
A cross-cultural study of users' craftsmanship perceptions in vehicle interior design

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Abstract: This paper investigates the user-perception of vehicle interior craftsmanship. A survey, involving subjects of two different nationalities (American and French), was conducted on a set of vehicles. Several tasks were asked of the subjects in order to study differences in craftsmanship perception, in particular, relative to the nationality of the subject. This paper proposes an interesting illustration of the use of social science techniques to investigate differences in the perception of products. Several analytic techniques such as Multidimensional Scaling (MDS), cluster analysis, analysis of variance, Principal Component Analysis (PCA) and preference mapping are presented to scientifically study user-perceptions.

Keywords: perceived quality; quantification of craftsmanship; user oriented design; MDS; multidimensional scaling; preference mapping.

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1 Introduction

In today's highly competitive market, a crucial issue in product design is the development of new products that meet users' needs and preferences. To improve attractiveness, a well-designed product should not only satisfy objectively defined requirements but should also satisfy users' psychological needs which are, of course, subjective. Through tools developed in the social sciences, the subjective needs and preferences of the user can also be quantified. This paper illustrates a handful of these techniques for the problem of measuring perceptions of craftsmanship for vehicle interiors across two different cultures – French and American.

Vehicles makers are extremely concerned about the perceived quality, a.k.a. craftsmanship (Crochemore, 2000). They noticed several years ago that the concept of 'hard quality' (robustness of the design) is not enough to be competitive. To have an accurate knowledge of users' perception of quality is vital for a company (Qualls and Rosa, 1995), and manufacturers must develop relevant assessment procedures in order to control their production.

Kansei Engineering, founded by M. Nagamachi at Hiroshima University about 30 years ago, is a powerful approach to product design involving user's perceptions. Nagamachi defines Kansei Engineering as a powerful ergonomic consumer-oriented technology that translates customers' feelings (Kansei) about a product into design elements (Nagamachi, 1995). Kansei Engineering has been applied to the design of automobiles, construction machines, home electric appliances, housing and costumes in studies conducted in Japan, Korea, England, Sweden and Netherlands. Jindo and Hirasago (1997) studied the styling and design specifications of passenger car interiors as a Kansei engineering application. They focused on the styling of the speedometer and the steering wheel of a passenger car. They collected subjective evaluations using semantic differential methods and analysed those ratings using multivariate statistical techniques. The results showed the relationship between the impressions and characteristics of styling that help to understand the conditions that create a desired impression. Tanoue et al. (1997) explored roominess and oppressiveness of a vehicle interior using Kansei engineering. They revealed that colour and shape play an important role on those perceptions. They also analysed the interior dimensions and proposed optimum dimensional ranges for roominess and oppressiveness.

Several studies tackle the problem of craftsmanship assessment. In Wang and Holden (2000), the authors developed a craftsmanship evaluation system, which computes an overall craftsmanship score for automobile products. This score is computed as the weighted sum of individual product attribute scores assessed subjectively. A study of the influence of customer demographic background (gender, age, education) on the craftsmanship assessment showed that this background has no significant influence on the assessment.

A procedure for craftsmanship evaluation of vehicle interiors developed at the University of Michigan is presented in Hossoy et al. (2004). This procedure is based on a list of perceived attributes and creates a Functional Dependence Table (FDT) that relates the 'attributes' (perceived by the user) to the design 'variables' (managed by the engineer).

This paper has three main objectives:

- to study the influence of subjects' nationalities on the underlying dimensions of their craftsmanship perception
- to study the influence of subjects' nationalities and vehicle models on craftsmanship ratings
- to study the influence of subjects' nationalities on preference rankings, and the correlation between subjects' overall preference rankings of vehicle interiors and their craftsmanship assessment scores.

The present study investigates, experimentally, the difference between two groups of subjects (American and French) in their perceptions of craftsmanship for vehicle interiors. The same list of attributes used by Hossoy et al. (1997) to study users' craftsmanship perceptions is used in the present study. Section 2 presents the procedure of craftsmanship evaluation developed in Hossoy et al. (2004). Section 3 describes the survey and the specific tasks required from the subjects. Section 4 provides analyses and interpretations of the data. The analytic techniques include Multidimensional Scaling (MDS) (Shepard et al., 1973), cluster analysis, Principal Component Analysis (PCA) and preference mapping techniques (Caroll, 1972). Section 5 presents conclusions.

2 Background on craftsmanship assessment

The procedure used for craftsmanship evaluation of vehicle interiors is part of a more general research project called 'Analytical Craftsmanship Project', a research programme between Johnson Controls Inc. (JCI) and the University of Michigan. This project has produced preliminary results (Hosoy et al., 2004) that will be used in this study.

In order to evaluate the perceived quality of vehicle interiors, a list of 22 perceived attributes was created, in collaboration with designers from JCI (Table 1). The underlying assumption is that the craftsmanship value of a product can be assessed by rating the product along predefined attributes. The list of attributes constitutes the basis for the craftsmanship evaluations carried out in this study. The list was considered as an input for this work, so it was not modified.

