AFFECTIVE EVALUATION OF VEHICLE INTERIOR CRAFTSMANSHIP: SYSTEMATIC CHECKLISTS FOR TOUCH/FEEL QUALITY OF SURFACE-COVERING MATERIAL

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Touch/feel quality of interior material is a critical element of customer's perception of overall product quality. Manufactures are increasingly interested in the affective evaluation as the perception of quality is heavily related to customer's feeling toward the product. Surface material quality is characterized by complex touch-feel sensations. In this study, 30 participants rated their affective reactions (how pleasant I feel) to surface materials of 30 different automobile interiors. Four categories of the material characteristics are used in the evaluation; crash pad plastic, steering wheel plastic, wood grain and metal grain. Consistent with previous research, it was found that both the visual quality and touch/feel quality influenced customer's perception of the material quality. Variables related to touch/feel quality is structured as 'an affective quality checklist' for automobile interiors to be used by a trim engineering team of an automobile manufacturer.

INTRODUCTION

The feeling of comfort in passenger car is playing an important role in buying decisions. Perceived quality is a concept that everybody intuitively understands, but it is difficult to define. Everybody is familiar with going to a showroom and judging the quality of the car by the finish of the material, the degree of craftsmanship, cost and the general ambience. The two aspects that cross all these factors are results and customer satisfaction. In other words, does the product meet or exceed customer satisfaction (Niebel and Freivalds, 2003)? Automobile manufacturers are trying to investigate this feeling in an objective and reproducible way. The Japanese term, 'Kansei Engineering", which could be summarized as the analysis of human expression of feelings on product, is becoming a widely recognized element of product design (Nagamachi, 1995). A variety of interior material is being used in modern consumer automobile. Visual and tactile properties of the compartment have strong influence on the overall quality judgment of the consumer. It is sometimes referred to as "show room quality" or "touch/feel quality".

The tactile perception during contact between skin and covering materials is one example of such elements of quality. Visual domains of sensory evaluation usually have means to test and measure the physical characteristics such as spectro-photo-colorimeter while few devices except subjective judgment exist in the analysis of touch/feel sensations. Characteristics of material greatly differ from each other in every feature such as shape, color, surface finish, granulites and surface patterns. Selecting design features critical to user satisfaction is one of the most important design decisions in the interior configuration of automobile design.

Substantial research has been conducted to study customer's feeling/impression on product design and the relationships between image/impression and product design features: car interiors (Tanoue et al., 1997), car speedometers (Jindo et al., 1997), cyber-banking systems (Kim et al., 1998), consumer electronic products (Han et al., 2000), and office chairs (Yun et al., 2001). However, little Kansei Engineering (Tanoue et. al., 1997) research have been conducted on touch/feel sensations for engineering materials while plenty of study exist on the sensory evaluation and hedonic quality for clothing/food industry. (Dillon et. al.,2001, Johnson et. al., 2002). For example, Giboreau et. al. (2001) studied the touch/feel quality of the automobile seat fabric based on the physical quality of fabric from the KES (Kawabata Evaluation System) method, grouping 26 different seat materials into 4 different axes of MDS (Multi-dimensional Scaling). Various descriptors and their physical characteristics were studied in that study for automobile seats. Hollins et. al. (1997) used a categorization task to examine the subjective tactile dimensions of various texture stimuli, such as wood, sandpaper, velvet. While methods described above provide a systematic way to compare physical characteristics to their sensory descriptors, it is not regarded as good indicators of human perception representative of touch/feel quality.

The purpose of this research is two-folded: (1) find out the design features related to the affective feeling of surface materials for automobile interiors and (2) develop a checklist to evaluate the features of the materials related to customer satisfaction. An experiment was conducted to evaluate the material characteristics related to affective feeling. Then, a checklist is developed to systematically evaluate affective aspects of material use in automobile interior design.

Method

30 subject (15 designers from the trim engineering department of an automobile company and 15 trained expert ergonomists from a university) evaluated the interior-covering material of 30 different automobiles (24 compact and 6 SUVs). 4 different interior parts were evaluated within a car : crash pad (plastic surface), steering wheel (plastic surface), wood grain and metal grain. Subjects used a 1-100 point magnitude estimation scale to enhance the sensitivity of the evaluation (Han et al., 1999, Yun et. al, 2001).

