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EASY AND FLEXIBLE SPECIFICATIONS AND PRODUCT EVALUATIONS BY EXPERT AND CUSTOMER COMPARISONS WITH EXISTING PRODUCTS

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ABSTRACT

As soon as the products to design must not only deliver pure services but have also to exhibit esteem or subjective functions such as aesthetics, style, cultural values and ergonomic considerations, both individual and group product evaluations as well as product specification are problematic. Indeed, for both design tasks, designers must qualify the expected properties of a product and find relevant measurement scales to quantify them. In this paper, we propose a design method named COMPARE for understanding the perception of existing products (before starting the creation process), for defining the specifications for a new product and, finally, for evaluating the emerging design concepts under the expected properties (perceptual attributes). The originality of this method is to be based on elementary and qualitative Pairwise Comparisons of products under given perceptual attributes (and also further Principal Component Analysis). It results in two fundamental properties of user-friendliness for the designer and easiness for automatically generate measurement scales under perceptual attributes. The COMPARE method has been experimented on the analysis and the design of automotive dashboards.

Keywords: Decision-making, specification aiding tool, product evaluation, decision-based design, pairwise comparison, AHP, COMPARE

1 INTRODUCTION

Many methods are committed in the design stages of specification and evaluation, two design tasks that are necessarily narrowly linked. Let us mention some important methods classified from their origin:

- **design methods**: QFD [1], axiomatic design [2], Pugh matrices [3].
- **multi-criteria decision-making (MCDM) methods**: Analytic Hierarchy Process – AHP **-** [4, 5], Promethee [6, 7] and pairwise comparisons – PC – techniques which are the core mechanisms within the two above-mentioned methods.
- **sensorial/perceptual design methods**: Semantic Differential Method – SDM – [8], Multi-Dimensional Scaling – MDS – [9].

No method is perfect to bring satisfaction on any of the four following important issues encountered when specifying and assessing products:

- How to name the expected or perceived properties of a product? This is the semantic issue.
- How to quantitatively assess a product under a semantic attribute without defining any precise measurement scale?
- How to aggregate the variability of individual assessments into a specification or a product evaluation?
- Which mix between experts and customers in the evaluation protocol?

We have tried to answer these four issues with a new method called COMPARE that provides an easy and flexible way to specify (a new product target) and evaluate candidate designs.

The proposed method COMPARE is an adaptation of AHP [4], uses an inner original Pairwise Comparison method [10-12], takes some elements from Promethee (the preference functions), and results in the same profile vectors (of products under the set of criteria/attributes) than MDS but in a much more accurate and flexible manner. Moreover, it considers two types of evaluation sessions as recommended in perceptual design: one is an expert evaluation, the second is a customer evaluation. In addition, COMPARE uses the factorial analysis method. The COMPARE method has been experimented for the first time by Petiot and Yannou in [13] on table glasses. For this paper, we have applied it on 10 automotive dashboards of a same car segment.

The second section presents the whole protocol for collecting data and locating the tasks of specification of a new product and evaluation of product solutions within the design process. The expert workshop context is presented in section 3. Section 4 explains an original process for resulting in a collection of 15 relevant semantic attributes (or decision criteria) for dashboards. The design of the expert workshop is presented in section 5. In section 6, three successive assessment methods are applied and those collected data are successively processed, they are: Multi-Dimensional Scaling [8], Semantic Differential Method [9] and our Pairwise Comparisons method (see [10, 11]). For this latter method, experts are asked to pairwise compare the 10 existing dashboards of a given car segment in a non-hedonistic way, meaning they do not have to provide their personal subjective viewpoint but to neutrally locate properties on scales defined by antonyms words (like feminine-masculine). The principles of the PC method are briefly explained (see [10-12]) to the detriment of the suggested protocol for filling the comparison matrices (each expert must partially fill 15 10x10 matrices). The evaluation protocol consists within a whole day to show adapted pictures (depending of the considered semantic attribute) of dashboards to experts in a given order. Once the data collected, digital treatments are made to consider if there is one or several behavioural clusters. Next a factorial regression allows to graphically represent the products and the semantic attributes as well on a factorial plan to figure out the correlations between attributes and perceived proximity of dashboards.

Section 7 explains the specification task. Two convenient solutions are proposed to generate a specification or target vector (on the 15 attribute scales) within a customer evaluation session. The first is a classical one in a marketing department, it consists in defining a point that is graphically satisfactory in terms of relative location with other existing products and/or of levels on attribute scales. The aforementioned factorial analysis allows then to compute the target vector. The second method is original. It consists in specifying relative pairwise comparisons with existing products letting each customer choosing the compared products and the semantic attributes he/she feels the more inspired to do with. After a PC re-computation, the target vector is automatically generated. Here, a clear property of COMPARE appears since there is no need to define specific and complicated scales for the semantic attributes ; they are automatically generated through the PC mechanism. This property is well explained in the paper. Some additional information is added to complete the specification sheet: preference functions to figure out how much the dissatisfaction to be more or less close to the target is, and a weight vector to express the relative importances of semantic attributes in the new product.

