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DESIGN CANDIDATE IDENTIFICATION VIA KANSEI-VR & AHP APPROACHES

TOWARD AN INTEGRATED KANSEI ENGINEERING PROCESS

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ABSTRACT

In this work the Authors show the first results of a research activity aiming at the identification of the most appealing design candidate via a new integrated Kansei Engineering process. The target was achieved by means of immersive experiments performed in Virtual Reality (VR) along with an Analytic Hierarchy Process (AHP) performed in a visual desktop environment (PC). Both the approaches aim at the direct involvement of users into the design process, as early as possible.

Focusing on the synthesis phase, once implemented the design candidates by different technical features according to a Fractional Factorial Design, the concepts are evaluated by users. The data collected by asking users to judge them are analyzed via suitable methods to guarantee the above assessment. For this purpose, two different evaluation approaches, although at different stages of the design process, are tested: the first one relies on the user experience with the product in VR whereas the second is allowable for a much cheaper visual pairwise comparison in a PC-based experimental set-up. The original result is that the two approaches can be complementary rather than alternative; here is introduced the way to harmonize them in an integrated Kansei Engineering process, in order to improve and speed-up the synthesis phase.

To describe the two approaches and highlight their peculiarities, an application to the design of railway coach arrangement and furniture (briefly referred to as "train interior") is presented.

Keywords: *Kansei Engineering, Virtual Reality, Design Evaluation, Pairwise comparisons*

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1. INTRODUCTION

The design of industrial products is today strictly connected to the continuous involvement of the user throughout the design process [1]. In this process one of the main target that designers have to hit is the identification of emotional needs of the user [2] to be satisfied by means of technical product features. Understanding user needs in an emotional framework requires two fundamental ingredients: the preliminary knowledge of the latent user needs, which helps designers to avoid unexpected reactions of the user when interacting with the product; the assessment of technical features more straightly addressed to emotional needs, the way that can drive the identification of design elements critical for product innovation [3]. Nevertheless, although there are more than a few practical techniques to measure the effectiveness of technical product features, "it is less clear how to evaluate the more emotional or affective perceptions of a product offering" [4] to the user. For this reason designers need some useful but easy to use methodologies aimed at identifying what better fits the relationship between product features and user's emotions with it, what is called synthesis model in the Kansei Engineering (KE).

Actually, many approaches aim at capturing user emotions in order to identify the optimal design solution in terms of emotional response. In this sense several studies proposed quantitative methods for detecting emotions based on monitoring self-report methods [5] (verbal and non-verbal questionnaires) or alternative techniques, such as facial expression coding systems [6]. Recently, Demir and Desmet [7] proposed an evaluation method based on "appraisal theory" whereas Chitturi [8] demonstrates analytically the difference of emotional experience associated with hedonic benefits and utilitarian benefits.

Nevertheless the variety of approaches, in the view of the synthesis phase these tools lack in objectively linking the relevant but latent emotional needs to the product features. Moreover, since usually the model is not built by the designer himself, a barrier could raise between who performs the analysis and the designer, the person who solely has in charge to embody the results into a better design. Hence, in real world, user research is often inconsistently applied in industry product design. Therefore an actual need for a lean synthesis method and a model representation that designers can clearly understand is recognized. The Authors faced with this problem and here discuss early results from an original approach to the synthesis phase, compared and integrated within a well established framework of KE [3] [9] [10] [11]. Specifically, the evaluation approaches to the synthesis are presented, through outcomes of several experimental activities carried out by means of:

1. one concept at time evaluation questionnaires, which data are elaborated via Ordinal Logistic Regression, administered to users involved in Virtual Reality (VR);
2. concepts' pairwise comparisons performed by user in a desktop environment, accordingly to the Analytic Hierarchy Process (AHP).

The new approach to design candidate identification in the KE based on the adoption of the AHP [12] allows to obtain a vector representation – very easy to be understood and exploited by the designer – of the most appealing design into the space of technical features and the semantic space both. The study is the result of the research activity on Kansei Engineering ongoing at the Department of Aerospace Engineering (DIAS) of the University of Naples Federico II.

