doi: 10.5821/conference-9788419184849.45

KANSEI ANALYSIS SHOWN IN A SINGLE MAP : MULTIPLE CORRESPONDENCE ANALYSIS OF DESIGN ELEMENTS AND KANSEI EVALUATION

A CASE OF LEATHER PATTERNS SIMULATED WITH 3D CG IN CHILDREN'S LOWER LEG ORTHOTICS

Shigekazu ISHIHARA[1a], Kosuke MORINAGA[a], Taku ISHIHARA[b], Keiko ISHIHARA[a]

[a] *Faculty of Rehabilitation, Hiroshima International University, Japan, i-shige@hirokokou-u.ac.jp,*

[b] *Institute of International Kansei Design, Japan*

ABSTRACT

In this study, we regarded the idea that supplementary variables and Multiple Correspondence Analysis are promising for analysis and visualize complicated relations in Kansei analysis. It could merge several different information tables and then project them into a map. Applying this advantage would make the overall view of Kansei. Design elements, samples, and associated Kansei words were shown in an MCA map. Leather patterns of children's lower leg orthotics are the objective of this Kansei evaluation. The leather surface was simulated with 3D CG with physically based rendering methods.

Keywords: *multiple correspondence analysis, multivariate analysis, 3D CG, surface, Kansei evaluation*

1 INTRODUCTION

1.1 Standard Kansei Analysis Methods

Since the beginning of the Kansei engineering in the early 1970s, invented by Prof. Mitsuo Nagamachi, Kansei Engineering has been involved in the development of many successful products such as MAZDA Roadster (Miata in the US, MX-5 in Europe and Asia), lighting devices, and home appliances from Panasonic, Milbon Deesse's Hair treatment products, Washer-Dryer from SANYO. Moreover, the methodologies of Kansei Engineering have been spreading to various

[1] Corresponding author.

industries. From car industries like Nissan, Mazda, FIAT and suppliers, home electronics industries like Panasonic, LG, and Samsung, cosmetics, food industries, and service industries such as hotels have intensively incorporated KE into their product planning and design process.

Several multivariate analysis techniques deliver Kansei structure and relations between design elements and Kansei evaluation. Following is the building procedure of Kansei engineering analysis and building Kansei systems.

(1) Selection of Kansei words

Select the Kansei words that are appropriate for what is intended. In the case of a house interior design, Kansei words are selected from interior magazines and books. Collected Kansei words are paired in the semantic differential (SD) 5-grade scale, like "beautiful [ ][√][ ][ ][ ] not beautiful". Most of the Kansei words are adjectives, but some words are uncommon jargon for specific domains. Thus, we call them "Kansei words" rather than adjective words.

(2) Assessment of the design components

The second step is to conduct a psychological experiment to collect subjects' Kansei. A semantic differential method questionnaire is made to evaluate products. Then, an experimenter presents slides, pictures, or real products to subjects for their assessment. These design element parameters (i.e., color, size, and shape of parts, components, or the whole design) are measured.

(3) Multivariate analysis of Kansei evaluation data

The next step is to analyze the latent structure of Kansei statistically. At first, Principal Component Analysis to find the correlational structure between Kansei words. Then, the implicit relations among Kansei words and physical attributes (i.e., color, size) are estimated. Hayashi's Quantification Theory Type I model has been used for this numerical estimation procedure. In these 20 years, we have often used Partial Least Squares regression as a computing method for solving the QT1 model (Ishihara, 2011).

(4) Development of Kansei Engineering System

The obtained relations among a component's design, features, structure, and the Kansei words are converted to rules that a computer uses for reasoning. An inference engine, graphics database, and graphics drawing engine are built for a complete system. Our Kansei engineering system can draw a design that corresponds to the user's Kansei from their input of Kansei words. We have developed various Kansei engineering systems, such as house interior, car interior design, and garment coordination.

1.2 Bourdieu’s Big-picture of social classes

French sociologist and public intellectual, Pierre Bourdieu (1930-2002) have published his monumental book, “La Distinction: Critique Sociale du Jugement” in 1979. This book revealed “social position” from quantitative data of different social surveys with multiple or single correspondence analyses.