Table 1 List of perceived attributes of vehicle interiors (assessment of craftsmanship)

| <i>No.</i> | <i>Name</i> |
|-----------------|---|
| f ₁ | Ability to easily discern where all controls are located |
| f ₂ | Hollow resonance |
| f ₃ | Component feel/sound of activation/engagement (Seatbelts, doors, buttons) |
| f ₄ | Buzz, Squeak, and Rattle (BSR) |
| f ₅ | Stitching quality |
| f ₆ | Adjustability of components |
| f ₇ | Shape harmony |
| f ₈ | Colour harmony |
| f ₉ | Storage space in front console |
| f ₁₀ | Visibility of mechanical elements and manufacturing distortions |
| f ₁₁ | Component/passenger interference |
| f ₁₂ | Material quality |
| f ₁₃ | Seated comfort |
| f ₁₄ | Difficulty reaching controls, lights and seatbelts |
| f ₁₅ | Consistency of tactile feel |
| f ₁₆ | Usability of vents |
| f ₁₇ | Usability of glove box |
| f ₁₈ | Usability of door pockets |
| f ₁₉ | Usability of sun visors |
| f ₂₀ | Usability of cup holders |
| f ₂₁ | Usability of trunk |
| f ₂₂ | Quality of finishing |

Several different methods to elicit preferences and ratings along these 22 attributes of interiors were used in the present study.

Several data analytic methods, well-known in marketing (Kaul and Rao, 1995), or sensory analysis (Evaluation Sensorielle, 1998; Petiot and Yannou, 2004) were used to analyse data emerging from this project (e.g., MDS, cluster analysis, PCA, preference mapping).

3 Methodology

A survey was conducted with students (French or American) at the University of Michigan. The subjects were all male mechanical engineering students, to reduce the noise in the data by providing some homogeneity. Fifteen (15) subjects, eight French (F1–F8) and seven American (A1–A7), participated in the survey. Eight (8) vehicles (V1–V8) were available for evaluation (see Table 2), actual automobiles being used for the different tests. The purpose of this survey is to show the feasibility of the approaches taken in the paper rather than present a representative analysis of a large population.

Table 2 Vehicles used for the survey

| | <i>Vehicle brand</i> |
|----|---------------------------------|
| V1 | <i>Hyundai Elantra ('00)</i> |
| V2 | <i>Mercury Sable ('99)</i> |
| V3 | <i>Ford Focus ('02)</i> |
| V4 | <i>Ford Taurus ('01)</i> |
| V5 | <i>Mazda Protégé</i> |
| V6 | <i>Nissan Infinity ('96)</i> |
| V7 | <i>Buick Regal ('01)</i> |
| V8 | <i>Chevrolet Cavalier ('00)</i> |

The following tasks were performed by the subjects:¹

Task 1: Description: Participants sorted the N attributes (Table 1) into mutually exclusive groups based on their perceived similarities, “in a way that makes sense to you”. The number of piles had to be greater than 1 and less than N .

Processing: Each subject’s piles were translated to a binary ($N \times N$) matrix indicating whether or not the subject grouped two attributes in the same pile. For each pair of attributes, (0) indicates that the attributes are in the same pile, (1) in a different pile. A weighted MDS was performed on the individual dissimilarity matrices. In order to conduct a cluster analysis (hierarchical ascendant classification), individual dissimilarity matrices were next summed for both groups of subjects, leading to the group’s dissimilarity matrix (Popper and Heymann, 1996).

Task 2: Description: Participants rated each vehicle interior along the N given attributes on a 7-point Likert scale: ‘*excellent*’ to ‘*failure*’.

Processing: An integer value (between 1 and 7) is used to code the 7-point scale. An analysis of variance with the factors ‘nationality’ and ‘vehicle model’ was conducted where the input was the ratings of each vehicle interior along each attribute.

In addition, the same data were subjected to a PCA after computing the correlation coefficient (Pearson) between each subject and selecting a panel of subjects homogeneous enough in their ratings. The data of this panel were used to compute the average attribute scores.

Task 3: Description: Participants provided their overall preference ranking of the vehicle interiors.

Processing: Preference mappings were computed to model the rankings of vehicle interiors and to find the correlation between the preference ranking and the attribute ratings.

4 Results and discussion

4.1 Cluster analysis of the attributes

With the dissimilarity matrices of each group of subjects (American and French) as input, a cluster analysis was carried out to define groups of similar attributes. A hierarchical ascendant classification was performed, using the Euclidian distance and the furthest-neighbour method as the linkage rule. This provides a dendrogram, a 'tree-like' diagram that summaries the process of clustering, in which the distance along the tree (horizontally) from one element to the next represents the relative degree of similarity (linking distance). The dendrograms are given in Figure 1 (American subjects) and Figure 2 (French subjects).

Figure 1 Dendrogram of the attributes (American subjects)