Section 8 concerns the evaluation task to evaluate the proposed product concepts regarding the defined specification. It is made within a third evaluation session with experts. Again, we use with COMPARE the flexible mechanism of comparing the product concepts to any existing product under any semantic attribute (at least one product under one attribute, but it is not limited). After a PC re-computation, we come up with a score matrix that we transform into a dissatisfaction matrix (making differences with the target vector). Then, we use the AHP theory to roughly make a weighted average and come up with a final rank of existing and new products. Then the designer has just to check that its proposal is ranked first. He/she can also check which semantic property would be worthy to redesign on.

We conclude in section 9 by summarizing the formal and practical properties and advantages of our COMPARE method.

2 FRAMEWORK OF THE COMPARE METHOD

Figure 1 presents the whole framework of the COMPARE method. Three different workshops must be considered at different moments. The first workshop is an experts workshop, its objective is to collect a large perceptual information on a set of similar existing products (within the same segment than the one we intend to design). After perceptual evaluations and processing of these data, a database has been built which is ready for the two next stages of *specification generation* and *concept evaluation*. But if the specification generation stage is performed by a users panel, this is again an experts panel which performs the concepts evaluations since the experts are accustomed to the perceptual dimensions they have provided in the first stage (see also [14]). The main originality of COMPARE lies in the fact that both specification and concept evaluation stages are performed through qualitative comparisons with existing products in a very meaningful way for experts and/or customers.

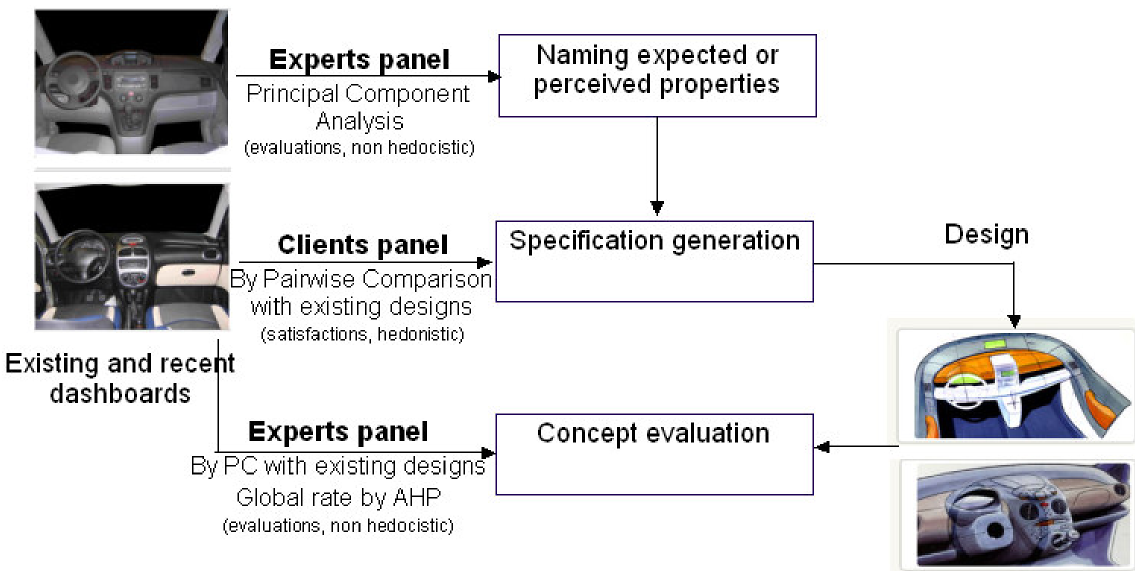


Figure 1: COMPARE framework for collecting data and locating the tasks of specification of a new product and evaluation of candidate designs within the design process

3 SETTING THE EVALUATION CONTEXT

A set of 11 automotive experts (of sales departments) have been gathered for a whole day of evaluation of 10 dashboards of recent cars belonging to the same marketing segment (of small cars), namely: (1) Audi A2, (2) Citroën C2, (3) Fiat Idea, (4) Lancia Ypsilon, (5) Nissan Micra, (6) Peugeot 206, (7) Renault Clio, (8) Renault Modus, (9) Toyota Yaris, (10) Volkswagen Polo. The 11 subjects have been immerged in a decision context. They have been described a target user profile (with 5 filing cards like the one in Figure 2-left) and a purchasing situation (see Figure 2-right). During this workshop, the 11 subjects are asked to assess dashboard pictures without actually seeing or touching these dashboards. We are conscious that there is a bias but it is also a way to isolate the dashboards since the car brands are not displayed and they are even removed from the pictures (see Figure 3).

Figure 2: The decision context is defined by target user profiles and a purchasing situation. Both graphical panels have been presented to the subjects.

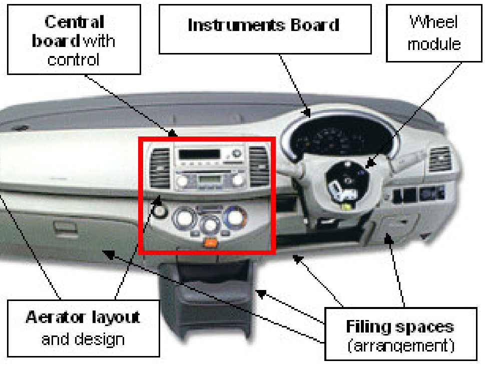
Figure 3: The 10 dashboards

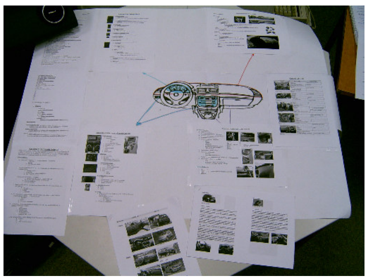
4 DETERMINATION PROCESS OF THE SEMANTIC ATTRIBUTES

The process to determine the determining perceptual attributes, in a semantic form, has been quite original. It is the result of two concurrent processes:

- A deductive process starting from a functional analysis of a dashboard and a geometrical description of a typical dashboard structure. Several dozens of service functions exist with expected performances. After a converging process, we came up with only 5 determining semantic attributes: *Understandability* of instruments board, Satisfactory *Space organization*, Control button *comprehensibility* (intuitive understanding of the central board), *Aerator layout* (pleasant design style), Satisfactory *arrangement* (or filing) *space* (for maps, glasses, coins, mobiles, cans).
- An inductive process starting from a synthesis of commercial brochures to make appearing the most striking, relevant and frequent adjectives used. Again, a converging process has allowed to result in a subset of 10 semantic attributes: *Comfort, Simplicity, Sportiveness, Masculinity, (perceived) Quality, Novelty, (design) Harmony, Modernity, Intelligence, Charming*.

DEDUCTIVE PROCESS





5 Semantic Attributes
Understandability of insruments board
Satisfactory **Space organization**
Control button comprehensibility (intuitive understanding of the central board)
Aerator layout (pleasant design style)
Satisfactory **arrangement** (or filing) **space** (for maps, glasses, coins, mobiles, cans)

INDUCTIVE PROCESS

Renault Modus
La Petite au Grand Cœur

Silhouette sympathique et **look malicieux**, Renault Modus offre la **modularité** d'un monospace dans un petit gabarit. **Accueillant et chaleureux**, il séduit au premier coup d'œil par sa **large surface vitrée**, qui autorise une **luminosité inégalée** dans sa catégorie.

A bord, le maître mot est **générosité**. **Tout a été conçu pour maximiser le confort intérieur**. L'espace offre de **nombreux rangements astucieux : sur la planche de bord et sous le plancher avant, dans les portes et boîte à gants de 11 litres**. Modus fait preuve d'une grande modularité : il innove sur son segment avec "Triptic", une banquette arrière coulissante qui passe de deux à trois places en un instant.

L'ergonomie et le confort acoustique de Modus en font un véhicule **agréable à conduire en toutes circonstances. A l'aise en ville comme sur route**, il offre une **conduite d'une grande souplesse**, tout en restant **d'un tempérament tonique et spontané.**

Outre une tenue de route irréprochable, Modus **bénéficie des dernières innovations du segment supérieur en matière de sécurité** : ABS, ESP, airbags, phares au xénon double distance, feux additionnels de virage et direction à assistance électrique variable.

10 Semantic Attributes
Comfort
Simplicity
Sportiveness
Masculinity
(perceived) **Quality**
Novelty
(design) **Harmony**
Modernité
Intelligence
Charming

Figure 4: The two concurrent processes to determine the perceptual/semantic attributes of dashboards

5 DESIGNING THE WORKSHOP

The 11 subjects were in a room where they had to proceed to three series of exercises:

- a MDS (Multi-Dimensional Scaling) exercise (about 20 minutes),
- a SDM (Semantic Differential Method) exercise (about 1 hour and 30 minutes),
- a PC (Pairwise Comparisons) exercice (about 2 hours and 30 minutes).

It was quite a hard task, but we will se that it has not be to made each time a new design is proposed. The 11 subjects were facing a wall on which two projectors were projecting dashboard pictures (see Figure 5). These pictures have been carefully prepared to be perfectly adapted to each step of the three evaluation exercises (see for instance Figures 6 and 7). The reader can find the details of the workshop in [15].