Combining multiple survey data, “La Distinction” reveals social classes and distinctions between classes. A big-picture view of social classes in his demographics shows an integrated view. “Upper classes” include higher / middle level education lecturers, freelance professionals (Bourdieu take examples as doctor, lawyer, architects.), executive officers, officers at government or public offices, senior engineers, and businesspersons (of industry and commerce). Educators have the highest cultural capital but have lesser financial capital; Businesspersons have the highest financial capital and lesser cultural capital. Freelancer professionals have both financial and cultural capital to a higher degree.

In Bourdieu’s perspective, each individual has a position in a multidimensional social space. A person is not defined only by social class membership but by these different capitals. Thus, asking people about their lifestyles, such as hobbies, dining habits, kinds of preferred music, preferred art form, painters, reading newspapers, kinds of automobiles, and physical activities, reveals their social positions and capitals with multivariate analyses objectively. Bourdieu’s methodology of mathematical analysis of heterogeneous data shares insights with Kansei engineering data analysis. Bourdieu predominantly relied on Correspondence Analysis and Multiple Correspondence Analysis for his research and intellectual insights. These analysis methods are developed statistician team led by Jean-Paul Benzécri (1932-2019) at Paris University No.6, Pierre and Marie Curie University.

1.3 Correspondence Analysis

Correspondence analysis (CA) has been studied since the early 1970s (i.e., Benzecri, 1992) as a method to visualize the relations between rows and columns of a contingency table. The below lines are taken from our paper (Ishihara, Ishihara & Nagamachi, 2007).

The concept and procedure of the correspondence analysis are based on Pearson's chi-square test, which is the most popular method to test the relations between rows and columns in a table. In the process of the chi-square test, the expected value of each cell is calculated from the sum of the row, the sum of the column, and the grand total; i.e., The expected value of cell $_{ij}$ is *(sum of the row$_i$) * (sum of the column$_j$) / (grand total).*

The difference between the expected and the observed value is *(observed - expected)^2 / expected*. The total difference over all cells is a chi-square value. If it is more significant than a particular value with the degree of freedom, we reject the null hypothesis and conclude that the rows are significantly associated with the columns.

The difference table is *i*-dimensional in rows and *j*-dimensional in columns. The rows and columns are projected onto a smaller number of dimensional (i.e., 2-dimensional) space in the process of the correspondence analysis. Each row is projected onto a reduced dimensional space; each column is also projected onto another space with the same number of dimensions. When we normalize and superimpose the two reduced dimensional spaces, we can understand the relationships between items listed in rows and columns in the difference table.

In Kansei engineering, we have applied CA to solve the Quantification Theory Type 3 model of Chikio Hayashi (1954). (Ishihara, Ishihara & Nagamachi, 2007)

1.4 Supplementary Points

In correspondence analysis, variables and individuals (measured sample) those used for composing CA map space are called active variables and active individuals. In this application, a active individuals are samples (e.g. leather11w) and active variables are design elements (i.e., large_grain) as shown in table 1.

CA can deal with additional variables. They are not used for composing CA map space. Map dimension and space were fixed with active variables and active individuals. The positions calculated from additional variables are called Supplementary Points. Then, the supplementary points show the correlational relations of additional information with active variables or individuals. Positions of supplementary variables are computed with eigenvector matrices that correspond as rows or columns of the contingency table.

Table 1 shows the variables and samples in this research. Supplementary variables are Kansei words. The rightmost column is *cute*. Kansei evaluation values exceeding the average of overall evaluation +1 SD were noted as *cute*.

Evaluations below -1SD were noted as *not cute*, and evaluations between +-1SD were *Neither Cute*. Kansei analysis shown in section 3.2 has 26 Kansei words as supplementary variables. Then figure 8 shows spatial relations between samples, design elements as active points, and 26 Kansei words as supplementary points.

1.5 Multiple Correspondence Analysis

Correspondence analysis represents an association between two categorical variables. Multiple Correspondence Analysis (MCA) deals with a set of categorical variables. If these variables are on the same kinds of scale (quantitative/categorical) and have the same coding scheme, these could treat as a variable set (Greenacre, 2017).

An indicator matrix or Burt matrix is used for coding a set of categorical variables. The indicator matrix has 0/1 style coding. Burt matrix has a set of square contingency tables of all variables of the set. A submatrix of the Burt matrix has n-row n-column that represents n variation of a categorical variable. Mathematical properties of the 0/1 coded indicator matrix are well written in Husson, F, Lê, S. & Pagès, J. (2017).