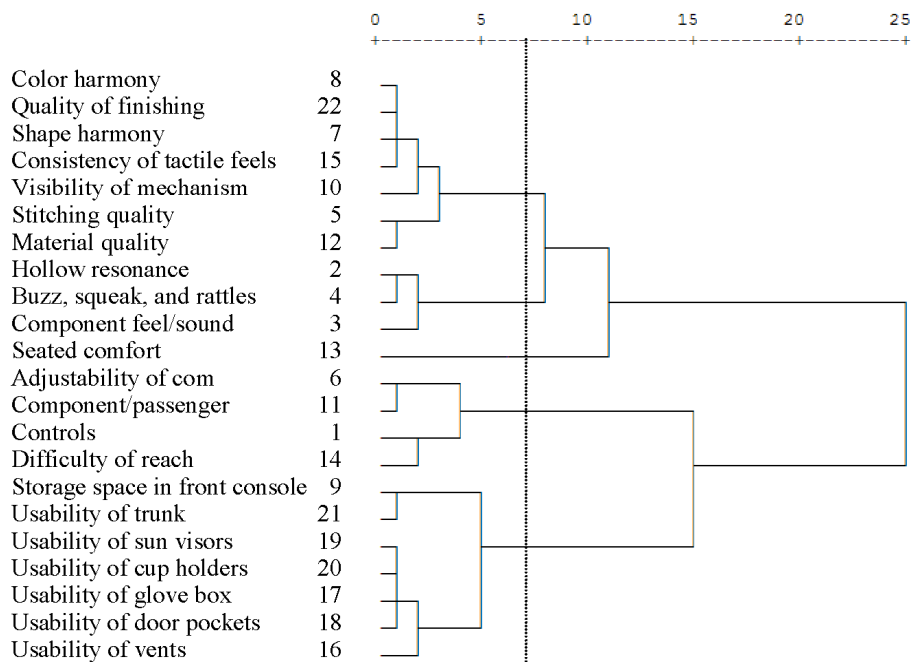
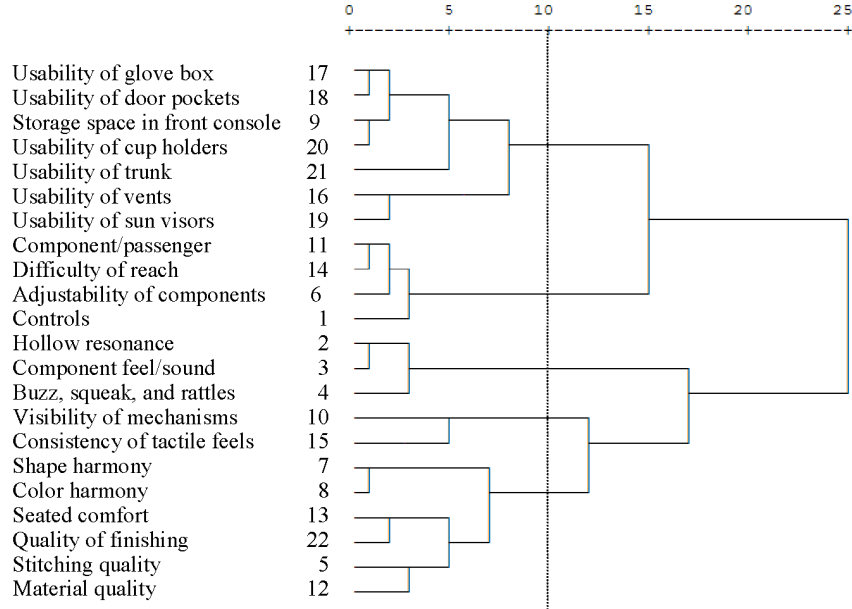


Figure 2 Dendrogram of the attributes (French subjects)

Five clusters of attributes can be identified for both dendrograms. The composition of clusters 1–4, given in Table 3, is very similar for both groups of subjects. Only subtle differences appear in clusters 4 and 5. By examining the semantics of the attributes, the clusters 1 to 4 are identified as ‘usability’, ‘adaptation to the driver’, ‘auditory attributes’ and ‘overall quality’. These clusters represent the main dimensions of craftsmanship perceived by subjects.

The agreement between both groups of subjects is good; they perceive the attributes in approximately the same way. The primary differences appear in attributes f10 (visibility of mechanical elements and manufacturing distortions), f13 (seated comfort) and f15 (consistency of tactile feel). The formulation of attribute f10 may not be clear enough for the subjects. It aggregates two aspects that could be separated (the visibility of mechanical elements and the visibility of manufacturing distortions). Similarly, the formulation of attribute f15 could be improved to define more precisely what has to be evaluated. Attribute f13 (seated comfort) is considered by American subjects as independent of the other attributes, while French subjects associate it with the overall quality.

In conclusion, there is good agreement between the two groups of subjects in their perception of the attributes. Nationality does not appear to affect the group-level perception of similarities between attributes, as indexed by the summed dissimilarity matrices.

Table 3 Composition of the clusters

| | <i>French subjects</i> | <i>Common</i> | <i>American subjects</i> |
|---------------------------------------|--|--|--|
| Cluster 1 Usability | | Storage space in front console Usability of vents Usability of glove box Usability of door pockets Usability of sun visors Usability of cup holders Usability of trunk | |
| Cluster 2 Adaptation to the driver | | Ability to easily discern where all controls are located Adjustability of components Component/passenger interference Difficulty reaching controls, lights and seatbelts | |
| Cluster 3 Auditory attributes | | Hollow resonance Component feel/sound of activation/engagement (Seatbelts, doors, buttons) Buzz, squeak, and rattle (BSR) | |
| Cluster 4 Overall quality | f13. Seated comfort | Stitching quality Shape harmony Colour harmony Material quality Quality of finishing | f10. Visibility of mechanical elements and manufacturing distortions f15. Consistency of tactile feel |
| Cluster 5 | f10. Visibility of mechanical elements and manufacturing distortions f15. Consistency of tactile feel | | f13. Seated comfort |

4.2 Weighted MDS study (individual differences) of the attributes

MDS is a method that represents perceived dissimilarities among pairs of stimuli as distances between points of a low dimensional space. Each point in the output configuration corresponds to one of the given objects. The larger the dissimilarity between the two objects, the further apart they would be in the spatial configuration. Useful insights generally result from examining the arrangement of points to uncover the dimensions that underlie judgements of dissimilarity. The dimensions that emerge from

such an MDS analysis can be interpreted as the perceptual dimensions that characterise craftsmanship. The main advantage of this method is that the tests are based on subjective dissimilarity assessments, which do not set any criteria or predefined semantic scale. An application of MDS for the study of product semantic is presented in Lin et al. (1996). In our study, the stimuli are the craftsmanship attributes, and MDS was used to reveal how the attributes are perceived by the subjects. A similar approach can be found in Trochim (1989) where MDS is used as a concept mapping process.