2. KANSEI-VR APPROACH

In previous works Authors showed how to improve quality of new products, taking advantage both from the application of KE methodology and participative design techniques in VR; indeed an immersive environment, with its realistic representations, can help designers to elicit user emotions connected to the product interaction process. The study is presented in [9] and [10] with reference to the application of Kansei-VR approach to the interior of a railway coach for regional transport.

The procedure to develop Kansei-VR approach follows these steps:

- spanning of semantic space by the collection of meaningful Kansei words;
- spanning of technical space in order to identify product features;
- synthesis by means of VR experiments and model build via suitable statistical techniques.

Specifically, the last step was performed through the methods described in the above mentioned references and here briefly sketched. Some design elements are identified in order to technically realize the product features, then concepts are generated combining different solutions (levels) of each design element (factor) accordingly to a suitable experimental plan (a Fractional Factorial Design based on orthogonal array). The concepts are evaluated in VR by users who rate them in the view of each Kansei word (by Semantic Differential scales). The collected data, coded accordingly to a Likert scale, are analyzed trough Ordinal Logistic Regression and the results define a model which highlights the stronger relations between Kansei words and design elements. The study was lead by the University of Naples Federico II at the VR laboratory named VRTest of the Competence Center for the Qualification of Transportation Systems founded by the Campania Region (www.dpgi.unina.it/ingind15).

2.1. Kansei Engineering application

The investigation was focused on the grey market constituted by users who systematically use the railway transportation service for medium range trips. Starting from a preliminary analysis on web sites of train user associations, 65 words strongly related to the user experience of the train trip were collected. Then these words were reduced, by means of the Factor Analysis, to just 5 Kansei words: Comfortable, Originality, Mobility, Versatility, Simplicity. Likewise, on the basis of information from specialized institutes and associations interested in railway transportation, was compiled a list of 65 design elements, among which, by means of the use of Affinity Diagram and Pareto Diagram, were identified the 5 most meaningful ones: Closed circuit monitoring system, Recyclability, Supports for standing passengers, Wide spaces, Windows. In order to launch the synthesis phase some simple but meaningful product concepts were generated by combining different arrangement of the previously identified design elements according to a suitable Factorial Design technique based on a supersaturated design [10]. The actual set of different concepts to be examined remained tiny tanks to the adopted factorial design. Then the concepts were evaluated with reference to the selected Kansei words by a group of expert users. The collected data were elaborated through the Ordinal Logistic Regression method, so to identify the meaningful relations between the Kansei words and the design elements. Specifically, Table 1 shows that among all the Kansei words, Comfortable is the most correlated one with the identified design elements, very strongly with Supports for standing passengers.

Table 1: Ordinal Logistic Regression results' summary (the greater the number of crosses the stronger the relation between the feature and the Kansei word)

	Comfortable	Originality	Mobility	Versatility	Simplicity
Closed circuit monitoring system	××				
Recyclability					
Supports for standing passengers	×××				
Wide spaces	××		××		
Windows					

2.2. Evaluation in Virtual Reality

Starting from the above results, the design element Supports for standing passengers was chosen for the successive detailed synthesis phase. Supports for standing passengers includes handrails, handles and perches, i.e. the supports assigned to those who stand inside of the coach, either because involved in going up/coming down or for lack of seats. According to a usability principle, it was decided to investigate on three particular aspects linked to the design of the chosen supports: the shape, the position and the colour. These aspects were assumed as factors to be investigated in order to improve the railway coach interior in terms of perceived comfort. For each factor three different design solutions were characterized, assumed as levels in a factorial design for generating product concept (Table 2). A complete factorial design expects 27 runs, but this number is too onerous for users, who could tire during evaluation, so biasing their judgments. Hence a fractional factorial design 33–1 (that implies just 9 runs) was adopted.

Table 2: Factors and levels for the railway coach interior

Factors	**Levels**	**HANDS**	**PERCHES**	**HANDRAILS**
A: Shape	0	Straight	Straight	Straight
	1	Straight	Undulating	Undulating
	2	Undulating	Helicoidal	Helicoidal
B: Position	0	On all sits	Absent	All along of corridor
	1	Alternating on sits	Alternating on sits	Absent
	2	Alternating on sits	Alternating on sits	All along of corridor
C: Colour	0	Turquoise	Turquoise	Turquoise
	1	Blue	Blue	Blue
	2	Orange	Orange	Orange

The supports were modeled in PTC pro/ENGINEER® CAD environment and inserted into the train virtual moke-up. Then, following the chosen factorial design, 9 concepts of train interior were generated and rendered in VR through Virtual Design 2® software. Then the concepts were shown in random order during a controlled experiment in immersive environment to a group of 10 expert users. They were asked to compile a questionnaire in order to express their judgment on each concept with reference to the Kansei word Comfortable; their answers were coded by a Likert scale.