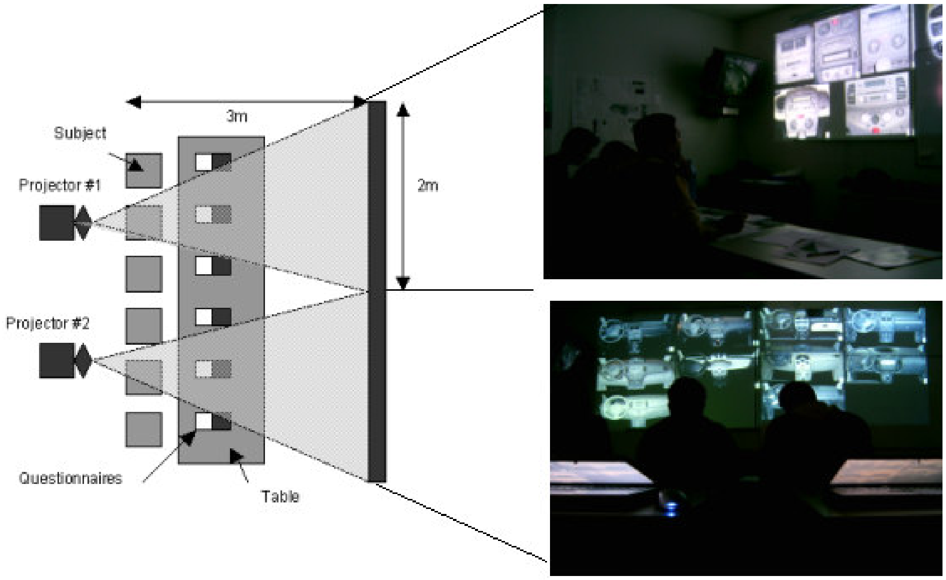


Figure 5: The geometrical configuration of the evaluation workshop

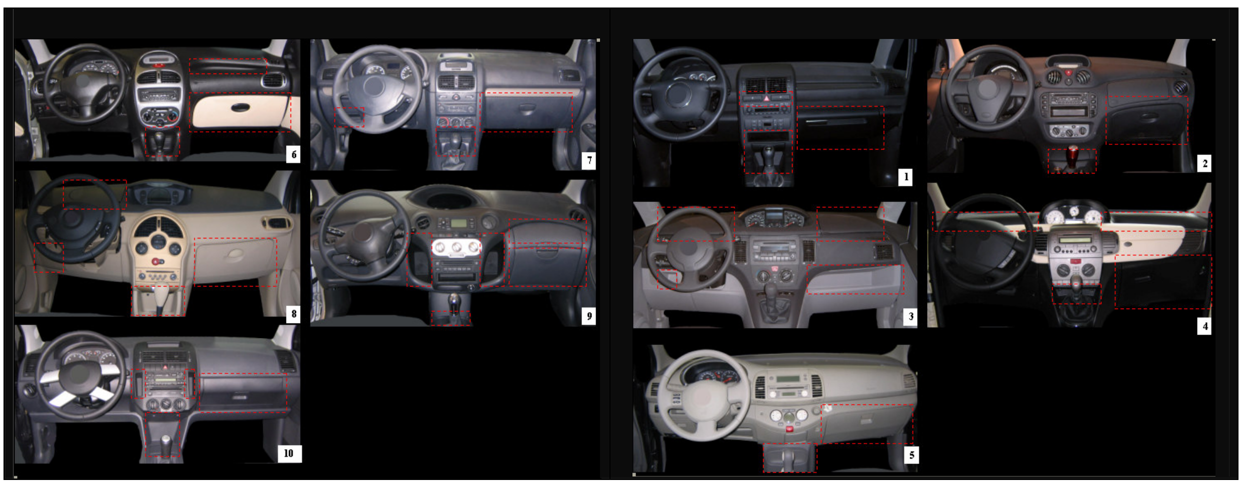


Figure 6: Pictures of dashboards for Pairwise Comparisons under the "Arrangement space" attribute

Figure 7: Pictures of dashboards for Pairwise Comparisons under the "Control button comprehensibility" attribute

6 THE THREE PERCEPTUAL DATA ANALYSIS

6.1 Multi-Dimensional Scaling

The Multi-Dimensional Scaling [8] has consisted in asking the subjects to group apparently similar dashboards together. Some explanations could also be provided. Table 1 is an example of such a qualitative clustering.

Table 1 : Example of a MDS evaluation

group #	Dashboard numbers	Keywords
1	*4, 6*	*Mix of colours*
2	*1, 7, 10*	*Few oval shapes*
3	*5, 8*	*Simple and nice*
4	*2, 3, 9*	*Central part too heavy*
5		

A factorial analysis (PCA: Principal Component Analysis) is performed and the dashboards are represented along the two first factorial axes (see Figure 8). The closer two dashbaords, the more likely they had to be grouped together by a subject. It is clear in Figure 8 that two groups of dashboards appear:

- On the left, 4 dashboards: *Renault Modus*, *Lancia Ypsilon*, *Fiat Idea* and *Toyota Yaris* all have their instrument board located in the middle of the dashboard.
- On the right, 4 dashboards: Audi A2, VW Polo, Renault Clio and Peugeot 206 all have a central board which has been assessed larger and more squared than for other dashboards.

These results reveal that the location of the instrument board and the shape of the central board are probably the most determining features which influence the customers perceptions.

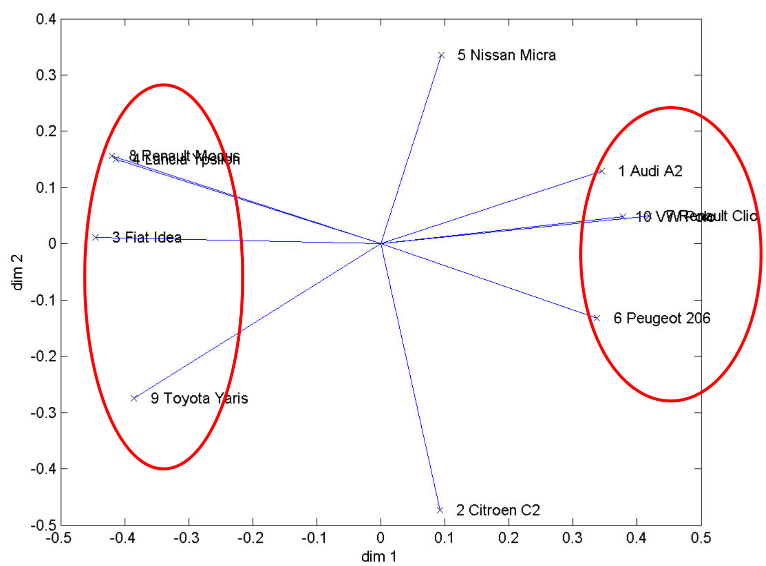


Figure 8: A Principal Component Analysis of the MDS data

6.2 Semantic Differential Method

The SDM method [9] is often used in product design. In [16], the authors show that designers and users have different perceptions of the form of a product. In [17], the authors even study the perceptual evaluation of car interiors, a similar study of ours but in a different objective. The 11 subjects are asked to successively fill semantic profiles for a given dashboard, a dashboard being rated under the

15 semantic attributes via a 7-levels Likert scale. For that, the 15 semantic attributes of Figure 4 have been expressed in pairs of antonymous adjectives (see Figure 9).

