Development of customer satisfaction models for automotive interior materials

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Abstract

As the functional characteristics of passenger vehicles reach at a satisfactory level, customers place higher concerns with the ergonomic and aesthetic aspects of the interior design. The present study developed satisfaction models of automotive interior materials for six parts including crash pad, steering wheel, transmission gearshift knob, audio panel, metal grain dash, and wooden grain dash. Based on literature survey, customer reviews on the web, and expert opinions, 8 to 15 material design variables were defined for the interior parts. The material design characteristics of 30 vehicle interiors were measured and customer satisfaction with the vehicle interiors was evaluated by 30 participants in the 20s and 30s. The material design variables were screened by evaluating their statistical, technical, and practical significance and satisfaction models were developed by quantification I analysis. The satisfaction models were used to identify relatively important design variables and preferred design features for the interior parts.

Keywords: Automotive interior material, customer satisfaction model, quantification I analysis, Variable screening, Relative importance of variable, Preferred design feature

Running Title: Customer Satisfaction Models for Interior Materials

1. INTRODUCTION

As the performance of a passenger vehicle reaches at a satisfactory level, issues of ergonomic and aesthetic designs are highlighted. When making purchase decisions, more customers place high importance on driving comfort, availability of convenience features (e.g., automatic headlight on/off, anti-lockout device, and underseat storage), luxuriousness of materials, and quality of finish than engine power and fuel consumption rate (Jindo and Hirasago, 1997; White, 2001; Welch, 2002).

Few studies have been conducted on the design of automotive interior materials in terms of customer satisfaction. Automotive manufacturers use luxurious materials (such as leather, wood, nonglossy metal, and polished chrome) in the interior to attract customers and continue their efforts to develop novel materials which are economical but look luxurious (White, 2001). Kansei engineering and ergonomic methods have been applied to identify preferred design features by analyzing the relationships between design characteristics and customer impressions. While many Kansei engineering studies on the interior design (e.g., Jindo and Hirasago, 1997; Nakada, 1997; Tanoue et al., 1997) have focused on the visual design characteristics (such as part size, shape, and color) of interior parts by using slides of various designs, few studies exist focusing on the material design variables (e.g., softness and slipperiness) of interior parts. It is desirable to consider both the visual (e.g., embossing shape and surface shininess) and tactile (e.g., surface roughness and softness) properties of interior materials because customer satisfaction with an interior material is determined by visual inspection as well as by touch (Ryu et al, 2003).

The present study was intended to: (1) Survey the design variables of automotive interior materials; (2) Develop customer satisfaction models for the interior materials with material design variables having statistical, technical, and practical significance, and (3) Identify relatively important design variables and their preferred design features based on the satisfaction models.

2. EVALUATION OF SATISFACITON WITH INTERIOR MATERIALS

2.1 Interior Parts and Vehicles

Six interior parts including crash pad, steering wheel, transmission gear shift (TGS) knob, audio panel, and metal grain dash, and wooden grain dash (see Figure 1) were selected to examine customer satisfaction with interior materials. These selected parts, located in the front of the interior, are most frequently interfaced with the driver.

[Insert Figure 1 about here]

The present study used 30 vehicles (23 compact and 7 sport-utility vehicles) to survey the design characteristics of interior materials and customer satisfaction. The vehicles were placed at a yard of an auto manufacturing company; of the vehicles, 6 were domestic and the other foreign, having various material design characteristics. The number of vehicles evaluated for each interior part varied as shown in Table 1 because some interior parts were absent at some vehicles.

[Insert Table 1 about here]

2.2 Material Design Variables and Measurements

The material design variables of each interior part were identified by surveying customer reviews of car interiors on the web, opinions of interior design engineers, and published papers. For example, for crash pad, shininess was selected based on a customer review on a car interior stating that the metal surface is too shiny, pattern size from an opinion of a design engineer at an auto manufacturing company, and softness from the study of Nishimatsu et al. (2001). Through this variable identification process, 8 to 15 design variables and corresponding design levels were defined for the interior parts; Table 2 illustrates 13 material design variables and corresponding design levels for crash pad.