The Weighted Multi-Dimensional Scaling (WMDS), an extension of MDS that allows individual differences in the similarity judgement process (Caroll and Chang, 1970), has been used in this study. In this method, the subjects are presumed to assign different importance weights to the dimensions and all subjects have a common spatial representation. The principle underlying WMDS is similar to the classical MDS, except that the Euclidian distances between stimuli are weighted:

$$\delta_{ijs} = \left[\sum_k w_{ks}^2 (x_{ik} - x_{jk})^2 \right]^{1/2} \quad (1)$$

where

δ_{ijs} : Proximity measure about stimulus pair (i, j) for subject s

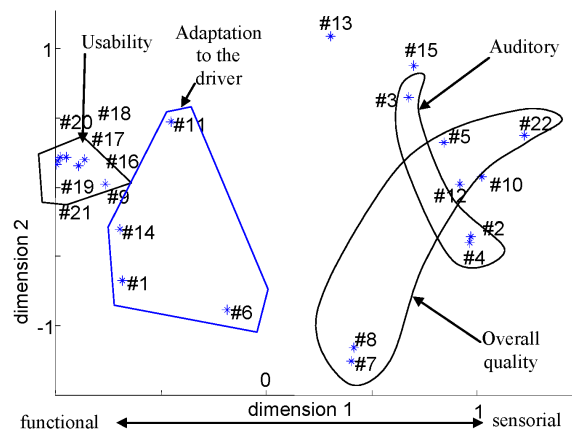
w_{ks} : Weight for subject s along dimension k

x_{ik} : Coordinate of stimulus i along dimension k .

With the individual-level dissimilarity matrices of all subjects as input, a WMDS analysis was conducted to compare the importance weights of the French and the American subjects. The method provides, as output, the coordinates of the attributes in a k -dimensional space (the group space) and the weights assigned by each subject to each dimension. The attributes are represented in a common space (the group space) and the weights represent the subject and indicate the importance he or she gives to the dimensions of the group space.

Figure 3 presents the locations of the attributes in a 2-dimensional space (average stress = 0.096). To facilitate the interpretation of the dimensions, the results of the clustering analysis are superimposed on the solution of the WMDS.

Figure 3 Position of the attributes in the 2D group space (see online version for colours)

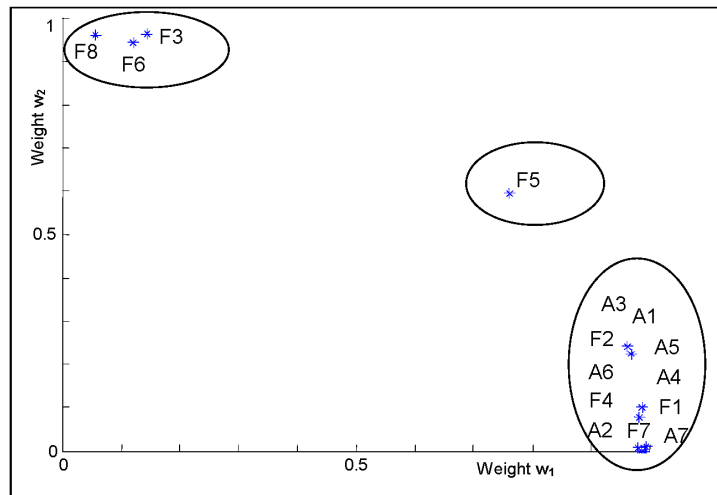


Dimension 1 can be interpreted as a dimension that opposes the 'functional level' to the 'sensory level'. Attributes on the left do not require sensory perception of the user (more or less functional); attributes on the right involve the human senses (visual and auditory) directly. No immediate interpretation of dimension 2 was possible without further exploration.

Figure 4 shows the weights assigned to the two dimensions by each of the subjects. Three groups of subjects can be identified in Figure 4:

- the group that gives more importance to the first dimension. It includes all American subjects (A1–A7) and four French subjects (F1, F2, F4, F7)
- the group that gives more importance to the second dimension (subjects F3, F6, F8)
- the subject (F5) who uses the two dimensions equally.

Figure 4 Weights of the subjects on dimension 1 and 2 of the group space (see online version for colours)



The WMDS analysis shows that American subjects (A1–A7) are homogeneous in their evaluation of the dissimilarity between attributes. They used, mainly, dimension 1. French subjects, however, used three different sorting strategies. Overall, the majority of the subjects (11/15) used dimension 1 for sorting the attributes.

4.3 Analysis of attributes ratings (task 2)

4.3.1 Analysis of variance

A two-way analysis of variance with interaction was employed to study the effect of the vehicle model and the nationality on the attribute ratings. The F -value was compared to the threshold value of the Fisher-Snedecor table with P -value = 0.05 (for the 'nationality' factor, $F_{5\%(1;13)} = 4.66$ – for the 'vehicle model' factor, $F_{5\%(7;91)} = 2.11$ – for the interaction, $F_{5\%(7;91)} = 2.11$). The decision rule is: if F -value $>$ $F_{5\%}$, then the factor has a significant influence on the rating. Table 4 presents the results of the variance analysis for each attribute.