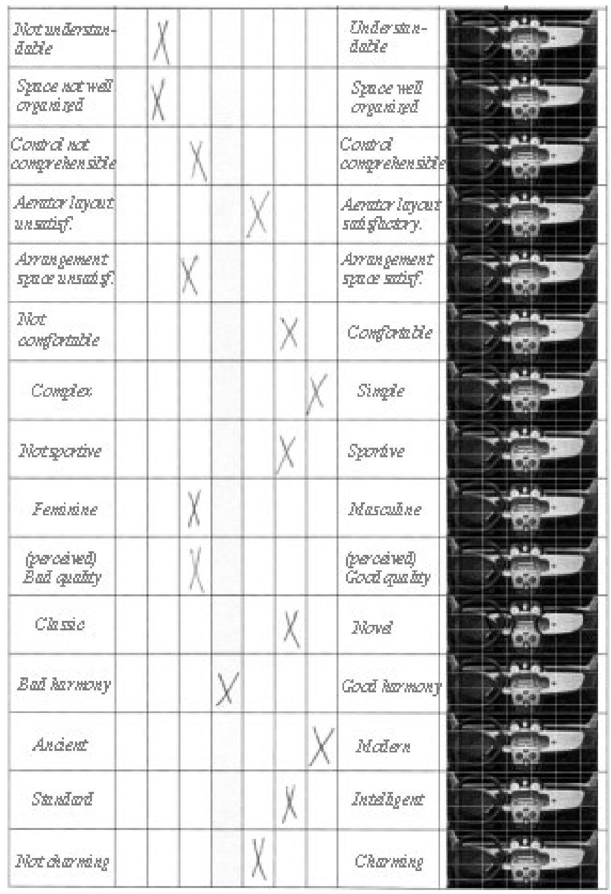
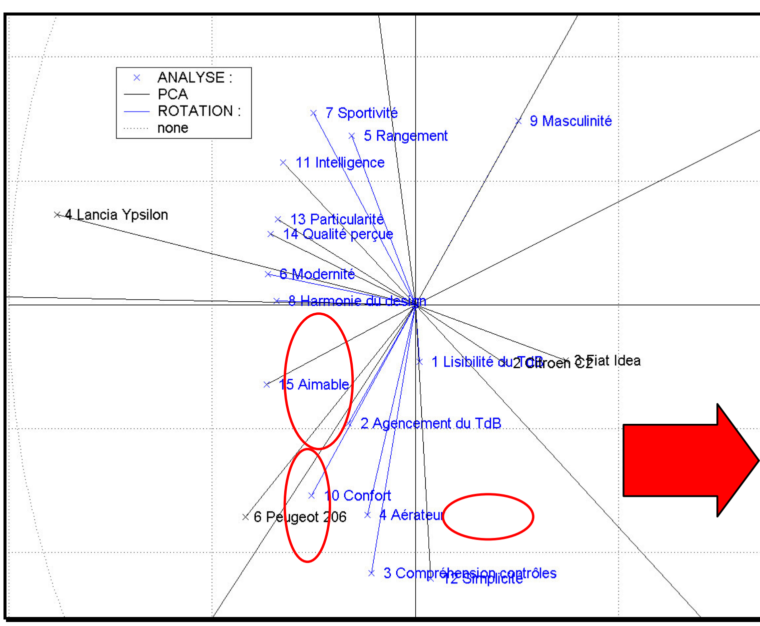


Figure 9: Example of a semantic profile (SDM) for dashboard #4



Harmony	**Harmony**
Charming	
Modernity	**Novelty**
Intelligence	
Novelty	
Understandability	—

Figure 10: A Principal Component Analysis of the SDM data. 4 attributes may be eliminated.

Again, a factorial analysis (PCA: Principal Component Analysis) is performed (see Figure 10) and the dashboards, as well as the semantic attributes directions are represented along the two first factorial axes. It allows to somewhat lower the number of necessary attributes for describing the problem from 15 to 11 attributes. Indeed:

- As soon as two semantic attributes which are almost synonymous are proved to be correlated (the attribute vectors in Figure 10 have the same direction), they can be merged. This is the case of (*Harmony*, *Charming*) and (*Modernity*, *Intelligence*, *Novelty*) which are merged into, respectively, *Harmony* and *Novelty*.
- As soon as the attribute vector is small enough, it may be neglected. This is the case of *understandability*.

6.3 Pairwise Comparisons

Here, a semantic profile is not obtained by rating straightforwardly but the 10 dashboard are successively pairwise compared under any of the 11 semantic attributes. The pictures of dashboards projected to the subjects are then adapted to the given semantic attributes to highlight like in Figures 6 and 7 for, respectively, the "*Arrangement space*" attribute and the "*Control button comprehensibility*" attribute.