[Insert Table 2 about here]

The material design characteristics of each interior part of a vehicle were measured by objective and subjective methods. For example, vernier calipers and the standard color table by Korean Color Research Institute (1991) were used to measure the size of embossing and the properties of a color, respectively. For a design variable (say, shininess) to which an objective instrument was unavailable, the design value was determined by subjective evaluation of 4 experimenters with a 7-point scale as illustrated in Table 2. When the subjective evaluations were different for a design variable, brainstorming was made to draw consensus; in case consensus was not drawn, the average of the subjective evaluations was used for the value of the design variable.

2.3 Participants

In the present study, 30 Korean males participated in the material satisfaction evaluation for the 30 vehicles. Of the participants, 21 were in the 20s and 9 in the 30s (mean = 28.7 and SD = 6.6). Their participation was compensated.

2.4 Satisfaction Evaluation Scale

The level of customer satisfaction with the interior materials of a vehicle was evaluated by using a modified magnitude estimation scale as shown in Figure 2. The participants were asked to evaluate the material of each interior part for a vehicle after visual and tactile inspection. The magnitude estimation scale has been employed in satisfaction evaluation studies such as Han et al. (2000) and Yun et al. (2001) because subjective evaluation with high sensitivity is obtained and various statistical techniques are applicable.

[Insert Figure 2 about here]

2.5 Procedure

The satisfaction evaluation in the study consisted of three sessions: introduction, satisfaction evaluation, and debriefing. At the introduction session, the purpose and method of evaluation were explained to the participants. Then, in the evaluation session, each participant visited the 30 vehicles and evaluated the materials of the 6 interior parts in each vehicle by following a predetermined order (the evaluation orders of the vehicles and interior parts were randomized by the balanced Latin-square design to counterbalance the effects of learning and fatigue). Lastly, at the debriefing session, any difficulties experienced during evaluation were surveyed. The satisfaction evaluation lasted 3 hours at a yard of an auto manufacturing company.

3. DEVELOPMENT OF MATERIAL SATISFACITON MODELS

Material satisfaction models were developed for the 6 interior parts by analyzing the material design characteristics and satisfaction evaluations of the 30 vehicles. The material design variables of each interior part were screened by evaluating their statistical, technical, and practical significance and then satisfaction models were developed with the screened design variables by the quantification I method (Jindo and Hirasago, 1997; Heo, 1998). The technical and practical significance of design variables is evaluated to exclude those from the model development whose effects on satisfaction are difficult to explain from a technical aspect or negligible from a practical aspect (Montgomery et al., 2001).

3.1 Screening Design Factors

3.1.1 Statistical Significance

The statistical significance of design variables was evaluated to include only those having statistically significant effects on satisfaction in the model development. The statistical significance of each design variable was tested by ANOVA including satisfaction as the dependent variable and the design variable, age, and the interaction of the design variable and age as factors; age was included in ANOVA to adjust the effect of difference in age among the participants in calculating the error sum of squares so that the effect of the design variable on satisfaction could be identified with better accuracy. As an example, Table 3 summarizes the results of ANOVA for the 13 design variables of crash pad, indicating all design variables except saturation are significant on satisfaction at $\alpha = 0.05$.

[Insert Table 3 about here]

3.1.2 Technical Significance

The technical significance of design variables was examined to identify if they affect satisfaction in a systematic manner and their effects on satisfaction are interpretable. A design variable should be better excluded from a satisfaction model if its effect on satisfaction varies at random or contradicts related existing understanding. The technical significance of a design variable was analyzed by examining a plot of average satisfaction by the design variable. For example, Figure 3 shows that brightness has technical significance because satisfaction changes in a quadratic pattern over the range of brightness while slipperiness lacks technical significance because satisfaction changes at random over the range of slipperiness. Table 3 summarizes the technical significance of the crash pad design variables and the order of relationship with satisfaction.