Both visual examination and tactile touch/feel are used in the evaluation. Make/model of the car being evaluated is intentionally screened (covered with tapes) as much as possible by the experimenter to eliminate the unwanted effect. All of test vehicles were placed at one place and the completely randomized experiment was conducted simultaneously. Figure 1 shows the photo of the car being evaluated.

Figure 1. Evaluation of Interior

After the customer evaluation, design variables related to affective feeling were measured and used as the pool of candidate variable. The design variables are defined as the collection of human interface features that the users touch, see and operate in the interior of an automobile. Two kinds of sensory perceptions are usually related to the affective quality of surface material: visual domain for color, pattern, appearance and touch/feel domain with hand and body contacts. Finishing is an important process in which chemical operations, raising, shearing, calendaring, and embossing are heavily involved. Including the basic properties of materials, variables were studied from literature, web site search, previous research on consumer electronic products, and expert suggestion.

The list of candidate variable is shown in Table 1. Depending on the nature of the product variable, both categorical (selection of a category for a product feature) and scale data (selection of a value of a product feature using a rating scale) were used to denominate the variables.

Product design features included in the regression model is shown in Table 1. Statistical significance using ANOVA and Stepwise multiple linear regression is tested with the evaluation score as the dependent variable and the material characteristic variable (listed in Table1) as independent variables. Statistical models were developed from variable screening and regression analysis. Detailed explanation of the data analysis procedures were presented in Ryu et al. (2003).

Table 1. Material characteristics used in the experiment

Code	Design variable	Definition and level description of variable
x1	Type of material	Type of raw material from which the interior part was made: categorical type - 1~4 (1: plastic, 2: polyurethane, 3: leather, 4: miscellaneous)
x2	Color	Color of material: categorical type - 21 colors (by the standard color table)
x3	Brightness	Brightness of color: continuous type - 2~9 (by the standard color table)
x4	Saturation	Pureness of color: continuous type - 0~16 (by the standard color table)
x5	Shininess	Degree of material shininess: continuous type - 1~7 (1:very dull, 7:very shiny)
x6	Shape of embossing	Shape of embossing: categorical type - 1~7 (1: pinhole, 2: circular concave, 3: circular convex 4: leathery, 5: stony, 6: flat, 7: miscellaneous)
x7	Size of embossing	Horizontal size of embossing: continuous type - 1~7 (1: < .1 cm, 7: > 2 cm)
x8	Marginal size of embossing	Distance between embossing : continuous type - 1~7 (1: < .1cm, 7: > 2cm)
x9	Arrangement of embossing	Regularity of embossing arrangement: categorical type - 0~1 (0: random, 1: regular)
x10	Clearness of embossing	Degree of embossing apparentness: continuous type - 1~7 (1: very indistinct, 7: very apparent)
x11	Roughness	Degree of surface roughness: continuous type - 1~7 (1: very smooth, 7: very rough)
x12	Softness	Degree of surface softness: continuous type - 1~7 (1: very soft, 7: very hard)
x13	Slipperiness	Degree of surface slipperiness: continuous type - 1~7 (1: very slippery, 7: very frictional)

RESULTS AND DISCUSSION

1. Affective Evaluation Experiment

Table 2 shows the result of ANOVA on 4 elements of interior materials, indicating that all variables except saturation and slipperiness are significant at α =.05 for crash pad plastic. For steering wheel plastic, all variables except slipperiness are selected. For metal grain, color, saturation, shininess, shape of embossing, clearness of embossing, and roughness of embossing are included. For wood grain, brightness, clearness of embossing, roughness, and slipperiness was found to be significant at α =.05.

As shown in Table 2, many design variables are included in the regression models. It is necessary to extract critical design features only and use the regression model expressed in the simplest form (Neter et al., 1990). Using the standardized coefficient of regression equation as the criterion for selecting/rejecting the variables in the equation, further simplification of the regression model is conducted.