The mean of scores from questionnaires were analyzed in order to select the best combination of factors, aiming at increasing perceived comfort. According to the results from the main effect plots, the expected optimal concept (A0, B0, C0) (Figure 1) was identified, not coinciding with the experimented optimal one (A1, B0, C0). So a confirmatory test was designed to verify the new result. In the last session the users were asked to express their opinion about the new concept (A0, B0, C0) accordingly to the same evaluation conditions. The result confirmed that (A0, B0, C0) was the best combination.

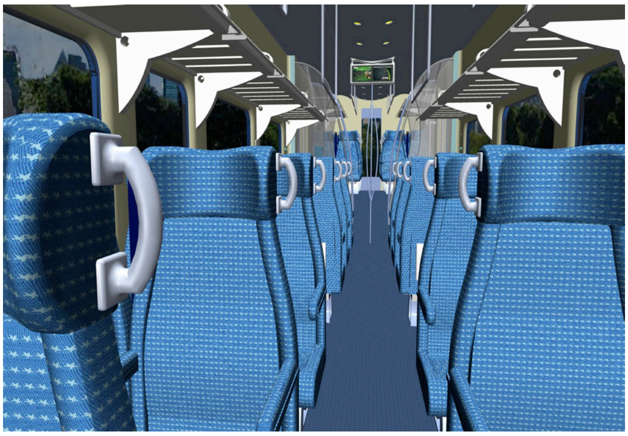

Figure 1: The expected optimal concept (A_0, B_0, C_0)

3. AHP APPROACH

One of the more challenging issue in visual assessment stems from the number of concepts to be evaluated; obviously, the higher this number the more significant the interpretative model will be. Conversely even a number of ten could be unfeasible from the point of view of evaluators; for instance a set of only nine concepts (as in the VR evaluation session just discussed above) has demonstrated to be almost large, because of the duration of the navigation through the train interior and the time necessary to fill in the questionnaires. Moreover, the concepts did not differ macroscopically but only by elements very small compared to the whole interior. Since evaluators might tired because the difficulties in discriminating between a concept to another, the results should be less meaningful to build the model.

Therefore, when in a further step of the interior design the focus moves on the sittings, we looked for an alternative approach in order to overcome this issue. To elicit a user preference model, marketing researches literature advice that only when there is no way to observe the user behavior (specifically her/his choices among alternatives) one is compelled to ask direct questions, but in the case in which one can unambiguously observe this choice, the set of observations may be very small [13]. Therefore an alternative experimental procedure was set up by asking each evaluator to repeatedly choose between two alternatives the preferred one and to express the degree of her/his preference [14]. Moreover in the previous studies it was observed that the main concern of the evaluators was to keep judgments' coherence among concepts. The possibility to express relative judgments, which does not ask for a prior absolute scale of assessment, is a simple solution to relax their anxiety. By collecting basic ideas from AHP and more specifically adopting the geometrical modeling in [12], an alternative approach to synthesis phase was deployed and a reasonable mean was defined to build a model from the results of different evaluators in a quite simple and communicable way.

3.1. New experimental procedure

In order to apply the AHP approach to the design of train sittings, first some design elements were identified via a Kano analysis [11] and singled out as the technical features (factors) each to be set in a certain way (level) in order to obtain the optimal concept (Table 3). One can argue that just visual evaluation suffices to assess the optimal sittings if the levels of each factor are quite different and the main interest of the analysis relies on the effect of their combination. Aiming at the most appealing sittings' concept in the user perspective, a number of evaluators were easily selected among people accustomed to the regional transportation service in order to evaluate and prioritize the different concepts according to their personal preferences. Since the required evaluations were relative in nature and the details could be easily appreciated by comparing the alternatives side by side, all the evaluators found out this procedure more comfortable than the former. Moreover, by applying the AHP analysis to the collected data, was possible to clearly pool the results from all the evaluators so eliciting the true direction of the group's preference in terms of the most appealing sittings' concept. Last but not least, the number of alternative was kept tight by splitting the whole set of alternatives to be examined in different subsets and submitting them to different evaluators.