[Insert Figure 3 about here]

3.1.3 Practical Significance

The design variables having statistical and technical significance were checked if their effects on satisfaction are large enough from a practical aspect. A design variable lacking practical significance should be excluded from a satisfaction model for simplicity of the model (Montgomery et al., 2001). The practical significance of a design variable was analyzed in three steps: (1) grouping the levels of the variable by a multiple comparison test, (2) calculating the average of satisfaction for each group, and (3) comparing the difference in average between the groups with a cut-off value designated. For example, as illustrated in Table 4, the levels of shininess were grouped into two (group 1: levels 1, 2, 2.5, 3; group 2: levels 4, 5, 6) by Duncan's multiple range test at $\alpha = 0.05$. Then, the satisfaction averages of the two groups and their difference were calculated. Lastly, the difference of the two group satisfaction averages was compared with a designated cut-off value (say, 5). Since the average satisfaction difference of the two groups (= 7) is higher than the cut-off value, shininess was evaluated as one having practical significance. Table 3 summarizes the results of practical significance for the crash pad design variables.

[Insert Table 4 about here]

Table 5 summarizes material design variables of the interior parts screened through evaluation of statistical, technical, and practical significance. Of the material design variables of the interior parts, 13 variables were selected for crash pad, 11 for steering wheel, 11 for TGS knob, 3 for audio panel, 7 for metal grain dash, and 4 for wooden grain dash.

[Insert Table 5 about here]

3.2 Material Satisfaction Models

Material satisfaction models (see Table 6 as an example) were developed for the interior parts with the screened design variables by the quantification I method. Kansei engineering studies such as Jindo & Hirasago (1997), Nakada (1997), and Tanoue et al. (2001) have used the quantification I method to analyze the effects of categorical and continuous design variables to customers' image and impression. Being similar to the generalized linear model (GLM) method, the quantification I method does not assume the distribution of error while the GLM method assumes the normality of error (Heo, 1998). The quantification I method, like the GLM method, can estimate the relative importance of design variables and customer impression for a set of design values, but cannot test the statistical significance of design variables in the model.

By using the material satisfaction models, the relative importance of material design variables and corresponding preferred design features were identified. The relative importance of design variables was evaluated based on partial correlation coefficients (R). For example, the quantification I analysis results of crash pad in Table 6 indicates that embossing shape (R = 0.194), hue (R = 0.174), embossing size (R = 0.146), and softness (R = 0.140) are relatively important variables. Next, the preferred design features were identified based on partial regression coefficients (β). For a categorical design variable, the design value having the largest β represents the most preferred design feature; for a continuous design variable, the preferred design feature is the minimum value if $\beta < 0$ or the maximum value if $\beta > 0$. For example, Table 6 indicates that the most preferred design features of crash pad include circular convex of embossing shape (categorical), the largest level (= 7) of brightness (continuous, $\beta > 0$), and the smallest level (= 1, very dull) of shininess.

[Insert Table 6 about here]

The four most important material variables and corresponding preferred design features of each interior part were summarized in Table 7. Depending on interior part, relatively important design variables and preferred design features varied. For example, Table 7 indicates that embossing shape was relatively important for customer satisfaction with crash pad, TGS knob, and metal grain dash and their preferred features were circular convex and pinhole for crash pad, pinhole and no embossing for TGS knob, and no embossing and circular dot for metal grain dash.

4. DISCUSSION

Three types of sources (customer reviews on the web, opinions of interior design engineers, and published papers) were effectively utilized to incorporate concerns of customers and experts in selecting design variables which may affect customer satisfaction with interior materials. By using the information sources, a comprehensive set of material design variables was defined for each interior part. Especially customer reviews on the web were readily available and included diverse views of customers so that they can be a valuable resource for the research of customer satisfaction.

Of the material design variables defined in the study, the values of five variables (shininess, embossing distinctness, surface roughness, softness, and surface slipperiness) were determined by subjective evaluation of four experimenters. In case an objective instrument is neither available nor applicable to measure a design variable, subjective evaluation is often used (Ulrich and Eppinger, 2000). In the present study, four experimenters who were acquainted with the definitions and levels of the five variables determined the design values of the variables for each vehicle through brainstorming. While the present study used the average of subjective evaluations to determine the value of a design variable in case consensus was not drawn among the experimenters, the mode and median of subjective evaluations can be employed as an alternative.