As shown in Table 1, the design element table in this study has three-valued and five-valued variables (i.e., grainSmall / Large / emboss dots / nubuck). Kansei evaluation has been coded in three-valued. These are automatically re-coded into the Indicator matrix with the FactoMineR package (Lê, S., Josse, J. & Husson, F., 2008).

In this study, we regarded the idea that supplementary variables and MCA are promising for analysis and visualizing complicated relations in Kansei analysis.

It could merge several tables of different kinds of information, then projects them into a map. Applying this advantage would make the overall view of Kansei like Bourdieu's integrated big-picture view.

Table 1. Design element table for Multiple Correspondence Analysis. More Kansei evaluation columns are followed by the rightmost "*cute*".

Sampl e No.	sample	Shiny/ Matte	grainSmall/Large/e mbossDots/nubuck	pressed	Color Black	*Kansei "cute"*
1	leather1	matte	large_grain	pressed_grain	black	*NotCute*
2	leather1w	matte	large_grain	pressed_grain	dark_brown	*NotCute*
3	leather2	matte	small_grain	not_pressed_g	black	*NotCute*
4	leather2w	matte	small_grain	not_pressed_g	dark_brown	*NotCute*
5	leather3	matte	nubuck	not_pressed_g	black	*NeitherCute*
6	leather3w	matte	nubuck	not_pressed_g	dark_brown	*Cute*
7	leather4	matte	nubuck	not_pressed_g	black	*NeitherCute*
8	leather4w	matte	nubuck	not_pressed_g	dark_brown	*NeitherCute*
9	leather5	matte	small_grain	not_pressed_g	black	*NotCute*
10	leather5w	matte	small_grain	not_pressed_g	dark_brown	*NotCute*
11	leather6	matte	nubuck	pressed_grain	black	*NotCute*
12	leather6w	matte	nubuck	pressed_grain	dark_brown	*NotCute*
13	leather7	matte	large_grain	not_pressed_g	black	*NotCute*
14	leather7w	matte	large_grain	not_pressed_g	dark_brown	*NotCute*
15	leather8	matte	nubuck	not_pressed_g	black	*NotCute*
16	leather8w	matte	nubuck	not_pressed_g	dark_brown	*NeitherCute*
17	leather9	matte	small_grain	pressed_grain	black	*NotCute*
18	leather9w	matte	small_grain	pressed_grain	dark_brown	*NotCute*
19	leather10	matte	embossDots	not_pressed_g	black	*NotCute*
20	leather10w	matte	embossDots	not_pressed_g	dark_brown	*NotCute*
21	leather11	shiny	large_grain	not_pressed_g	black	*NotCute*
22	leather11w	shiny	large_grain	not_pressed_g	dark_brown	*NotCute*

2 METHODS

In this research, we have applied our virtual prototyping method (Matsubara et al., 2010) to evaluate sample variations of children's lower leg orthotics (Morinaga et al.,2019). Usually, children's shoes do not use leather, but for lower leg orthotics, leather is standard because of installing shafts and tolerance for torsions. Because children's lower leg orthotic is specially made for each patient, the patient and parents hope to have the orthotics along with their preferences. The leather has many variations on its surface finishing; then proper proposal based on KE is strongly needed.

At first, we scanned entire lower leg orthotics. HP Z 3D camera (HP Inc.) was used for the simultaneous scan of the shape and its textures. Then a new model was made by hand from the tracing of the scanned model. Manual tracing was done with Blender 2.6 (Blender foundation).

Leather surface variations were generated with Substance Painter 2017 (Allegorithmic Inc.). Variations of leather patterns, bump patterns, specular (surface glossiness), and colors were applied in 22 samples, as shown in Figure 2.

