# MODELLING DESIGN REQUIREMENTS OF A FLOOR PLAN.

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*Abstract*

*Currently many real estate developers offer their products through their websites. The aim of this medium is not only to facilitate understanding of the building, but also to capture the attention of potential customers, provoking feelings and emotions that influence the purchase decision, especially in the case of off-plan property sales. Understanding the cognitive factors behind customers' evaluation processes prior to a purchase is of great interest for defining successful design criteria.*

*The interior space of the property is one of the most important aspect in users' purchase decisions.*

*The paper aims to determine which property design elements in floor plans provoke the emotions users use to describe its interior design.*

*A field study was carried out on a sample of 75 individuals who evaluated a set of images of real estate promotions.*

*The results show that the landings and corridors are fundamental; the area must be spacious so that larger surface areas score best; the living room must be well differentiated from the bedrooms; the valuation of the space depends on the graphic form of presentation, the use of warm colours and the degree of detail in the plans has a positive influence on the assessment.*

*This information may be of great interest for architects and designers in the graphic representation of the space.*

***Keywords:*** *layout Design, Customer Satisfaction, Design Process, Perception.*

## INTRODUCTION

New information technologies have had a great impact on the modes of operation in architecture, engineering and construction and have enabled all the participants in these industries to access the construction supply chain (Lee et al. 2011). Furthermore, traditionally, product information was only available in paper format. Advances in computer technology have encouraged the appearance of electronic catalogues with full product information so that potential customers can access all that information through the Internet and web technologies. Thus the web can be used to create new marketing channels and to identify customer groups as it improves the efficiency of certain information-intensive activities and the cost and transaction operation time between the firm and the customer.

Currently many real estate promoters offer their products through their websites. These sites provide full detailed information on the company and its products. The information offered through the sites is fundamental, especially in markets like the Spanish market where most properties are sold off plan. The final purchase decision will depend on many aspects such as location and costs, but if the property has not been built, other, more intangible aspects presented in that commercial information will become particularly important.

In an increasingly competitive market and with the current real estate crisis particularly in Spain, increasingly more sophisticated tools are being used to provide that information. Thus renders, infographs, virtual tours through the building etc., are becoming more and more common (Llinares and Iñarra 2014). These computer systems help designers and architects to take the user to the real estate product. Of the information facilitated through these means, plans become particularly important as users use them to interpret the interior of the property (spaciousness, distribution, orientation…). Thus, they have a twofold function, firstly to attempt to facilitate understanding of the space and secondly to capture the attention of potential customers by evoking feelings and emotions that will positively influence the purchase decision. A favorable assessment may depend on objective characteristics (property size, number of rooms, aspect…) but can also depend on subjective c haracteristics. Thus the colour used in the plans or the inclusion of furniture in the presentation can cause a positive reaction in the observer and incite the final purchase.

But, is it possible to determine what concrete elements users' global assessments depend on? Is the information supplied through floor plans important in the global assessment? And if so, what specific elements of the floor plan are the most important? Finding an answer to these questions would appear to be fundamental for architects and designers when making computer assisted representations of the property.

Many studies have analyzed user perception or response to different aspects of building design.

Thus for example, the perception of space has been the object of many studies. Some authors have measured this perception by examining the size and shape of different spaces (Allen et al. 1978; Passini 1984; Sadalla and Oxley 1984; Sullivan and Chen 1997; Salama 2009; Wong 2010; Torres et al. 2013). Other authors have measured spatial cognition based on user orientation in a concrete space, using cognitive maps(Canter 1977) or through "the point in the directio n" technique (Lindberg and Gärling 1981; Okabe et al. 1986). However, in all these studies, the user evaluates a real space and not the space generated through an architectural computer tool.

Another line of works focuses on the perception of a property interior. Some authors have measured the perception or emotional response to this space using the theoretical framework described by Mehrabian and Russell (1974). These authors describe emotion through only three basic underlying dimensions: pleasure, arousal and dominance. Other works (Nasar 1981; Nelson and Rabianski 1988; Stamps and Krishnan 2006; Opoku and Abdul-Muhmin 2010) have identified the relationship between the physical characteristics of interior spaces in the property and the overall assessment of the property. However, most of these studies use real spaces or photographs of the properties to evaluate the space rather than the floor plans, which are the object of our study.