The present study screened design variables by evaluating their statistical, technical, and practical significance in a stepwise manner to develop a stable, practical satisfaction model. Many Kansei engineering and ergonomic design studies often omit evaluating the technical and practical significance of design variables in model development. In contrast, the present study showed how to consider the technical and practical significance of design variables as well as their statistical significance in the stage of variable screening for model development. At the statistical significance evaluation stage, variables were screened by checking if their effects on customer satisfaction were statistically significant. Then, at the technical significance evaluation stage, variables were examined if their effects on satisfaction showed a systematic, interpretable trend. Lastly, at the practical significance evaluation stage, variables were evaluated if their effects on satisfaction are practically appreciable. The variable selection process illustrated in the present study would help designers develop a stable, meaningful model by excluding those whose effects are statistically insignificant or difficult to interpret or practically insignificant.

The quantification I analysis on material satisfaction produced low (< 0.2) partial correlation coefficients for the material design variables. These low partial correlation coefficients could be resulted from that major design variables are missing in the study or a higher variation of customer satisfaction by individual preference rather than by material design variables. Since the present study selected material design variables for the interior parts by referring to various sources of information in a comprehensive manner, it is less likely to omit major design variables. Therefore, it is conjectured that the low partial correlation coefficients of the material design variables with customer satisfaction is caused by a large variation of satisfaction among the participants due to individual preference.

The material satisfaction models developed in the present study showed that relatively important design variables and corresponding preferred design features varied depending on interior part. For example, of the six interior parts, material type was selected as one relatively important for two parts (steering and TGS knob); the preferred design feature of embossing shape was circular convex for crash pad and pinhole for TGS knob. Therefore, in designing the materials of the interior parts, it is recommended that different materials be used by considering relatively important design variables and their preferred design features. However, care should be placed not to cause impression of disharmony with the interior design due to use of different materials for the interior parts.

Lastly, further research is needed to generalize the material satisfaction models for diverse populations. The present study recruited only 30 Korean males in the 20s and 30s. To better detect the effects of material design variables on customer satisfaction under the limited study condition, the present study controlled gender and age in selecting the participants. However, due to the control in recruiting participants, the material satisfaction models would be applicable to only the population of Korean males at the 20s and 30s. By using participants of different gender, age, and culture, the sensitivity of the satisfaction models would provide valuable information in the design of automotive interior materials.

5. CONCLUSION

The present study investigated customer satisfaction with six parts (crash pad, steering wheel, TGS knob, audio panel, metal grain dash, and wooden grain dash) of the car interior. The material design variables of the interior parts were defined from a survey of customer reviews of car interiors on the web, literature review, and opinions of interior design engineers. The material design characteristics of 30 vehicle interiors were measured by objective and subjective methods and the levels of customer satisfaction with the vehicle interiors were surveyed for 30 Korean males in the 20s and 30s by using the magnitude estimation scale.

Customer satisfaction models were developed for the materials of the six interior parts with material design variables having statistical, technical, and practical significance. The statistical significance of a design variable was evaluated by ANOVA, the technical significance of the variable by examining the trend of customer satisfaction over the range of the variable, and the practical significance of the variable by checking if the effect of the variable on satisfaction is practically appreciable. With the screened design variables, satisfaction models were developed for the interior parts by quantification I analysis.

Lastly, based on the satisfaction models, relatively important design variables and corresponding preferred design features were examined. The partial correlation coefficients and partial regression coefficients of the models were used to identify relatively important design variables affecting customer satisfaction and their preferred design values, respectively. It was found that relatively important design variables and preferred design features varied depending on interior part.

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Table 1 The number of vehicles evaluated (by interior part)

Interior part	Number of vehicles
Crash pad	30
Steering wheel	30
Transmission gear shift (TGS) knob	30
Audio panel	28
Metal grain dash	14
Wooden grain dash	5