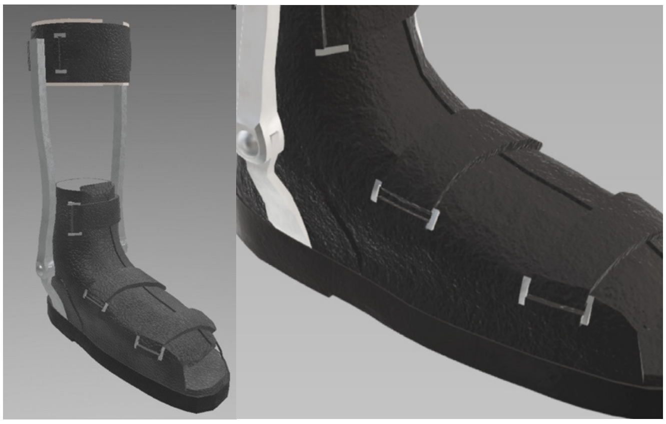

Figure 1. A model for Kansei evaluation on surface finishing.

Figure 2. Simulated leather patterns

Eight participants evaluated the samples (6 males and two females in their 20s and 30s). Sixty-six Kansei words were used for the evaluation. The principal component analysis extracted the Kansei structure.

3 RESULTS

3.1 Authentic Analysis Results

The principal component analysis results are shown in Figure 3 below. We consider first and 2nd PC. In the principal component loadings plot, at the + side of the 1st pc, there are *comfortable*, *casual*, *loveable* and *want to wear*. At the – side of the 1st pc, there is *plain*. PC first corresponds to attractiveness. We can find several polarized relations. In the direction of one to one-half o'clock, there are *cool, sophisticated, innovative, impressive*, and *urban*. At the opposite, seven and a half o'clock, there are *dull* and *coarse*. At two o'clock, there are *attractive, refined, beautiful,* and *good sense*. At eight and a half o'clock, there is *plain*. From 4 to 5 o'clock, there are *girlie, tender, light*, and *softly*. At ten and a half, there are *hard, massive,* and *masculine*.

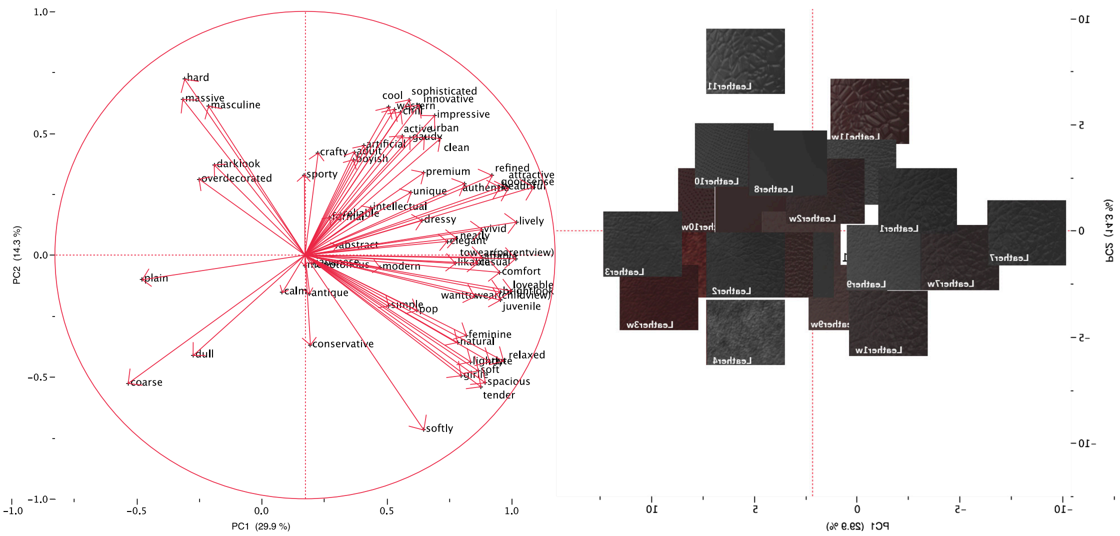

Figure 3. Principal component loadings of Kansei words (left) and principal component score of leather patterns (right)

On the right-hand side of the 1st pc, nubuck leathers (buffed surface to raise protein fiber) correspond to *juvenile, comfortable, lively* and *lovable*. *Feminine, soft, natural*, *cute* and *tender* were consistent with gray nubuck leather 4 and dark brown nubuck 4w.