Table2 . Result of ANOVA on design variables

Code	Design Variable	Crash pad	St'ng wheel	Metal grain	Wood grain
x_1	Type of material	o	o	x	x
x_2	Color	o	o	o	x
x_3	Brightness	o	o	-	o
x_4	Saturation	x	o	-	x
x_5	Shininess	o	o	o	-
x_6	Shape of embossing	o	o	o	x
x_7	Size of embossing	o	o	-	-
x_8	Marginal size of embossing	o	o	-	-
x_9	Arrangement of embossing	o	o	-	-
x_{10}	Clearness of embossing	o	o	o	o
x_{11}	Roughness	o	o	o	-
x_{12}	Softness	o	o	-	-
x_{13}	Slipperiness	x	x	x	O

(o: significant at α =.05, X: not significant, - : not entered in the experiment)

Table 3. Preference setting of the design variables (Crash Pad)

Code	Design Variable	Preference from Duncan Grouping	Possible Improvements
x_1	Type of material	PU(polyurethane) > plastic	PU (polyurethane)
x_2	Color	orange > blue, yellow > achromatic, deep blue,indigo	orange
x_3	Brightness	very bright, very dark > neutral brightness	very bright, very dark
x_5	Shininess	dull > shiny	dull
x_6	Shape of embossing	pinhole, circular concave > leathery, stony > circular convex, miscellaneous	pinhole, circular concave
x_7	Size of embossing	over 7mm > 1 ~ 5mm > 5 ~ 7mm	over 7mm
x_8	Marginal size of embossing	less than 1mm >over 1mm	less than 1mm
x_9	Arrg'ment of embos'ng	irregular > regular	irregular
x_{10}	Clearness of embos'ng	unclear > very clear	unclear
x_{11}	Roughness	tender > rough	tender
12	Softness	soft > hard	soft

Table 3 shows the summary of customer preference analyzed through Duncan grouping test for crash pad material (α =.05). As the result, the product variables related to the touch/feel quality of crash pad material are classified into a preference scale with respect to each design variable. For example, PU(polyurethane) material received more favorable response relative to plastic material in the type of material category while orange color was found to be superior to blue and yellow in the color category. Since all of these variables are not statistically independent to each other, it is difficult to generalize the result to other variables. However, analyzing the results of the touch/feel quality in this way can provide more detailed guidance on material selection and design.

Other techniques such as stepwise regression and reduced subset modeling were also tried to further improve the performance of the statistical model. The details of this technique of statistical analysis were reported in previous research (Ryu et. al., 2003).

Both visual and touch/feel variables were related to the affective evaluation scores on materials. Embossing patterns such as size, clearness and roughness were found to be related to customer evaluation scores while arrangement and softness characteristics were not.

Although not reported in this study, similar studies on the other parts of the interior such as overall interior coordination, gearshift knob, center fascia, display panel, door grip and heater controls are also conducted. In those parts, design variables other than material characteristics were included in the candidate list and used in statistical modeling.

2. Affective Evaluation Checklist

Based on the result of the statistical modeling and practical considerations from trim engineering team, a checklist for the affective evaluation of plastic materials in automobile interior is designed. The design variables selected in the statistical modeling are used as input for each part of the checklist.

Using the summary of variables listed in Table 3, the affective feeling checklist for crash pad material can be constructed for: type of material, color, brightness, shininess, shape of embossing, size of embossing, marginal size of embossing (embossing distance), arrangement of embossing (regular pattern vs. irregular pattern), clearness of embossing, overall roughness, and overall softness. Since statistical models exist for all affective aspects of interior material, separate checklist can be developed for other categories of interior material.

The complete structure of the checklist is shown in Table 4. For instance, 11 items for material quality, 8 items for parts coordination, 7 parts for ergonomics, and 6 items for convenience parts are constructed and structured in the checklist.

As shown in Table 4, the checklist investigates various points of the material characteristics and their appropriateness. It is intended to be used in the initial design stage to check whether the consideration of the affective aspects of interior material is executed to a satisfactory level. As the criteria of the checklist, a pass/fail (on/off) system is used for checking whether the conditions required from the checklists are met or not for the interior items being evaluated.