PC methods are well known methods of Multi-Criteria Decision Analysis. Instead of assessing a particular *score* for the performance of a product on a scale in an absolute manner, the idea is to estimate the relative importance of the scores of some pairs of products (most of the time the scores ratio) under a given criterion. This leads to a pairwise comparison (PC) matrix, which can be processed to extract a realistic normalized vector of scores. Pairwise comparisons are known to be easily administrated because decision makers assessing the products in our case, only focus on a pair of products and on a criterion instead of brutally facing the whole multi-attribute issue. So as not to compel decision makers to fill the overall PC matrix as in the well known eigenvector method of Saaty [5], we have preferred the *Least Squares Logarithmic Regression* (LSLR) PC method proposed by [18] and [19]. Sparse PC matrices are then tolerated, which is preferable for the relative assessment of numerous products (more than eight). We have contributed to extend this LSLR PC method on several interesting aspects: qualitative comparisons can be expressed on a 7-levels Likert scale (see Figure 11: *Much lower*, *Lower*, *Slightly lower*, *Equal*, *Slightly greater*, *Greater*, *Much greater*), uncertainties may be expressed in the form of distributions, a consistency indicator (even parameterizable) may be computed for any comparison matrix and used to improve the decision quality. A detailed description of this PC method can be found in [10, 11, 20].

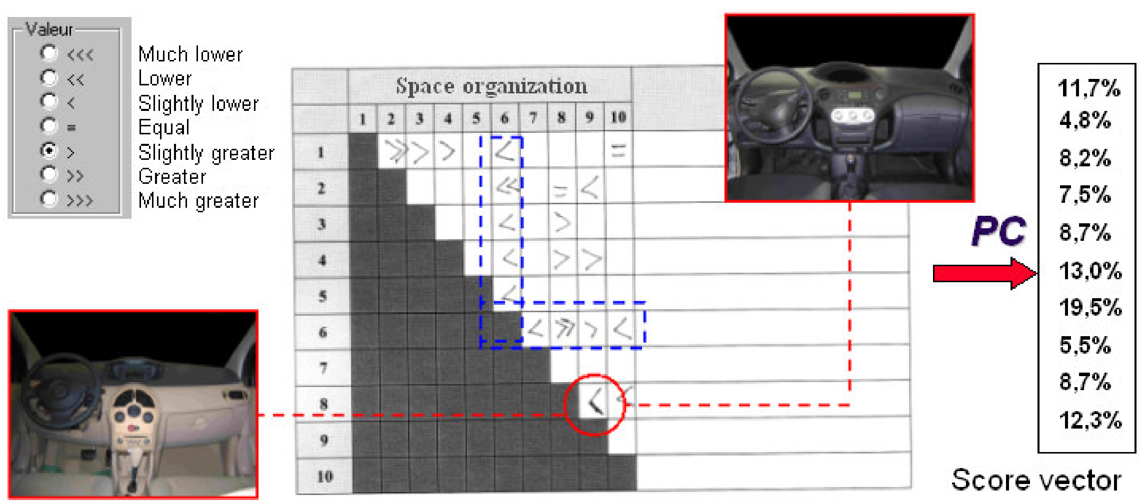


Figure 11: The Pairwise Comparison process

In case of scarce comparison matrices like in Figure 11, one has to pay attention to the fact that the equation system be solved to obtain a score vector. In cases where a dashboard is compared to no-one, the system cannot be solved. This is why we have imposed the experts the following evaluation rules:

- For a given semantic criterion (e.g., *space organization*), choose a *reference dashboard* which is considered as median in term of satisfaction.
- Compare systematically all the other dashboards with the *reference dashboard*. It amounts to entirely fill the row and the column corresponding to the *reference dashboard*.
- Complete the matrix to 20 comparisons (i.e., 11 in addition) at least instead of filling the 45 possible. Of course, the user is supposed to compare the most meaningful comparisons for him/her between easily comparable dashboards.

These rules are easily understood by the experts and they have found it flexible.

On the one side, the data are here in excess. This is why PC methods are known for delivering robust and precise score vectors. On the other side, PC methods automatically build here quantitative scales with no necessity to precisely define them. The PC evaluation stage is then a more sophisticated stage than the SDM stage, but the SDM stage has been useful for lowering the number of semantic attributes before. Again, a factorial analysis (PCA: Principal Component Analysis) is performed (see Figure 12).