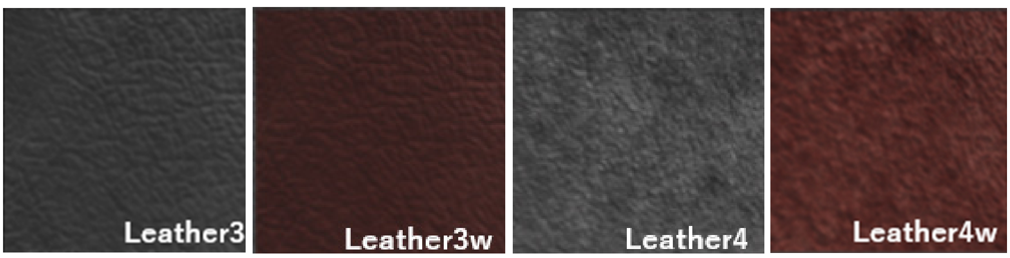

Figure 4. Nubuck leather as *juvenile, comfort, lively* and *lovable*.

Cool, western, innovative, and *gaudy* are placed in one o'clock direction. The corresponding leather is leather 11 and 11w that have a large pattern and glossy surface.

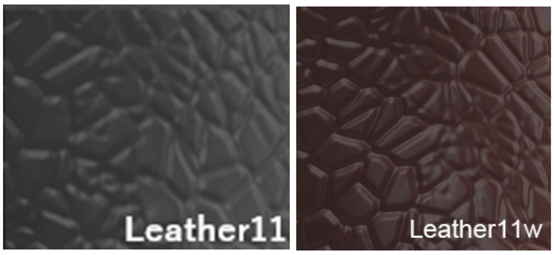

Figure 5. Glossy leather as *cool, innovative* and *gaudy*.

Refined, attractive, *good sense*, *comfortable* and *beautiful* at 2 o'clock direction tie with leather 10 and 10w. They have small bump dots in wavy alignment.

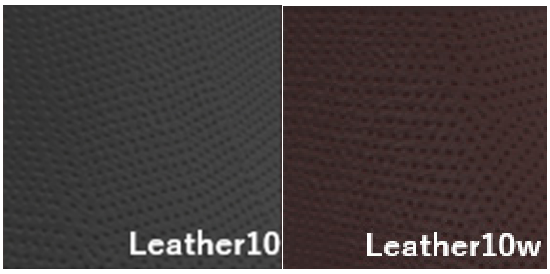

Figure 6. Dotted leather as *refined, attractive, comfortable* and *beautiful*.

3.2 PLS Regression Results

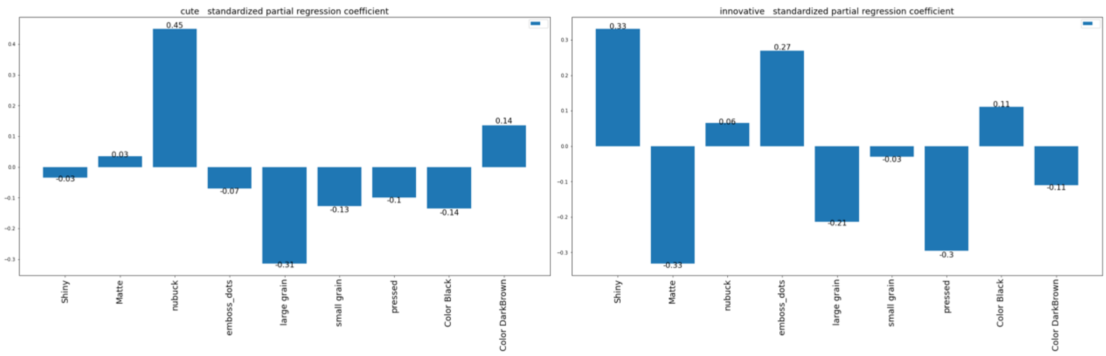

Figure 7. PLS regression analysis of design elements and Kansei, Left: *Cute*, Right: *Innovative*

Usually, we use PCA for Kansei structure analysis first, then use PLS regression for estimating associations between design elements and Kansei evaluation. Figure 7 shows the analysis results. These Kansei-design elements graphs would make for each of Kansei words; then, we have to be considered many bar graphs in Kansei engineering analysis.

3.3 Multiple Correspondence Analysis Results

Many beneficial relations could be read from an MCA map, shown in figure 8.

1. Color variation (black / dark brown) placed at the origin. Color has almost no relation to entire design element mapping and to Kansei evaluations. All varied color samples (shown in black, i.e., 10 and 10w) take the same position.