Table 3: The factors and their corresponding levels adopted for the sittings

Factors	Level -1	Level +1
Factor A : footrest	no	Yes
Factor B : light system	fixed	Mobile
Factor C : armrests	fixed	Mobile
Factor D : tip top table	no	Yes

The identification of most appealing concept had a follow up after about a month which involved the same group of evaluators. This second experimental set up, again performed by the AHP approach adopted for the concepts' evaluation, helped designers to depict the direction into the semantic space implicitly adopted by each evaluator to drive her/his choices among concepts. Since the domain for the sittings was the same that the one defined for the whole train, the above direction can be suitably represented in the semantic space by the Kansei words already identified at the beginning. This suggested that the new experimental procedure can supply the same kind of results that sprang from the Kansei-VR approach and inspired us to integrate the AHP approach into a unique KE process.

Therefore the AHP approach was integrated as a parallel synthesis phase at small scale that can speed-up the whole process by simplifying the model building at subsystem level. Obviously, when the subsystem is integrated into the whole system a verification experimental session at full scale (in VR) is required to check the results: only once sittings were verified into the coach the model loop was completed.

The general form of the step procedure to perform Kansei-AHP is sketched in the following:

First experimental set up:

1. the design elements are varied among concepts accordingly to a suitable factorial design;
2. via the AHP analysis the concepts are evaluated through the pairwise comparisons and the resulting priorities arranged into the matrix A;
3. the vector stemming from the previous step (the first eigenvector of the matrix V obtained as the root square of A) is drawn in the space of factors – it sketches the direction the user aimed at in the view of the most appealing design in the technical space.

Second experimental set up:

1. via the AHP analysis the Kansei words identified from the spanning of the semantic space are prioritized through their pairwise comparisons;
2. the vector obtained as above here defines a kind of weighting of the Kansei words – it represents the most appealing design for the user in the semantic space.

Specifically, to express their judgments in terms of pairwise comparisons evaluators gave the orientation and the magnitude of their preferences. From the practical point of view, for each pair of concepts, visually proposed by adjacent moke-ups, they chose the best one and input a number in order to quantify this preference. The numbers were integers ranging between 1 – which stands for equivalence of the two alternatives – and 9 – meaning that the chosen alternative is absolutely better than the other (Figure 2, left side). By means of these $8 \times 7 / 2 = 28$ pairwise comparisons an 8×8 matrix, say A (showing units on the diagonal and with element $a_{ij} = 1/a_{ji}$) was filled and the vectorial AHP procedure allowed to extract the complete ranking of alternatives embedded in the 28 relative evaluations.

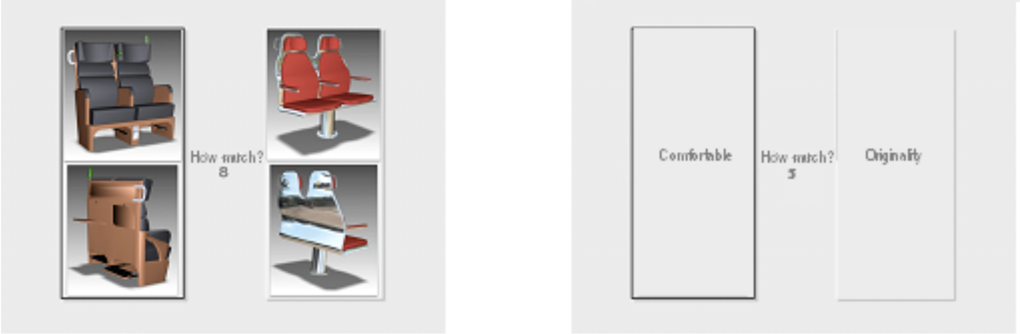

Figure 2: Samples of the pairwise comparisons among concept (on the left) and among Kansei words (on the right)