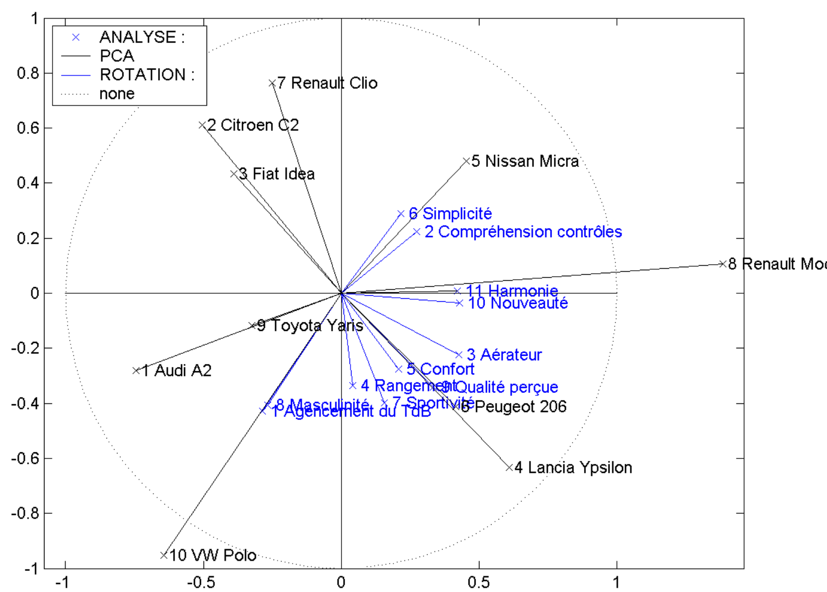


Figure 12: A Principal Component Analysis of the PC data

7 GENERATION OF A SPECIFICATION

At this stage, the lists of 11 score vectors for the 11 subjects constitute a sort of database of the perceptual evaluation of existing products of the same category.

Two solutions may exist to generate a target vector for a new design of dashboard. The first one is well known by those researchers and practitioners who use these SDM and factorial analysis approaches. It consists in locating in the factorial space (see Figure 13) a place that can be interesting to occupy for a product (relatively to other product proximity). The coordinates of a point in the factorial space are sufficient to immediately deliver the target score. But this is not a valuable solution since the target score provided is not very meaningful (the values mean nothing) to the designer to orientate his/her design and to be further used in a concept evaluation.

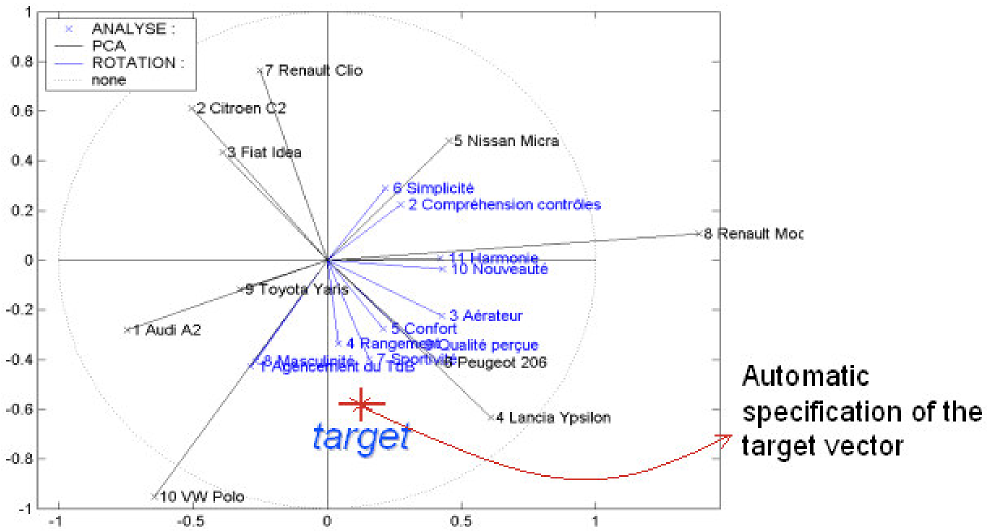


Figure 13: Graphical determination of the target specification

This is why we propose a much convenient solution in the COMPARE method. It simply consists in defining the target by relative and qualitative constraints (or comparisons) with the existing dashboards under the different semantic attributes. For instance in Figure 14, the target dashboard is said to be less organized than dashboard #3 but equally organized than dashboard #9. A PC calculation is then restarted with one row and one column more for the PC matrices (see Figure 14). The target score for the "*space organization*" is obtained and the scores for the other existing dashboards are slightly modified. These modified scores prove that they do not have any profound meaning by themselves, the important and constant data being here the relative constraints of the target with the existing dashboards. Here the specification has been made in interviewing customers.

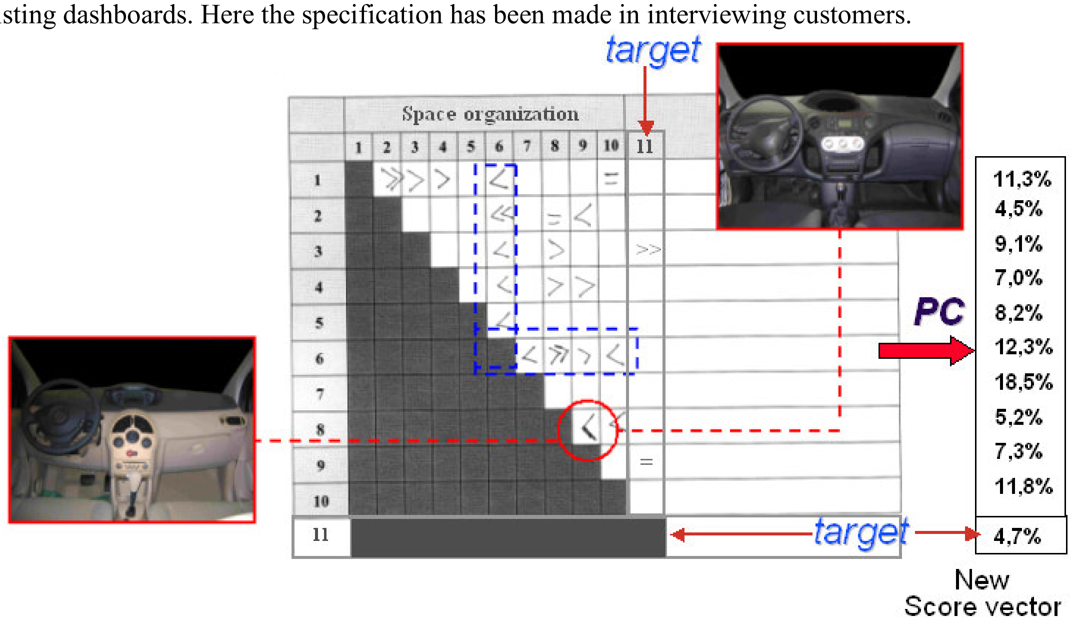


Figure 14: Determination of the target specification by completions of comparison matrices