The plans for a property have also been studied. Some works analyze plan structure by applying graph theory or space syntax (Bafna 2003; Zimring and Dalton 2003; Franz et al. 2005; Brandyopadhyay and Merchant 2006; Franz and Wiener 2008). These works, however, do not aim to analyze observers' cognitive factors. In this regard, there is another line of works focusing on psychological aspects, that is, on analyzing the underlying cognitive process in the interpretation of floor plans when choosing a property (Dellaert and Stremersch 2005; Rouwendal and Meijer 2006; Hofman et al. 2006; Ishikawa et al. 2011; Gao et al. 2013). The most important limitation in these studies is that they use parameters and product characteristics established by experts, that is, they are based on symbolic attributes defined previously by experts on the matter. These symbolic attributes do not necessarily signify the same for users or fully cover their perceptions. Thus, it is essential to include techniques which enable systematic measurement of users' emotional impressions and their relationship with the design elements. This would enable the "user's voic e" to be included in the design process.

In a different area of application where user-oriented products are developed, there are techniques such as Kansei Engineering which are able to quantify perceptions and relate them to design criteria. Nagamachi (1995) defines Kansei Engineering as " *a technology for translating consumer feelings and images of a product into design elements*". This technique considers that individual judgment is not only influenced by the stimuli (a combination of objective and subjective parameters) but also by the scheme of concepts of a concrete group of users (semantic space). Kansei Engineering uses differential semantics to measure the perceptual space (Osgood et al. 1957). This technique

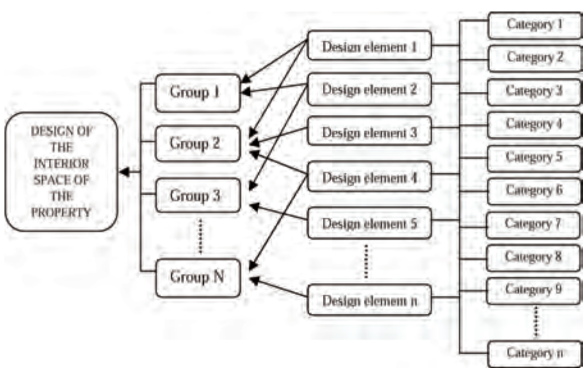


*Figure 1. Scaled analysis to determine product properties.*

| | |
|---|---|
| **Purpose** | Relate the cognitive factors of the interior space with the design elements of the plan of the building interior |
| **Subjects** | 75 |
| **Materials** | Questionnaires with 10 questions and 107 stimuli |
| **Analytical tool** | - Linear Regression Analysis<br>- General Linear Model- Univariant<br>- Posthoc Bonferroni test |

*Table 1.Data treatment, techniques and expected results.*

is one of the most commonly used methods for assessing product perception (Jindo et al. 1995; Matsubara and Nagamachi 1997; Petiot and Yannou 2004; Llinares and Page 2007, 2011). Having obtained users' affective dimensions, the next phase involves indentifying what design elements cause them. This relation between design elements and semantic attributes can be determined by applying statistical treatments such as linear regression, neural networks or fuzzy logic (Hsiao and Huang 2002; Schütte 2005).

The paper aims to determine which property design elements in floor plans provoke the emotions users use to describe its interior design.

## MATERIALS AND METHODS

The methodology followed is based on a field study which collected interviewees' evaluations of the stimuli (Table 1).

In this paper we attempt to identify the relation between cognitive factors of the interior space with the design elements of the plan of the building interior. This work necessitated parametrizing the plan into specific design elements. The idea is to translate the complexity of the product into a composition of parameters that represent the reality that stimulates user perception of the product. The parameters had to reflect the elements that could influence the individual's evaluation (from the colour of the plans to the property surface area). The complex nature of this task is due to the high number of parameters in a floor plan. The lack of a more closely defined hypothesis for the design parameters that determine the perception associated to a floor plan means that the model requires an excessive number of explana-

