not so remarkable and the feature

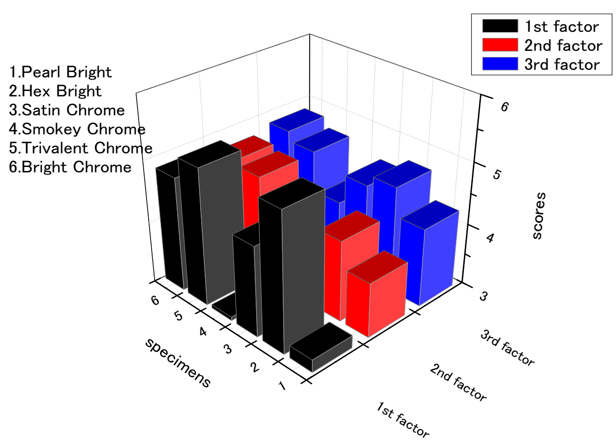

Fig.6 The results of all specimens for JP female group

was common among all Japanese subjects, as already described above.

In this study, the application of semantic differential (SD) method could be applied to plating, when the many scales and many specimens were involved. Not so expensive application software, SPSS, could be used for the factor analysis and the other procedures. The processes could be applied to general cases where any types of plating and any scales would be used for the analysis. This study could show the possibility. However, the selection of scales should be adjusted and fitted to the market trend and also to what kind of people would be the target for specimens. In this experiment, the scales were selected by the authors randomly, since the purpose was purely academic. However, this study suggests basically that the surface finisher would have a chance to apply the semantic differential method to any practical cases, when they would launch on the business for any surface treatment products in any countries.

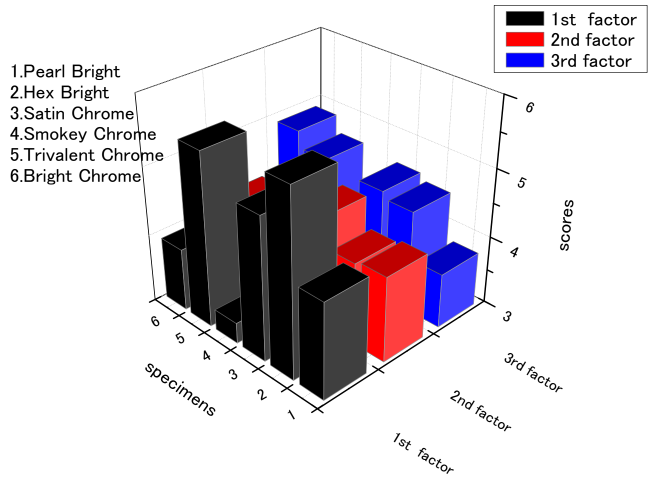

Fig.7 The results of all specimens for JP male group

CONCLUSIONS

Semantic differential method was applied to the glossy plating design process in this study. Our previous study was devoted to the same purpose. However, lots of values could be treated by using software and the process was established in this study completely and successfully. The following points can be mentioned as results.

(1) Factor analysis could be carried out easily, when the application software, SPSS, was utilized. It made it possible for us to treat numbers of values in a short time.

(2) In this study, 33 scales selected by the authors randomly were analyzed and grouped into three types by factor analysis. All of them could be named as surface tone factor, sensation factor and space factor, by that the meanings of scales in those groups were understood holistically.

(3) The analysis could show the differences of tendencies between genders and also between nationalities.

(4) The successful analyses in this study suggest that this process for SD method can be applied to practical design of surface treatment, when the scales will be chosen appropriately.

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