Table 2 Material design variables: crash pad

Factor	Description	Levels	Var. type
Material type (x_1)	Type of material	1 to 4 (1: plastic, 2: polyurethane, 3: leather, 4: others)	Categorical
Hue (x_2)	Color determined by its dominant wavelength	1 to 8 (1: yellow, 2: achromatic, 3: navy blue 4: indigo, 5: goldenrod, 6: blue, 7: bluish violet, 8: orange)*	Categorical
Brightness (x_3)	Lightness of a color	0 (black) to 10 (white)**	Continuous
Saturation (x_4)	Purity of a color	0 (desaturated) to 16 (saturated)**	Continuous
Shininess (x_5)	Glossiness of material surface	1 to 7 (1: very dull, 7: very shiny)	Continuous
Embossing shape (x_6)	Shape of embossing	1 to 6 (1: circular concave, 2: circular convex, 3: pinhole, 4: leathery, 5: stony, 6: others)	Categorical
Embossing size (x_7)	Horizontal length (unit: cm) of embossing	1 to 7 (1: < 0.1, 2: 0.1 ~ 0.3, 3: 0.3 ~ 0.5, 4: 0.5 ~ 0.7, 5: 0.7 ~ 0.9, 6: 0.9 ~ 1.1, 7: > 1.1)	Categorical
Inter-embossing clearance (x_8)	Clearance (unit: cm) between embossing patterns	1 to 7 (1: < 0.1, 2: 0.1 ~ 0.3, 3: 0.3 ~ 0.5, 4: 0.5 ~ 0.7, 5: 0.7 ~ 0.9, 6: 0.9 ~ 1.1, 7: > 1.1)	Categorical
Embossing regularity (x_9)	Regularity of embossing arrangement	0 and 1 (0: irregular, 1: regular)	Categorical
Embossing distinctness (x_{10})	Distinctness of embossing	1 to 7 (1: indistinct, 7: very distinct)	Continuous
Surface roughness (x_{11})	Roughness of material surface	1 to 7 (1: very smooth, 7: very rough)	Continuous
Softness (x_{12})	Softness of material	1 to 7 (1: very hard, 7: very soft)	Continuous
Surface slipperiness (x_{13})	Slipperiness of material surface	1 to 7 (1: very frictional, 7: very slippery)	Continuous

* Only colors found in the 30 vehicles evaluated in the present study were listed.
** The levels of color brightness and saturation are specified in the Korean standard color table by Korean Color Research Institute (1991)

Table 3 Evaluation of statistical, technical, and practical significance: crash pad

Design variables	Statistical significance[1]	Technical significance[2]	Practical significance[3]
Material type (x_1)	❍	❍	❍
Hue (x_2)	❍	❍	❍
Brightness (x_3)	❍	❍ (quadratic)	❍
Saturation (x_4)	×	-	-
Shininess (x_5)	❍	❍	❍
Embossing shape (x_6)	❍	❍	❍
Embossing size (x_7)	❍	❍ (quadratic)	❍
Inter-embossing clearance (x_8)	❍	❍	×
Embossing regularity (x_9)	❍	❍	×
Embossing distinctness (x_{10})	❍	❍	❍
Surface roughness (x_{11})	❍	❍	❍
Softness (x_{12})	❍	❍	❍
Surface slipperiness (x_{13})	❍	×	-

(Notes)
1. $P < 0.05$ for statistical significance
2. Linear relationship between a design variable and satisfaction unless otherwise specified
3. Least significant difference = 5 for practical significance

Table 4 Evaluation of practical significance (crash pad): shininess

Shininess*	*N*	Average	Duncan Grouping	Group average	Difference between group averages
1	90	65	A	63	7
3	269	63	A		
2.5	60	63	A		
2	210	61	A		
4	90	57	B	56	
6	29	55	B		
5	148	55	B		

* 1 ~ 7 (1: very dull, 3: dull, 5: shiny, 7: very shiny)

Table 5 Screened material design variables for interior parts

Interior parts	Design variables (No. of variables)
Crash pad	Material type, hue, brightness, shininess, embossing shape, embossing size, embossing distinctness, surface roughness, softness (9)
Steering wheel	Material type, hue, brightness, saturation, shininess, embossing shape, embossing size, embossing regularity, embossing distinctness, surface roughness, softness (11)
TGS knob	Material type, hue, color uniformity, saturation, embossing shape, embossing size, embossing regularity, embossing distinctness, surface roughness, softness, surface slipperiness (11)
Audio panel	Material uniformity, hue, color uniformity (3)
Metal grain dash	hue, brightness, shininess, embossing shape, embossing distinctness, embossing density, surface roughness (7)
Wooden grain dash	Brightness, embossing distinctness, embossing density, surface slipperiness (4)