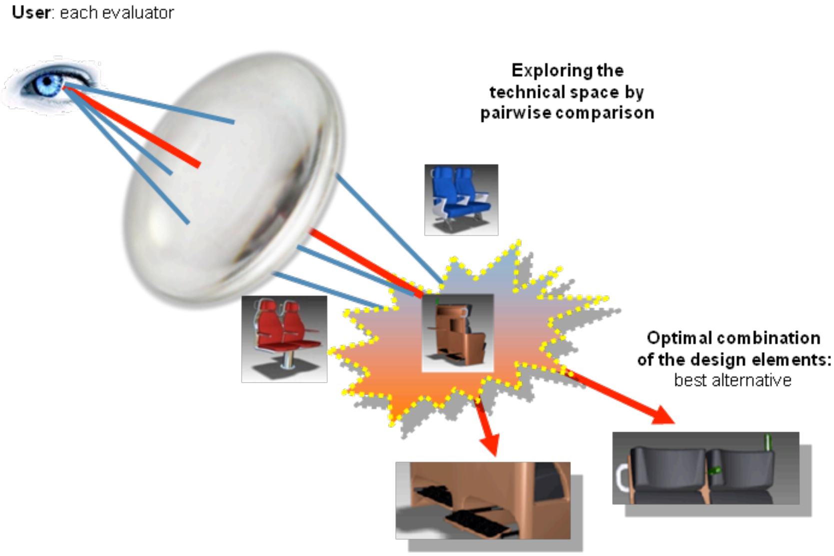

Figure 3: The visual suggestion of the meaning of pairwise comparisons among concepts

One could visualize evaluator's preference as an ideal direction she/he latently keeps in mind while spanning the space. The Figure 3 illustrates the idea by means of a fictitious lens tied to that direction: any other direction is, at some extent, corrected by the optics (like blue optical rays deviated by the lens). Trivially, only eigenvectors of the matrix V represent the directions which are not bend by the optics and the first one utterly gives the principal optical axe (followed by the red ray).

3.2. Model representation

Since we aimed at a graphical presentation of the results, the rankings were represented as vectors in the technical space; this in turn suggested that vectors could express the direction along which the evaluators focalized their preferences (see Figures 3 and 4). Being uniform the weight attached to each evaluator, each vector was normalized to unit magnitude. Once the AHP experimental phase was completed, data were analyzed for each evaluator. The first eigenvector obtained from each of the nine evaluators is projected onto the 3-dimensional space of principal factors x = A (armrest type) y = B (light type) and z = C (footrest). Then the results were graphically compared and discussed within each subset and finally pooled in a unique resultant vector, so expressing the best guess for the preferences of the target population of (Figure 4).

Obviously the more the consensus among evaluators into the same subset the stronger the contribution to the resultant, so this geometrical shaped pooling guaranteed by itself to melt idiosyncrasies. The same analysis was performed for the second experimental set-up and the resultant vector calculated.

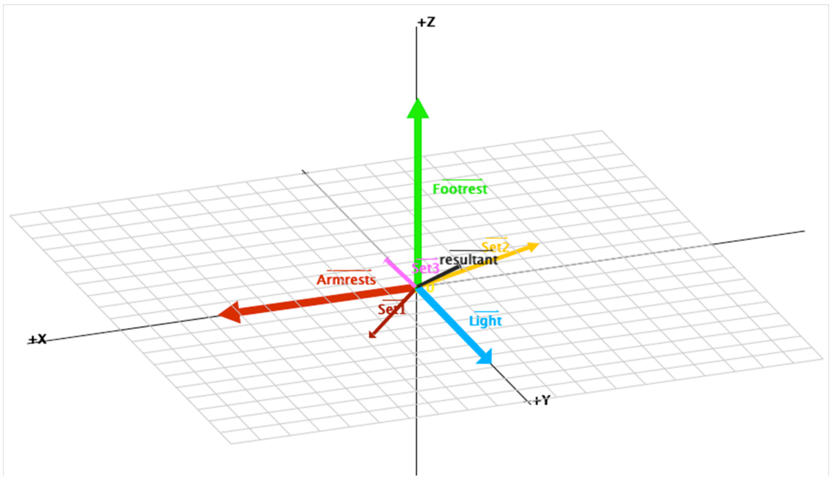

Figure 4: Vectors for each of the analyzed subsets and their resultant

In order to build the model, the vector identified by the Kansei words is projected on the first one represented in technical space; the so calculated components of the factors over the Kansei words (not independent) are the contributions of each design element to the Kansei. Therefore the Table 4, similar to Table 1, can clearly summarize the results of the Kansei-AHP approach.