Table 4 Analysis of variance table for the two factors ‘nationality’, ‘vehicle model’ and interaction

| | f_1 | f_2 | f_3 | f_4 | f_5 | f_6 | f_7 | f_8 | f_9 | f_{10} | f_{11} |
|-------------------------------|------------|------------|------------|----------|------------|------------|------------|------------|------------|------------|------------|
| Nationality <i>F</i> -value | 0.09 | 3.10 | 0.38 | 1.43 | 1.13 | 0.02 | 0.65 | 1.25 | 0.02 | 0.21 | 0.14 |
| Significant 5% | No | No | No | No | No | No | No | No | No | No | No |
| Vehicle model <i>F</i> -value | 0.32 | 4.43 | 2.37 | 1.32 | 2.70 | 6.06 | 10.2 | 4.87 | 7.63 | 1.22 | 5.77 |
| Significant 5% | No | <i>Yes</i> | <i>Yes</i> | No | <i>Yes</i> | <i>Yes</i> | <i>Yes</i> | <i>Yes</i> | <i>Yes</i> | No | <i>Yes</i> |
| Interaction <i>F</i> -value | 1.11 | 0.86 | 0.87 | 0.98 | 1.03 | 1.83 | 0.87 | 0.77 | 1.08 | 0.89 | 1.32 |
| Significant 5% | No | No | No | No | No | No | No | No | No | No | No |
| | f_{12} | f_{13} | f_{14} | f_{15} | f_{16} | f_{17} | f_{18} | f_{19} | f_{20} | f_{21} | f_{22} |
| Nationality <i>F</i> -value | 0.01 | 1.89 | 0.64 | 0.19 | 3.05 | 2.11 | 0.00 | 0.27 | 0.03 | 2.13 | 0.50 |
| Significant 5% | No | No | No | No | No | No | No | No | No | No | No |
| Vehicle model <i>F</i> -value | 3.80 | 0.74 | 2.86 | 1.43 | 1.55 | 2.60 | 3.51 | 1.47 | 5.37 | 2.23 | 3.25 |
| Significant 5% | <i>Yes</i> | No | <i>Yes</i> | No | No | <i>Yes</i> | <i>Yes</i> | No | <i>Yes</i> | <i>Yes</i> | <i>Yes</i> |
| Interaction <i>F</i> -value | 0.22 | 1.10 | 1.14 | 1.09 | 2.54 | 2.52 | 0.28 | 0.41 | 1.70 | 2.31 | 1.43 |
| Significant 5% | No | No | No | No | <i>Yes</i> | <i>Yes</i> | No | No | No | <i>Yes</i> | No |

For all the attributes, the ‘nationality’ effect is not significant, suggesting that it is not an influencing variable for craftsmanship assessment. This conclusion conforms to the study results in Nagamachi (1995). Of course, these results are qualified because of the relatively low statistical power due to the small sample size.

The ‘vehicle model’ effect is significant for 15 attributes (f_2 - f_3 - f_5 - f_6 - f_7 - f_8 - f_9 - f_{11} - f_{12} - f_{14} - f_{16} - f_{18} - f_{20} - f_{21} - f_{22}). For these attributes, the ratings of the subjects are globally discriminating, according to the vehicle model. The agreement between subjects is then sufficiently good to reveal differences between the vehicles.

For the other attributes, the difference between vehicles is too weak relative to the subjects’ agreement. Two major reasons can explain this result:

- the interiors were too similar in terms of craftsmanship (the ‘inter class’ variance is too small), or the attributes are too generic to capture differences between vehicles
- the agreement on attribute ratings between subjects is too weak (the ‘intra class’ variance is too large).

To avoid the first problem, definitions of attributes can be provided to the subjects. They can be trained and calibrated on craftsmanship evaluations to avoid the second problem and provide reliable assessments. Indeed, a company that is interested in assessing the perceived quality of its products should train assessors and control the homogeneity of the group of assessors. This step is typical in sensory analysis, where a panel of experts is used as an objective measurement instrument.

The interaction ‘vehicle model \times nationality’ is significant for only 3 attributes (f_{16} - f_{17} - f_{21}): Usability of vents – door pocket – trunk. For these attributes, the impact of the nationality depends on the type of vehicle. In other words, the French and American samples provided different ratings, which depend on the type of vehicle. For the other attributes, the lack of significant interaction effect is an interesting result, because it signifies that the groups of nationality perceive, in a similar way, the difference

between vehicles (at least within the limits of statistical tests given the relatively small sample size).

4.3.2 Homogeneity of the group of subjects

The input of this analysis is the ratings of each subject for each vehicle interior along the 22 attributes (Task 2). In order to explore whether there is a common trend in the ratings, the inter-subject correlation coefficient R_{xy} (Pearson) was computed for each pair of subjects, and for each attribute.

$$R_{k_{xy}} = \frac{\sum_{i=1}^n (xk_i - \bar{x}k) \times (yk_i - \bar{y}k)}{\sqrt{\sum_{i=1}^n (xk_i - \bar{x}k)^2} \sqrt{\sum_{i=1}^n (yk_i - \bar{y}k)^2}} \quad (2)$$

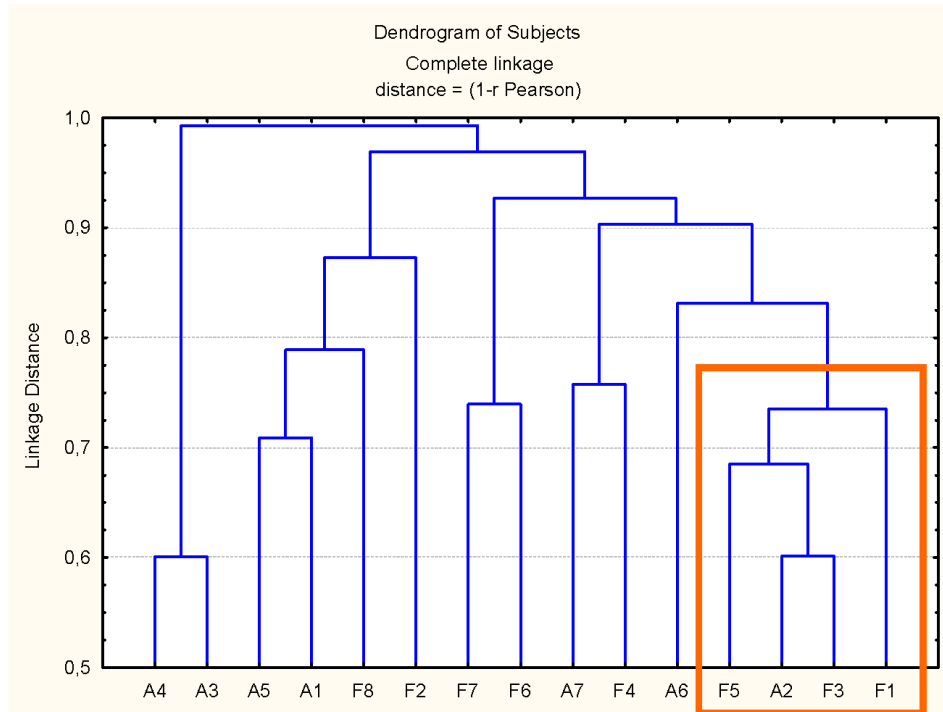
x_{ki} : Rating provided by subject x , for attribute k , for vehicle i