Table 6 Quantification I analysis results and preferred design features: crash pad

Factor	Partial correlation coefficient (R)	Level (description)	Partial regression coefficient (β)	Preferred design feature
Material type (x_1)	0.012	1 (plastic)	-0.24	
		2 (polyurethane)	0.32	❍
Hue (x_2)	0.174	1 (yellow)	-5.54	
		2 (achromatic)	-0.92	
		3 (navy blue)	-0.95	
		4 (indigo)	-1.18	
		5 (goldenrod)	14.84	❍
		6 (blue)	5.81	
		7 (bluish violet)	-1.32	
		8 (orange)	10.83	❍
Brightness (x_3)	0.038	2 (dark) to 7 (bright)	-3.89	7 (bright)
Shininess (x_5)	0.074	1 (very dull) to 6 (very shiny)	-1.15	1 (very dull)
Embossing shape (x_6)	0.194	1 (circular concave)	-0.02	
		2 (circular convex)	13.07	❍
		3 (pinhole)	8.38	❍
		4 (leathery)	-1.51	
		5 (stony)	-2.63	
		6 (others)	8.38	
Embossing size (x_7) (unit: cm)	0.146	1 (< 0.1)	0.80	
		2 (0.1 ~ 0.3)	-2.43	
		3 (0.3 ~ 0.5)	2.55	❍
		4 (0.5 ~ 0.7)	-1.88	
		5 (0.7 ~ 0.9)	-1.88	
Embossing distinctness (x_{10})	0.075	2 (indistinct) to 7 (very distinct)	-1.20	2 (indistinct)
Surface roughness (x_{11})	0.019	2 (2: very smooth) to 7 (very rough)	0.32	7 (very rough)
Softness (x_{12})	0.140	1 (very hard) to 7 (very soft)	1.66	7 (very soft)

Table 7 Important material design variables and preferred design features (arranged in descending order of the magnitude of partial correlation coefficient)

Interior parts	Design variables	Partial correlation coefficients (*R*)	Preferred design features
Crash pad	Embossing shape	0.194	Circular convex, pinhole
	Hue	0.174	Goldenrod, orange
	Embossing size	0.146	0.3 ~ 0.5 cm
	Softness	-0.140	Very soft
Steering wheel	Material type	0.122	Leather
	Brightness	0.103	Bright or dark
	Embossing size	0.080	> 0.5 cm
	Embossing distinctness	0.089	Very distinct or indistinct
TGS knob	Material type	0.214	Leather
	Embossing shape	0.132	Pinhole, no embossing
	Softness	-0.053	Very hard
	Color uniformity	0.043	Not uniform
Audio panel	Color uniformity	0.156	Not uniform
	Material uniformity	0.117	Uniform
	Hue	0.095	Bluish violet
Metal grain dash	Shininess	0.101	Very dull
	Saturation	0.090	Desaturated
	Embossing shape	0.033	No embossing, circular dot
	Hue	0.021	Chrome
Wooden grain dash	Surface slipperiness	0.128	Very slippery
	Brightness	0.080	Bright
	Embossing density	0.049	Very low
	Embossing distinctness	0.047	Very distinct