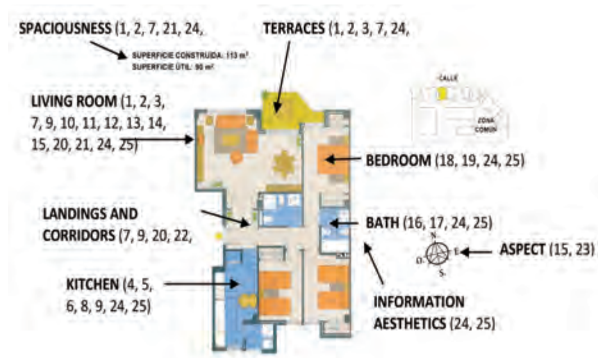


*Figure 2. Groups and design elements. Parametrization of the design elements in a floor plan taking into account the graphic representation. The design elements and the different categories are included. Note: 1. Terraces; 2. Location of terraces; 3. Size of terraces; 4. Annexes to kitchen; 5. Kitchen table; 6. Shape of kitchen; 7. Possibility of extending the kitchen; 8. Kitchen next to the living room; 9. Shape of property; 10. Location of living room; 11. Shape of living room; 12. Annexes to living room; 13. Possibility of extending the living room; 14. Windows in the living room; 15. Aspect of living room; 16. Aspect of building; 17. Main bathroom; 18. Bathrooms; 19. Location of bedroom; 20. Annexe to bedroom; 21. Night-day separation; 22. Net surface area; 23. Landings and corridors; 24. Colour of plans; 25. Finish of plans.*

tory variables. To simply this process, a scaled analysis was done, by putting together groups of design elements according to their similarity (Figure 1), which were then subsequently ungrouped after obtaining the mathematical models.

The grouping was done with the Affinity Diagram (Terninko, 1997). This technique enabled a total of 25 design elements to be grouped into 9 sets (Figure 2).

These design elements were obtained from a search of websites of estate agents advertising their promotions in Valencia, from consulting industry journals and interviews with experts (architects, promoters, etc). These elements had to reflect all the aspects related to the interior space of the property represented on the floor plan. Thus the elements reflected attributes related to objective characteristics such as the surface area and orientation of the property, elements related to the aesthetics of the presentation, (colour and finish of the plans), and attributes related to each of the rooms: kitchen, bathrooms, living room, bedrooms, terraces and landings and corridors. Some design elements were included in several groups as they were considered to influence various aspects of the property. Thus for example, the colour of the plans (design element number 25) was included in the different rooms (bathroom, living room, kitchen…) as it was considered that the colour used in the representation could influence the user's assessment. Each design attribute was formed by different categories. For example the design element "colour of the plans" included the categories "black and white", "warm colours", "cold colours" a nd "warm and cold colours". Table 2 shows the set of 25 design elements and their corresponding categories.

After parametrizing the product the following field study was carried out

**Subjects.** Sample consisted of 75 subjects chosen using simple random sampling. Each subject replied to 3 questionnaires to give a total of 225 replies.

**Questionnaire.** The questionnaire contained the 9 groups obtained previously and the global assessment variable. This variable was reflected by the phrase *"Generally speaking, I think the interior space of the property is well designed"*. The assessment was carried out using a 5 point Likert scale: *Totally disagree, Disagree, Neutral, Agree and Totally agree*.

**Stimuli**. A set of 107 images of floor plans of dwellings was produced. The images were obtained from advertising catalogues on estate agents' websites. All the images included the following elements: image of the floor plan, location of the building in the block, net surface area and orientation of the property (Figure 3). The aim was to provide as varied a sample of stimuli as possible, attempting to ensure that all possible combinations of design elements were represented to avoid nesting.