y_{ki} : Rating provided by subject y , for attribute k , for vehicle i .

The average Pearson coefficient R_{xy} between subjects was computed.

A cluster analysis was run on the correlation matrix (all correlations are classically transformed in distance as $1-R_{xy}$) to explore possible patterns in the ratings of the American and the French subjects. The dendrogram of the subjects (Figure 5) shows no trend of nationality difference, i.e., American and French subjects are not clustered into identifiable groups. Each major cluster contains both American and French subjects.

Figure 5 Dendrogram of the subjects. Definition of the panel {F5, A2, F3, F1} (see online version for colours)



One can notice two atypical subjects, A4 and A3, whose evaluations are very different from the rest of the group. The agreement between the subjects is rather poor, the group is heterogeneous; for this reason, the average value of the ratings along all the subjects will not be representative of the group. Therefore, a subgroup of the subjects {F5, A2, F3, F1} was considered as a homogeneous 'panel' of subjects. Analyses on the 11 subjects not in the panel are reported as appropriate. The ratings of these four subjects were used to compute a matrix with a representative set of average ratings for each vehicle interior. The next subsection describes how these data were analysed using the Principle Component Analysis.

4.3.3 PCA study

A standardised Principal Component Analysis (PCA with centred and equal variance data) of the average matrix (vehicles/attributes) of the 'panel' was performed. The eigenvalues of the factors and the corresponding percentages of variance are given Table 5.

Table 5 Factors and corresponding % of variance

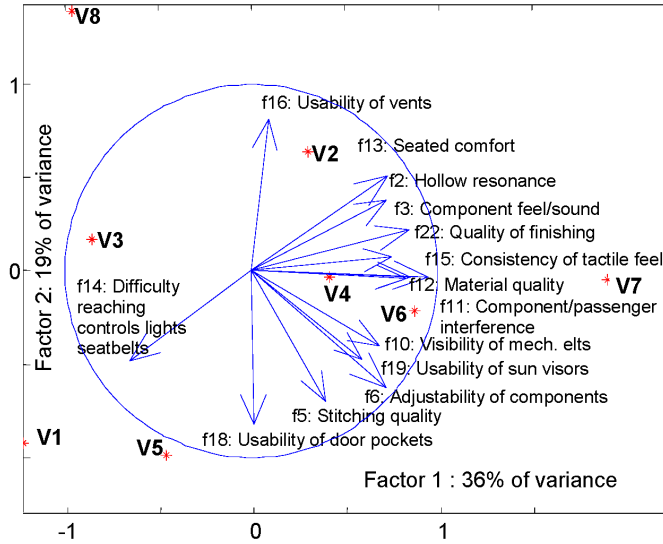
| <i>Factor</i> | <i>Initial eigenvalues</i> | | |
|---------------|----------------------------|---------------------|-----------------------|
| | <i>Total</i> | <i>Variance (%)</i> | <i>Cumulative (%)</i> |
| 1 | 8.02 | 36.47 | 36.47 |
| 2 | 4.23 | 19.25 | 55.72 |
| 3 | 3.38 | 15.37 | 71.09 |
| 4 | 2.11 | 9.61 | 80.7 |
| 5 | 1.90 | 8.83 | 89.53 |
| 6 | 1.35 | 6.13 | 95.66 |
| 7 | 0.94 | 4.30 | 100 |

Six eigenvalues are greater than 1, which means that at least six dimensions are needed to have a good representation of the data (97.66% of the variance explained). The fact that six dimensions are needed means that the perceived quality is multidimensional. The fact that the vehicles used for the study were similar (compact cars) and of the same range reinforces this interpretation of high multidimensionality of craftsmanship and independence of the attributes.

Figure 6 is a superimposed representation of the vehicles and the attributes in the plane of the two first factors. For clarity of the figure, only those attributes close to the correlation circle, i.e., attributes well represented in the factorial plane, are plotted.

One must keep in mind that this representation has a relatively poor fit (only 55% of variance explained). In particular, distances between vehicles in the factorial plane correspond to dissimilarities between vehicles, but proximities between vehicles in the factorial space can be artificial (due to the projection) and are difficult to interpret. But visual interpretations are possible and interesting conclusions can be drawn.