Figure 1 Interior components of a passenger car

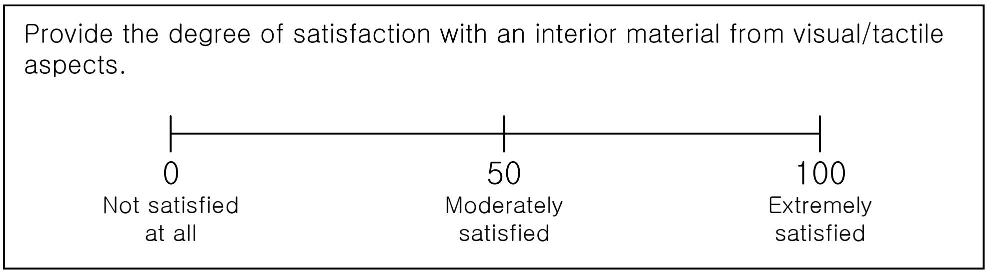
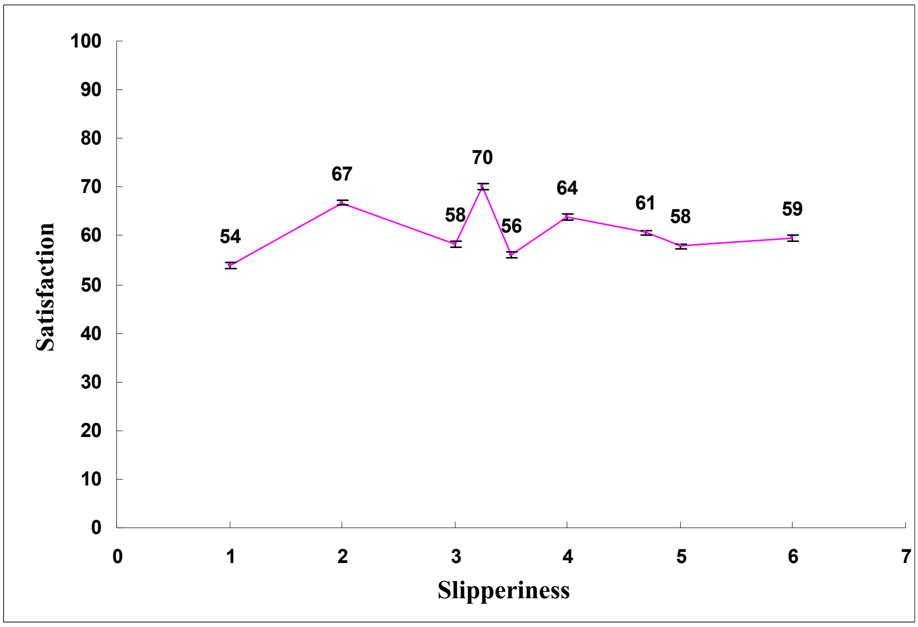
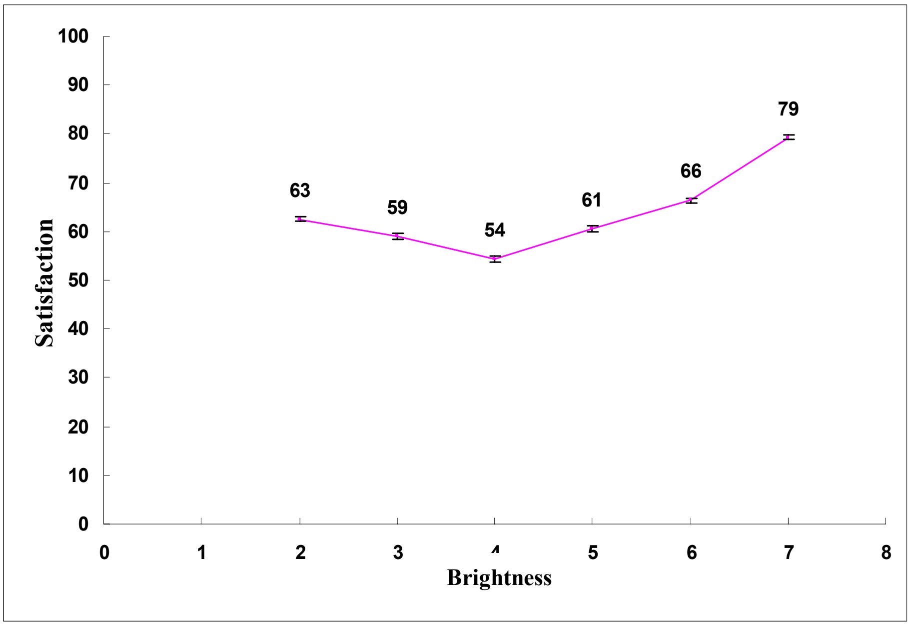


Figure 2 Modified magnitude estimation scale for material satisfaction evaluation



(a)



(b)

Figure 3 Examples of technical significance analysis (crash pad): (a) slipperiness, (b) brightness