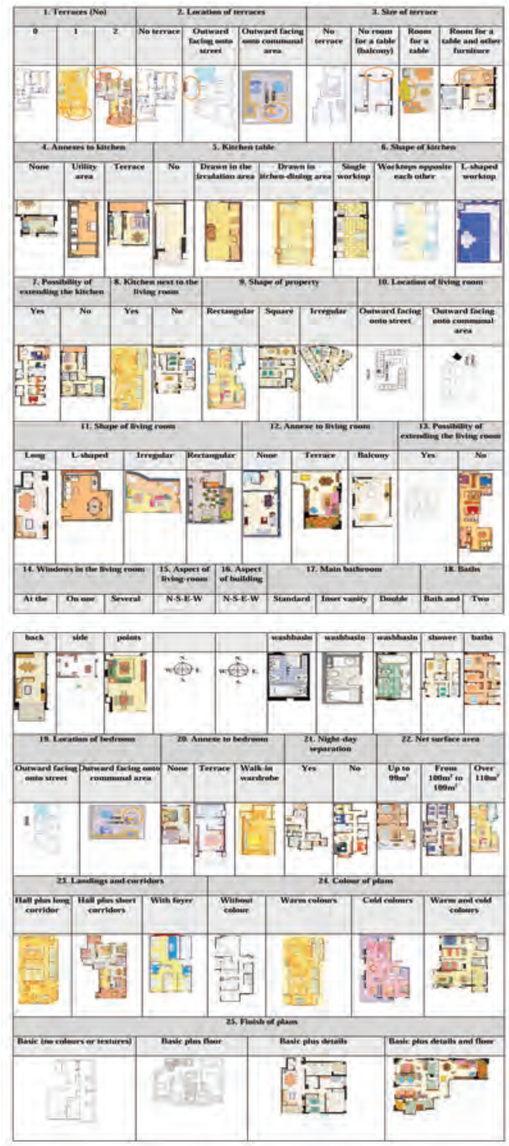


Table 2. *Design elements and categories.*

**Data processing.** From the data base of answers, the following statistical treatment was carried out using statistical software SPSS 16.0 (Figure 4).

***(a) Identification of the important groups in the interior design of the property.*** Linear regression was applied taking as dependent variable the perception of "well designed interior space" and as independent variables

Figure 3. *Examples of the stimulus.*

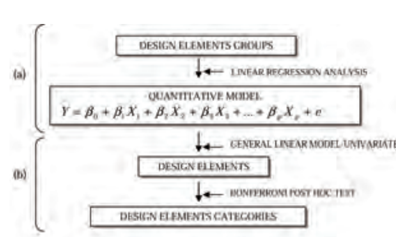


Figure 4. *Stages in identification of the different categories of design elements that influence perceptions.*

| DESIGN ELEMENT (F; s.l.) | | | | | |
|---|---|---|---|---|---|
| Category 1 | Average value | | | | |
| Category 2 | Average value | | | | |
| Category 3 | Average value | | | | |
| Category 4 | Average value | | | | |

Table 3. *Table 3. Example of table with results from the Bonferroni post-hoc test: For the same design element, where the horizontal category bars intersect, the perception associated to the categories is the same. In this case the average value is observed to determine the most influential category. Displacement in relation to the horizontal bars indicates the direction of difference. Thus displacement to the right indicates an increase in the associated perception. Note: Average value of the different categories of design elements corresponds to the average assessment made by the subjects in the sample. The significance level (p<0.05) associated with the F test obtained in the Univariate General Linear Model shows that the design element explains a significant part of the model.*

the 9 groupings of design elements. This technique will provide a quantitative model that explains the perception of “Good layout” on the basis of the identified groups (Figure 4a).

**(b) Identification of the design categories that influence the design of the interior space of the property.** The Univariate General Linear Model procedure was used, taking each group as dependent variable and each design element as independent variables. The Bonferroni post-hoc test was applied to design elements with more than two categories. This technique showed which categories achieve a significant difference in perception and the direction of the differences found. Table 3 shows how the results are presented with the interpretation of the Bonferroni post-hoc test (Figure 4b).

## RESULTS

The interior space of the property is one of the most important aspect in users’ purchase decisions. The results have intended to determine which design elements cause that sensation.

(a) *Identification of the important groups in the interior design of the property.*
As noted in the section on material and methods, the 25 design elements in a floor plan were grouped into 9 sets of elements. These groupings were: spaciousness, aspect, aesthetics of the information, Landings and corridors, kitchens, baths, bedrooms, living room and terraces (Figure 2). Linear regression was used to determine the important groups in the global assessment of “good design of the interior space”. This analysis (Table 4) determined that of the 9 groupings that configure a floor plan, 5 are important in the assessment of the design or layout of the interior space (p<0.05). These groups are, by order of importance: landings and corridors, surface, living room, aesthetics of the information and the kitchen.

*(b) Identification of the design categories that influence design of the interior space of the property.*
Having identified the groups that influence assessment of the design of the interior space of a property, these sets of elements were degrouped to determine what design elements and in particular, what categories influence that assessment. The technique used for that was the univariate general linear model and the Bonferroni post hoc test. The results for each of the 5 groupings of significant design elements for the perception of good design of the interior space are shown below. Table 5 shows the most significant results.

| | B | SE | Beta | t | Sig. |
|---|---|---|---|---|---|
| *(Constant)* | -.239 | .089 | | -2.693 | .008 |
| Spaciousness | .223 | .071 | .210 | 3.135 | .002 |
| Information aesthetics | .143 | .053 | .154 | 2.721 | .007 |
| Landings and corridors | .378 | .058 | .368 | 6.514 | .000 |
| Kitchen | .135 | .060 | .127 | 2.251 | .025 |
| Living room | .156 | .072 | .126 | 2.162 | .032 |
| | | | | R=.673 | |

Table 4. *Design groups ordered according to influence on good design of interior space (regression analysis).*