Table 4: Analysis results: Kansei words priorities and design elements contribution to them (the greater the number of crosses the stronger the relation between the design element and the Kansei word)

	Comfortable	Originality	Mobility	Versatility	Simplicity
Footrest					
Light system	×	×			
Armrests					
Tip top table	××	×			
Priorities	0,696	0,440	0,343	0,342	0,237

4. CONCLUDING REMARKS

The development of a new procedure for the synthesis phase offered the chance to test in practice the Kansei process by means of a VR approach along with an AHP approach. The latter relied on direct comparisons between two concepts selected time by time from the whole set of alternatives and the use of a geometrical version of AHP for analyzing and interpreting the results. Since the AHP supplied useful results in a form that can be expressed analogously to the output of the Kansei-VR approach, a suitable way to integrate it into an unique KE process was deployed. This gave the opportunity to exploit the power of VR approach to generate and assess system architecture and gather the benefits from a small scale quicker experimental approach to identify the most appealing design candidate at subsystem level too. The early results obtained by Authors were encouraging: the sense of presence offered by VR is irrenounceable at architecture level whereas visual PC based experimental set-up is helpful to evaluate improvements at subsystem level. Only the most appealing design candidates for each subsystem have to pass a confirmatory VR experiment into the system architecture. The integrated approach could allow one to evaluate more design candidates by more evaluators without raising the time and resources request by VR experiments.

4.1. Acknowledgments

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REFERENCES

1. Nielsen J., *Usability Engineering*, Academic Press, Boston, MA, 1993.
2. Norman D. A., *The Design of Everyday Things* (Originally published as: The Psychology of Everyday Things), Basic Books, New York, 1988.
3. Lanzotti A., Matrone G., Tarantino P., Vanacore A., *Statistical Design for Innovation in Virtual Reality*, in “Statistics for Innovation - Statistical Design of “Continuous” Product Innovation”, Erto P. (ed.), Springer-Verlag Italia, 27–41, 2009.
4. Barnes C., Lillford S. P., Decision support for the design of affective products, *Journal of Engineering Design*, Vol. 20, No. 5, pp. 477–492, 2009.
5. Pieter M.A., Hekkert, P., Special Issue Editorial: Design & Emotion, *International Journal of Design*, Vol. 3, No. 2, pp. 1–6, 2009.
6. Ekman P., Friesen W., Hager J., *Facial Action Coding System*, Salt Lake City, Utah: Research Nexus, 2002.
7. Dermir E., Desmet M.A., Appraisal Pattern of Emotions in Human Computer Interaction, *International Journal of Design*, Vol. 3, No. 2, pp. 41–51, 2009.
8. Chitturi R., Emotion by Design: A Consumer Perspective, *International Journal of Design*, Vol. 3, No. 2, pp. 7–17, 2009.
9. Di Gironimo G., Lanzotti A., Matrone G., Papa S., Tarantino P., Concept Design of a Railway Coach: Quality Elements Identification Through a Kansei-VR Approach, *Proceedings of 6th International Conference IPMM*, 25-29 June, Salerno (Italy), 2007.

10. Lanzotti A., Tarantino P., Kansei engineering approach for total quality design and continuous innovation, *The TQM Journal*, Vol. 20, No. 4, pp. 324–337, 2008.

11. Lanzotti A., Di Gironimo G., Matrone G., Patalano S., Renno F., Virtual concepts and experiments to improve quality of train interiors, *International Journal on Interactive Design and Manufacturing*, Springer Paris, Vol. 3, No. 2, pp. 65–79, 2009.

12. Zahir S., Geometry of decision making and the vector space formulation of the analytic hierarchy process, *European Journal of Operation Research*, Vol. 112, pp. 373–396, 1999.

13. Haddawy P., Ha V., Restificar A., Geisler B., Miyamoto J., Preference Elicitation via Theory Refinement, *Journal of Machine Learning Research*, Vol. 4, pp. 317–337, 2003.

14. Petiot J.F.; Yannou B., Measuring consumer perceptions for a better comprehension, specification and assessment of product semantics, *International Journal of Industrial Ergonomics*, Vol. 33, No. 6, pp. 507–525, 2005.