Table 4. A sample checklist for interior touch/feel quality

Design Objects	Design Objects	Design Variables
Material Quality	Steering Wheel	Shininess, Color, Embossing, Luxuriousness
	Crash Pad	Tactile Impression, Manufacturing Quality
	TGS Lever	Material Type, Surface Roughness, Embossing Size
	Door Trim	Material type, Arrangement
	Head Lining	Luxuriousness, Consistency
	Pillar Covering	Luxuriousness, Matching , Color
	Heater Control	Material Coordination, Color Consistency
	Metal Grain	Pertinence of Metal Grain, Pertinence of Use, Shine
	Plastic	Color, Luminosity, Pattern Type, Pattern Size, Spacing, Surface Roughness
	Wood Grain	Luminosity, Density, Smoothness
	Leather	Color, Luminosity, Shininess, Pattern Size,, Space, Arrangement, Pattern Luminosity, Surface Roughness
Parts Coordination	Overall Interior Coordination	Overall Coordination, CP & CF Connection, Form Consistency, Fitting line Treatment, Parts Arrangement
	Crash Pad Balance	Overall Balance, Stability, Symmetry, Simplicity
	Door Trim, Cabin Room,	Color Agreement, Material Arrangement, Form Standardization, Parts Connection
	Color Coordination	Wood Grain/Metal Grain Match, Material Consistency
	Material Coordination	Front/Side/Back Material Consistency, CF Material Consistency, CF Parts Material Consistency
	Door Trim and Other Parts	Shape Coordination, Trim/Door Connectivity, Grip/Door Connectivity
	Junction Parts	Burr, Parting Line, Sharp Edge, Gap, Steering Column Connection
	Parts Assembly	Shape Coordination, CF/CP Coordination, Mechanical Connectivity, Crack, Strain, Arrangement
Ergonomics	Center Fascia Element Design(1)	Readability, Label Understanding
	Center Fascia Element Design(2)	Knob Shape, Knob Size, Knurling/Serration, Functional Sound, Functional Weight, Functional Repulsion
	Emergency Light	Sound, Weight, Height, Depth
	Cluster Gauge	Visibility, Gauge Size, Back Panel Color, Symbol Size, Illumination, Ergonomic Design Principle
	Miscellaneous Displays	Visibility, Readability, Color Agreement, Size Agreement, Symbol Type Agreement
	Audio Components	CF Coordination, Consistency, Standardization, Button, Material
	Functional Disagreements	Functional Direction, Functional Shape, Movement, Post-Movement Status
Convenience	Glove Box	Functional Type, Characteristics, User Convenience
	Console	Size, User Convenience, Location, Arm Rest Function
	Cup Holder	Location, Shape, Capacity, Functionality
	Arm Rest	Location, Functionality, User Convenience
	Luggage	Capacity, User Convenience
	Miscellaneous	Characteristics, User Convenience

For example, a designer can check the appropriateness of steering wheel material based on its shininess, color, embossing and luxuriousness. Tactile impression and manufacturing quality were the two most important items to be evaluated for the material quality of the crash pad.

Using the items listed in Table 4, a complete checklist for evaluating the touch/feel quality of an automobile interior was also developed. The complete checklist had 120 items from various points of affective evaluation such as material craftsmanship, part coordination, ergonomics, convenience and craftsmanship. Using the checklist items suggested in Table 4, designer can evaluate the overall quality of the interior finish expressed as the ratio of unsatisfactory items to the satisfactory items on the list.

CONCLUSION

Affective feelings of automobile interior finish materials are investigated in this study. Based on the Kansei engineering evaluation technique, variables related to the affective feeling on specific parts of the automobile interior material are identified and described in detail.

The results showed that both visual and touch/feel quality of the material is important to customer response. Some material characteristics considered important by the designers were not considered important by the customers. Ornament covering materials such as wood grain and metal grain showed marginal influence on affective feeling with considerably less variables included in the statistical model.

Development of an affective evaluation checklist was also conducted using the result of the affective evaluation. When designing the properties of interior materials, automakers need an objective and reproducible method to aid the decision process. The result of the study and the corresponding checklist are attempts to understand consumers who are at the very end/front of the design process: how do consumers perceive the touch of a material in the car interior? What type of material characteristics are they expecting in a new car? how the perceived touch/feel quality can be optimized in the design process?

The checklist approach suggested in this study is a first step to answer those questions. The checklist tried to include both consumers and designers perceptions in the definition of checking items. This checklist can become a powerful descriptive tool in terms of transferring consumer perception/choice to design/technical communication if used effectively. This checklist, if extended, can be used in other parts of automobile design processes such as benchmarking the competitors, experiments on surface quality, checking the finish of the manufacturing process and finally evaluating the current design and finding out the missing points.

The concept of touch/feel quality is found to be a valuable criterion for evaluating the potential performance of a product on customer's affection toward the product. The checklist approach based on the modeling of affective feelings on a product could provide a systematic method to review and improve a product at the initial design stage.

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