*Group 1. Landings and corridors*. This is the group with the greatest impact on the perception of “Good design of the interior space” ( β: 0.378; p=0.000). Of the design elements in this group the univariate general linear model determined as significant (p<0.05) only the shape of property (F: 3.447; p=0.034). That is, that the shape of the property influences the assessment of landings and corridors and these in turn influence assessment of the interior design. There are three possible categories for shape of the property (rectangular, square and irregular). The Bonferroni post hoc test determined that the categories with the greatest influence are rectangular and irregular (horizontal bars displaced to the right). There are no significant differences between them (horizontal bars intersect); thus, the one with the greatest influence is the one with the highest average. Thus the category “irregular-shape d property”, with an average of 0.732 is the most significant in this group (landings and corridors). Table 5 (a, b) shows the best and worst assessed properties in terms of the group landings and corridors.

*Group2. Spaciousness*. This is the second most influential group in the perception of “Good design of the interior space” ( β: 0.223; p=0.002). The univariate general linear model determined that the following elements had a significant influence on the assessment of the surface area: net surface area (F: 5.097; p=0.007), colours of the plans (F: 3.033; p=0.019) and number of terraces (F: 2.614; p=0.050). Thus the sensation of spaciousness of a property improves with the increase in net square meters, and the increase is significant after $100m^2$. Furthermore, it can be seen that plans in warm colours, (reds, oranges, etc.) create a greater sensation of spaciousness for users. Finally, although the differences were not significant, the perception of spaciousness increases with the number of terraces. Table 5 (c, d) shows the best and worst assessed properties in terms of the group spaciousness.

*Group 3. Living Room*. Of the set of rooms in the property, the living room has the greatest influence on the assessment of the design of the interior space (β: 0.156; p=0.032). The design elements that influence in the assessment of the living room are: night-day separation (F: 6.660; p=0.002) and *net surface area* (F: 3.253; p=0.041). Assessment of the living room improves when it is well differentiated from the bedrooms (night-day separation). Furthermore, when the net surface area is larger, assessment of the living room also improves as larger properties also have more spacious living rooms. It should be noted that it would have been interesting to analyze the variable “living room surface area”, but this a spect is not offered in the commercial information to users. The results show that there is a considerable improvement in the assessment of the living room in property surface areas of more than $100m^2$. Table 5 (e, f) shows the best and worst assessed properties for the group “living room”.
*Group 4. Information aesthetics.*This aspect has the

| Linear Regression | General Linear Model –Univariate (Post-hoc Bonferroni) | |
|---|---|---|
| GROUP 1. LANDINGS AND CORRIDORS (β = 0.378 s.l.:0.000) | SHAPE OF PROPERTY (F=3.447; s.l.:0.034) | |
| | Rectangular | 0.536 |
| | Square | 0.050 |
| | **Irregular** | 0.732 |
| GROUP 2. SPACIOUSNESS (β = 0.223 s.l.:0.002) | NET SURFACE AREA (F=5.097; s.l.:0.007) | |
| | Up to 99 $m^2$ | 0.379 |
| | From 100 $m^2$ to 109 $m^2$ | 0.617 |
| | **Over 110 $m^2$** | 0.875 |
| | COLOUR OF PLANS (F=3.033; s.l.:0.019) | |
| | Without colour | 0.684 |
| | **Warm colours** | 1.025 |
| | Cold colours | 0.481 |
| | Warm and cold colours | 0.421 |
| | TERRACES (No) (F=2.614; s.l.:0.050) | |
| | 0 | 0.684 |
| | 1 | 0.554 |
| | **2** | 0.732 |
| GROUP 3. LIVING ROOM (β = 0.136 s.l.:0.032) | NIGHT-DAY SEPARATION (F=6.660; s.l.:0.002) | |
| | No | 0.537 |
| | **Yes** | 1.100 |
| | NET SURFACE AREA (F=3.253; s.l.:0.041) | |
| | Up to 99 $m^2$ | 0.722 |
| | From 100 $m^2$ to 109 $m^2$ | 0.917 |
| | **Over 110 $m^2$** | 1.062 |
| GROUP 4. INFORMATION AESTHETICS (β = 0.143 s.l.:0.007) | COLOUR OF PLANS (F=8.349; s.l.:0.000) | |
| | Without colour | -0.283 |
| | **Warm colours** | 0.825 |
| | Cold colours | 0.615 |
| | Warm and cold colours | 0.224 |
| | FINISH OF PLANS (F=8.174; s.l.:0.000) | |
| | Basic | -0.224 |
| | Basic+floor | 0.192 |
| | Basic+details | 0.435 |
| | **Basic+details+floor** | 0.655 |
| GROUP 5. KITCHEN (β = 0.135 s.l.:0.025) | KITCHEN TABLE (F=11.613; s.l.:0.000) | |
| | No table | 0.123 |
| | Drawn in the circulation area | 0.611 |
| | **Drawn in kitchen-dining area** | 1.000 |
| | SHAPE OF KITCHEN (F=5.588; s.l.:0.004) | |
| | Single worktop | 0.419 |
| | **Worktops opposite each other** | 0.923 |
| | L-shaped worktop | 0.847 |