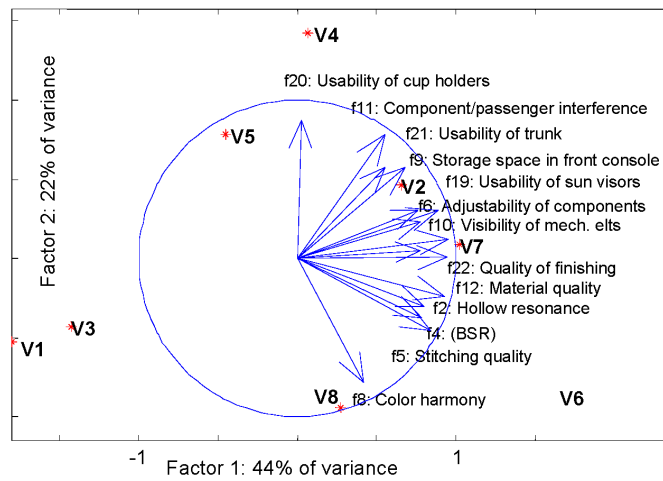
Figure 6 Ratings of the panel: representation of the vehicles and the attributes with PCA in the plane of the two first factors (see online version for colours)



One vehicle, V7 (*Buick Regal*), is very different from the other vehicles on dimension 1. This vehicle V7 is well-rated on the attributes that are highly correlated with dimension 1 (e.g. f22, f15, f12, f11, f10), and vehicle V1 (*Hyundai Elantra*) or V3 (*Ford focus*) are poorly-rated on the same attributes. Along dimension 2, vehicle V8 (*Chevrolet Cavalier*) is very different from the other vehicles. It rated well on attribute f16, but poorly on f5 and f18. In conclusion, two dichotomies in the ratings between vehicle V8/V5 and V7/V1 are revealed by the plane of the two first factors.

To see how the 11 subjects not selected in the panel provide different ratings, a PCA was done on the average ratings of this group of 11 subjects. The plane of the two first factors is represented Figure 7.

Figure 7 Ratings of the remaining subjects: representation of the vehicles and the attributes with PCA in the plane of the two first factors (see online version for colours)



We noticed the same tendency as with the panel: vehicle V1 and V3 are poorly rated on the majority of the attributes, whereas Vehicle V6 and V7 are positively rated. But the opposition between V8 and V5 (panel) is not so clear, and V4 is now particular on dimension 2.

4.4 Interpretation of the preferences (task 3)

The goal of this section is to interpret the preferences of the subjects and to present a methodology that links users' preferences to the craftsmanship assessment. Preference surveys are generally conducted on a large panel of customers (many hundreds) by marketers, and these surveys are used for customer segmentation. The present study illustrates the methodology with 15 subjects and we acknowledge that an analogous study needs to be completed with a larger group of subjects.

In the survey (task 3), the subjects were asked to rank the vehicles based only on the interior. The scores of the vehicles (score = 8 – rank) given by the subjects are given Table 6.

Table 6 Preference scores of the vehicles for the 15 subjects

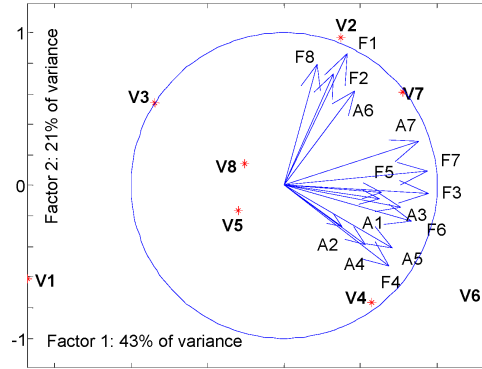
| | <i>F1</i> | <i>F2</i> | <i>F3</i> | <i>F4</i> | <i>F5</i> | <i>F6</i> | <i>F7</i> | <i>F8</i> | <i>A1</i> | <i>A2</i> | <i>A3</i> | <i>A4</i> | <i>A5</i> | <i>A6</i> | <i>A7</i> |
|----|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| V1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 2 | 1 | 1 | 0 | 0 |
| V2 | 7 | 5 | 4 | 3 | 5 | 3 | 6 | 7 | 2 | 7 | 4 | 2 | 0 | 7 | 5 |
| V3 | 5 | 4 | 2 | 0 | 1 | 2 | 1 | 6 | 4 | 0 | 0 | 5 | 2 | 3 | 1 |
| V4 | 2 | 1 | 5 | 6 | 7 | 6 | 4 | 4 | 3 | 5 | 6 | 6 | 5 | 1 | 3 |
| V5 | 1 | 2 | 3 | 4 | 2 | 1 | 3 | 3 | 6 | 2 | 3 | 4 | 3 | 6 | 2 |
| V6 | 3 | 3 | 7 | 7 | 4 | 7 | 7 | 1 | 7 | 6 | 5 | 7 | 7 | 4 | 6 |
| V7 | 6 | 6 | 6 | 2 | 3 | 4 | 5 | 5 | 5 | 1 | 7 | 3 | 6 | 5 | 7 |
| V8 | 4 | 7 | 1 | 5 | 6 | 5 | 2 | 2 | 1 | 3 | 1 | 0 | 4 | 2 | 4 |

4.4.1 Internal preference mapping

In order to represent the differences between the preferences, a standardised PCA is performed on Table 6. This technique is known as internal preference mapping (MDPREF) (Caroll, 1972). The plane of the two first factors is represented Figure 8.

The panel of subjects is homogeneous concerning the preferences (the arrows are roughly in the same direction). Vehicle V1 is strongly rejected, vehicles V6, V7 or V2 are appreciated. Two categories of subjects can be defined: category {F8, F2, F1, A6}, mainly attracted by the vehicles V2 and V7, category {F4, A5, F6, A3, F3, F7, A7}, which prefers vehicle V6. This information would be interesting to segment the market and propose different products to customer. For the other subjects, the quality of their representation in the plane (the norm of their vector) is too weak to draw conclusions. Nationality is not significant in the expression of preference (French and American are mixed in the map).

Figure 8 Internal preference mapping: representation of the vehicles and the subjects. Each subject is represented by an arrow, which is oriented in the direction of increasing preference (see online version for colours)



4.4.2 External preference mapping

The objective is to determine whether the preferences of the subjects (F5, A2, F3, F1) are correlated with their craftsmanship assessments.