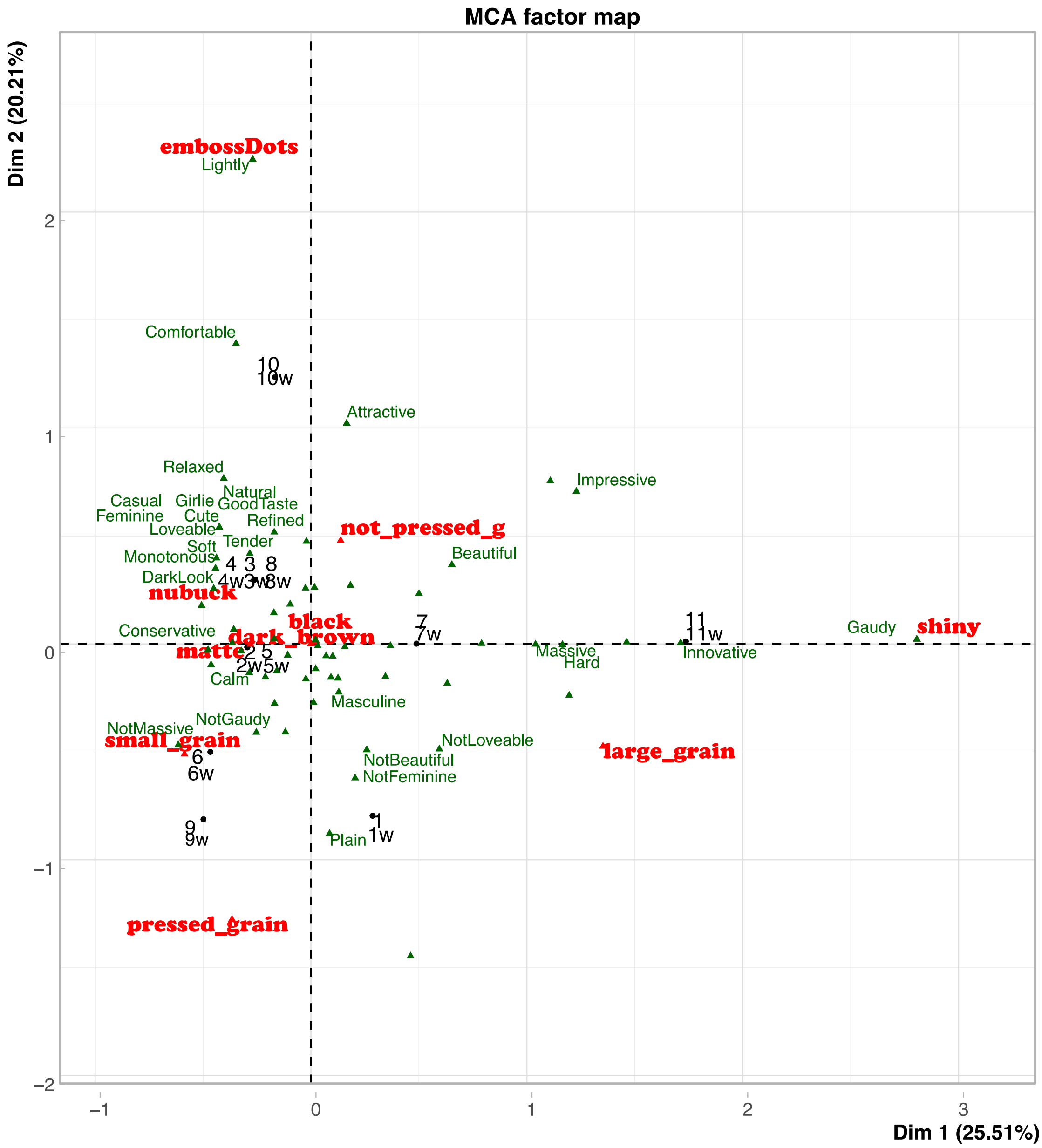

Figure 8. Multiple Correspondence Analysis results (red: design elements, black: samples, green: Kansei words (as supplementary points))

2. Design elements, Shiny and Matte, are alternatives to each other (in a logical sense). The position of two reflects exclusive coding. Shiny takes the position close to samples 11 & 11w; those two only are shiny patterns. Shiny is close to *gaudy* and *innovative*. Matte is close to Kansei, *conservative* and *calm*, and close to samples 2, 2w, 5,5w, 3,3w, 4,4w, and 8,8w.