GOOD DESIGN OF THE INTERIOR SPACE


*Table 5. Summary of the results.*

greatest subjective component in the assessment of the interior design of the property (: 0.143; p=0.007). The presentation of the information of the layout influences how it is assessed. The significant design elements in this group are *colours* (F: 8.349; p=0.000) and *finishes* (F: 8.174; p=0.000) of the plan. As regards colour, the best assessed categories by users are the use of cold or warm colours, used independently. The combination of these colours in a plan (category "warm and cold colours") worsen s the aesthetics. The worst assessed plans are the ones that have not been coloured ("wi thout colours" category). Furthermore, assessment of the presentation of the information improves as the level of detail in the plans increases, with an average negative assessment when there is no detail ("basic" category).


*Figure 5. Ge4 Services Firms in the Lake Constance Region based on the intensity of network connectivity.*

Table 5 (g, h) shows the best and worst assessed properties for the group "information aesthetics".

*Group 5. Kitchen*. Another room that also influences layout is the kitchen (: 0.135; p=0.025). A good assessment of the kitchen is related to the following design elements: the drawing of a *table in the kitchen* (F: 11.613; p=0.000) which helps to show the size and *shape* of the kitchen (F: 5.588; p=0.004). Users assess the space more positively when there is a table drawn in a kitchen-dining area as their assessment is significantly higher than it is for a kitchen without a table or one drawn in a transit area. As regards kitchen shape, kitchens with worktops that are opposite each other or L-shaped are given significantly better assessments than kitchens with worktops along one side only. Table 5 (i, j) shows the best and worst assessed properties for the group "kitchen".

## CONCLUSION

The study examined the elements in plan design that make the user assess the interior space of the property as well designed. Understanding this relationship is fundamental as this factor has the greatest impact on the final choice of residence and is directly linked to the spatial representation of the property. This analysis was done applying linear regression techniques and a univariant general linear model (with post-hoc Bonferroni test).

The results show that firstly, landings and corridors are fundamental. Good assessments of this aspect are associated with irregular interior spaces. Secondly, the area must be spacious so that larger surface areas score best, and the largest properties in the sample obtained the highest scores (with surface areas over $110m^2$). The sensation of spaciousness is also associated to the number of terraces, so that the more terraces a property has, the better the score for the space. An interesting aspect of spaciousness is its relationship with floor plan colours. Thus the use of warm colours means that users perceive the spaces as larger. Thirdly, the living room in the property is important. For a positive evaluation of the interior space, the living room must be well differentiated from the bedrooms (what could be called a good night-day separation). Another aspect that impacts on the living room is the surface area of the property so, when a property is large, the living room is perceived as being more spacious and the interior space is better valued. Fourthly, the valuation of the space depends on the graphic form of presentation. Thus the use of warm colours (red, yellow…) and the degree of detail in the plans (details of flooring, furniture…) has a p ositive influence on the assessment. Finally, the kitchen is also important. Thus the evaluation of the space is better when there are worktops along both sides and if there is table in the dining area of the kitchen.

Therefore, it has been possible to define design guidelines for architects and designers concerning the graphic representation of the space (Figure 5). The image shows an example of a floor plan, with the evaluation of its attributes (the influence of each category in the final perception was assessed by summing for each design element the product between the average assessment of each category for each group of elements and the coefficient of the group in the regression model), its link to the evaluation of the design interior space.

Real stimuli and a combination of design elements in the sample given by the availability of those combinations in the real product mean that an excessive number of parameters are introduced, making it practically impossible to obtain a balanced sample design for independent study of the main effects of each variable. To avoid this problem as far as possible, this study attempted to obtain a balanced sample with all the possible combinations of design elements to minimize nesting.

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