A linear model (PREFMAP vector model) (Tanoue et al., 1997) has been used to interpret the preferences. The principle of external preference mapping is to fit a multiple regression model using the factorial coordinates of the vehicles (PCA – Figure 6) as independent variables and the preference scores given by the subject (Table 6) as the dependent variable.

For each subject i , the model of preference is given by the regression equation:

$$P_i = \alpha F_1 + \beta F_2 + \gamma + \varepsilon_i \tag{3}$$

where

P_i is the preference of a vehicle, given by subject i

F_1 is the coordinate of the vehicle, along factor 1

F_2 is the coordinate of the vehicle, along factor 2

ε_i is the residual, minimised by the least square method.

The outputs of the method are the determination coefficient r^2 of the regression and the direction cosines (rescaled regression coefficients α and β). The vector model of each subject can then be plotted in the factorial plane. The origin of the vector is located at the origin of the frame, the values of the direction cosines give the orientation of the arrow, the arrowhead points in the direction of increasing preference, and the norm of the vector is proportional to the determination coefficient r^2 .

The determination coefficients of the regression performed for each subject are given in Table 7.

Table 7 Determination coefficients of the linear regression for each subject

| | $F1$ | $F3$ | $F5$ | $A2$ |
|-------|------|------|------|------|
| r^2 | 0.66 | 0.84 | 0.52 | 0.03 |

Three categories of subjects can be identified:

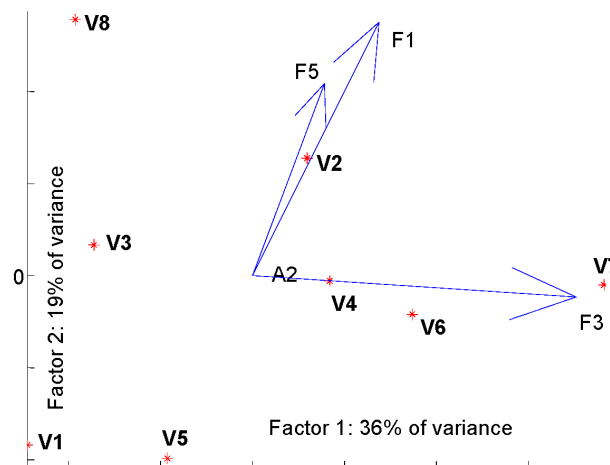
- Subjects for which the linear model gives a good interpretation of their preferences $\{F1, F3\}$ ($r^2 > 0.55$). The vector model of these subjects can be plotted in the factorial space (Figure 9).
- Subjects for which the linear model gives a bad interpretation of their preferences $\{F5\}$ ($0.55 > r^2 > 0.15$). The vectors model of this subject is plotted for information in the factorial space (Figure 9).
- Subjects for which the linear regression cannot give an interpretation of their preferences $\{A2\}$ ($r^2 < 0.14$). The vectors model of these subjects is not plotted in the factorial space.

For the last two categories of subjects, several explanations can be drawn:

- The 22 attributes may not be sufficient to explain subjects' preferences. Subjects have based their preference judgements on attributes other than those provided in the list. It is also possible that they did not base their evaluation only on the interior (the brand image can have unconscious effects).
- The subjects were not able to express their preference (or expressed a random preference).
- The linear model used (vector model) may be too simple, and a more complex model (e.g., quadratic model) can be used instead.

On the other hand, for the first category of subjects, the study of the correlation between preferences and the attribute ratings can reveal interesting information for designers and manufacturers. Attributes that point in the same direction as preferences may be interpreted as important for the user, and the effort to improve the design should be concentrated mainly on these attributes. For example, for subject F3, attributes f11, f12, f15, f22 are collinear to his vector model, which means that under this model the participant's preferences are driven primarily by those four attributes.

Figure 9 External preference mapping; representation of vectors model of the subjects in the factorial space (ratings of the panel) (see online version for colours)



5 Conclusions

This research demonstrated a comparative cross-cultural study of craftsmanship assessment for vehicle interior design and proposed a methodology to interpret consumer preferences.

An experimental study was conducted with a set of 15 subjects (French and American) and a set of eight vehicles. A list of 22 craftsmanship attributes with 7-point rating scales were used for evaluation.

The first main finding was that the nationality of the subjects had little influence on the perception of attributes. Although the perception of French subjects is more heterogeneous (WMDS), there is a good deal of agreement between the two nationalities on their perception of the attributes. Four clusters of attributes were identified for both groups of subjects. Of course, it can be argued that a limitation of the study is that there were only eight French and seven American subjects. Perhaps with more participants the statistical power would be greater to detect small differences. Further, a feature of the subject recruitment is that all were male mechanical engineering students (justified under the rationale of noise reduction) so this may have contributed to the relatively high degree of similarity. We make no claims about the generalisability of these findings to the French and American populations in general.

Next, it was noticed that the nationality of the subjects has no influence on their craftsmanship assessment, and that the effect of the vehicle model is significant for only a few attributes. For many attributes, the assessment task may not be intuitive enough to be done without training. When the subjects are not trained, the inter-subject variance is significant, and assessments in such cases cannot be reliable. In a company, assessments need to be made by experts who are trained for the purpose, and have the same characteristics as a measurement instruments (repeatability, reproducibility, calibration, sensibility).

Finally, a methodology based on preference mapping techniques was described to uncover the link between users' preference rankings and attribute ratings. It was noticed that the nationality of the subjects has no influence on their preference.

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Note

¹Because the French subjects were not perfectly bilingual, the survey's questions were translated and both questionnaires (French and English versions) were given to them. The assumption here is that this translation does not affect the results.