8 EVALUATION OF NEW DESIGNS

Let us imagine that once the target defined by relative comparisons with existing dashboards, two dashboard candidates be proposed by the designers (see Figure 15). The evaluation of these two candidate designs is made in several stages:

1. The two dashboard candidates are compared with the 10 existing dashboards, like for the target. I.e., two rows and two columns are added for any comparison matrix, leading to 13x13 matrices

(including 10 existing dashboards, the target and the 2 new candidate designs). This is the very core of the COMPARE method.

2. A PC calculation is then restarted to obtain the final scores for the existing dashboards, but also the target and the two dashboard candidates as well.
3. The specifications must be now completed by a preference function (see Figure 16) and corresponding thresholds for each semantic attribute (see Table 2). The preference function $P_i(.)$ of semantic attribute *i* is in charge of calculating a preference value $P_i(T_i, D_{ij})$ (between 0 and 1) function of the target score T_i and the current score value D_{ij} of the candidate design #*j*. These preference functions are classical for outranking methods like PROMETHEE (see [6] for instance).
4. Lastly, the specifications must be completed by a *weight vector* w_i associated to the semantic attributes (see Table 2) because they are more or less important. Naturally, a last pairwise comparison is made between the 11 semantic attributes. This PC is based on customer interviews.
5. An AHP (*Analytical Hierarchy Process*) process is started with the calculation of preference vectors for all the dashboards (existing and candidates). Next, these preferences are normalized under each semantic attribute (i.e., only 1 point is dispatched over the *normalized preferences* of a semantic attribute). These two operations may be summarized by the following formula:

$$\overline{p}_{ij} = P_i(T_i, D_{ij}) / \sum_{j=1}^{N} P_i(T_i, D_{ij}) \qquad (1)$$

6. The final grade attributed to any dashboard *j* (existing and candidate) is given by the following formula:

$$grade(j) = \sum_{i=1}^{R} w_i . \overline{p}_{ij} \qquad (2)$$

R being the number of semantic attributes. A rank is finally established between the existing and candidate dashboards.

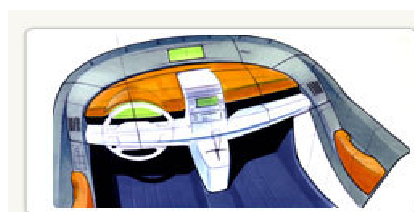


Figure 15: The two dashboard candidates D1 and D2

Table 2: Specification data in COMPARE

Semantic attributes	Target score T_i	Weight w_i	Preference function type	Specification threshold x%	Specification threshold y%
Space organization		12%	1	30%	
Comprehensibility		10%	2		30%
Aerator layout		5%	1	30%	
Arrangement space		15%	3	15%	15%
Comfort		8%	2		30%
Simplicity		6%	1	30%	
Sportiveness		5%	3	15%	15%
Masculinity		4%	2		30%
Quality		11%	2		30%
Novelty		14%	3	15%	15%
Harmony		10%	1	30%	

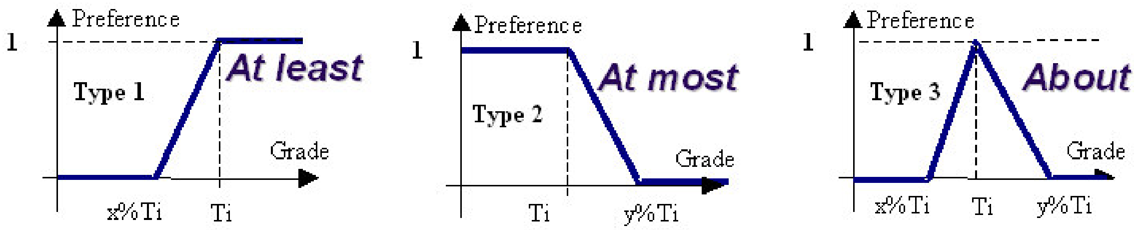


Figure 16: Preference function types in COMPARE

9 CONCLUDING REMARKS

The COMPARE method has been presented for defining a target specification and evaluating new candidate designs by merely comparing in a qualitative manner the designs under each semantic attribute. This method has turned out to be very easy, convenient and flexible to use. It has been proved on a practical example of the perceptual evaluation of 10 car dashboards belonging to the same marketing segment. The COMPARE method relies on a Pairwise Comparison method which has been already validated by the scientific community (see [10, 11, 20]).

The perceptual evaluation process that is thoroughly explained herein has also been used to propose an original method for synthesizing tendencies on design parameters starting from expected levels of semantic attributes (see [21]).

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