3. Nubuck and not_pressed_grain samples are 3,3w,4,4w,8,8w, and *tender, soft, cute, natural, feminine, relaxed, casual,* and *monotonous*.

4. Pressed_grain samples are 9 and 9w, 1,1w and 6, 6w. 6 & 6w are also nubuck. Pressed_grain related with plain. Not_pressed_grain is the alternative and related to *beautiful, refined,* and *impressive*.

5. Although the nearest samples of Small_grain are 6 and 6w, consistent samples are 2,2w,5,5w, and 9,9w. Small_grain associated with *not_massive* and *not_gaudy*. Samples 6 and 6w would locate the inertia balance between Prosessed_grain and Not_processed_grain. Benzécri (1992) explained CA as the overall stabilizing process of dynamics, then local inconsistency in global consistency could happen.

6. Embossed_dots associated with 10 and 10w, and *comfortable*, *attractive*, and *lightly*.

Found relations from #1 to #5 in the above lines are compatible with PCA and PLS regression results. The relation embossed_dots and lightly are not revealed by PCA, but evaluation data of 10 has high on lightly. We consider that MCA has more sensitivity than PCA in some cases for expressing associations between Kansei and design elements.

4 CONCLUSION

Utilizing the methods of supplementary variable and MCA, visualizing complicated relations in Kansei analysis was achieved. Two different mappings (PC loadings for Kansei structure, PC scores for samples) and many bar graphs of Kansei and design elements are integrated into an MCA map. Integration of confounding and different kind of information and its visualization would contribute to showing the benefits of Kansei engineering to a broader audience.

REFERENCES

Ishihara, S. (2011) Chapter 5 Statistical Analysis for Kansei/Affective Engineering, in Nagamachi. M. (ed.) Kansei/Affective Engineering, CRC Press.

Bourdieu, P. (1979) La Distinction: Critique Sociale du Jugement, Les Éditions de Minuit, Paris. (English edition: Distinction: A Social Critique of the Judgment of Taste, Harvard University Press, Japanese edition: Distinction, Fujiwara Publishing)

Benzécri, J.P. (1992) Correspondence analysis handbook. Marcel Dekker, N.Y.

Ishihara, S., Ishihara, K. & Nagamachi, M. (2007) The Graphical Analysis Method for Non-Linear Relation between Kansei Evaluation and Design Elements, Ergonomia, 29(2), 107-121.

Hayashi C. (1954) Multidimensional quantification – With the applications to analysis of social phenomena. Annals of the Institute of Statistical Mathematics, 5, vol.2, 121–143.

Matsubara, T., Matsubara,Y., Ishihara,S. and Inokuchi,S. (2010) Virtual Prototyping With Real-Time Rendering for Kansei Engineering Of Leather Grain Patterns on Car Dashboard Panels, Trans. of Japan Society of Kansei Engineering, 9(2) 119–128 (2010)

Morinaga, K., Takeue, K., Ishihara, T., Ishihara, S., Hirano, M. Arizono, H., Tsuji, T., Francis, A., Anderson, S. (2019) Kansei Based Evaluation of 3D CG Material Surface in Children's Lower Leg Orthotics, Proc. the 20th International Symposium on Advanced Intelligent Systems and 2019 International Conference on Biometrics and Kansei Engineering, 275-280.

Ishihara, S. (2018) Analysis methods of Kansei engineering data, PO Academy Journal (Japanese Academy of Prosthetists and Orthotists), 26(3) 165-173 (in Japanese)

Pharr, M. & Humphreys, G. (2004) Physically Based Rendering, Morgan Kaufmann.

Greenacre, M. (2017) Correspondence Analysis in Practice, Third Edition, Taylor and Francis.

Lê, S., Josse, J. & Husson, F. (2008). FactoMineR: An R Package for Multivariate Analysis. Journal of Statistical Software. 25(1). pp. 1-18.

Husson, F, Lê, S. & Pagès, J. (2017) Chapter 3 Multiple Correspondence Analysis (MCA), in Husson, Lê, Pagès, Explanatory Multivariate Analysis by Example Using R 2nd Edition, CRC Press