Introduction

Hospital design plays an important role in the experience of patients, visitors and staff, as physical environments can affect emotional states and have an influence on health. There are many studies considering the impact of specific architectural variables on humans (Joseph & Hamilton, 2008; Ulrich et al., 2008), and into color in particular (Gray, Kesten, Hurst, & Anderko, 2012; Yu, & Yoon, 2010; Tofle et al., 2004), which has the great advantage of being an easily modifiable factor.

The first known European example of an architectural space being designed, with specific colors, for medical purposes, was in 1912, when the architect Howard Kempt Prossor developed a series of color schemes for English hospitals treating neurasthenia and nervous disorders; an idea that this gained importance in the medical field (Farrer-Brown, 1957). Later designers and researchers have tried to specify color criteria for hospital spaces to influence patients' outcomes (O'Connor, 2011).

In recent times, it has been shown that some variation and contrast in color can have a positive impact on patients (Mahnke, 1996), so color guidelines have been included in hospital design manuals (Dalke et al., 2006). Lawson & Phiri (2002) show that chromatic variation of the environment reduces the recovery time of patients with mental illnesses by 70% when compared to monotonous architectural spaces.

Generally, studies evaluating color-related emotions in interior spaces use the scales of Osgood, Suci, and Tannenbaum (1957): dark/light, pleasant/unpleasant, fresh/stale, heavy/light, calm/exciting, dull/sharp, tense/relaxed, warm/cool, interesting/boring, or Küller´s (1991) standardized version of the "Semantisk Miljöbeskrivning" (SMB) or "semantic environment description" which includes criteria such as pleasantness, complexity, unity, enclosedness, potency, social status, affection, and originality. These color-emotion scales are used in later studies about color and architecture. Küller, Mikellides, and Janssens (2009) demonstrated that a red room is more psychologically arousing than a blue room and that both are more arousing than a grey one. Al Ayash et al. (2015) demonstrated that a blue room was perceived as more pleasant, calming and interesting than red and yellow rooms. These studies, however, have two main limitations.

On one hand, **the methodology used to gather users' affective responses is based on assessment questionnaires designed by experts. This approach might lead to erroneous results being obtained as non-experts may misunderstand the concepts set out by the experts. Secondly, the concepts under study may already have been defined using different stimuli or in other geographical and time contexts.** Although the results of these works are undoubtedly plausible, studies using variables that reflect the affective and emotional mental structure of specific users are also needed. When users' conceptual schemes have been established it is possible to find quantitative relationships between their subjective responses to design features. This is the methodology proposed by Kansei Engineering (KE) (Nagamachi, 1995).

KE is a consumer-oriented technology for new product design developed in the 1970s at the Kure Institute of Technology (Hiroshima, Japan). This method, that unites Kansei (feelings and emotions in Japanese) with the engineering discipline, attempts to identify and quantify users' perceptions of a product in their own terms and to find quantitative relationships between these subjective responses and design features (Nagamachi, 1995). To identify and quantify users' perceptions, KE uses the semantic differential method. This technique, developed by Osgood et al. (1957), analyzes the semantic structures of a product through adjectives and expressions which reflect users' emotional impressions. This step is fundamental for studying, in a subsequent phase, the relationship between design features and subjective judgements, as that relationship can scarcely be established if the users do not understand the concepts.

Most of the applications of this methodology are in the field of industrial development, and (Nagamachi, 2002) is not used much in the field of architecture (Nagamachi, 1998). Studies in healthcare design using the semantic differential method include Harun and Ibrahim (2009) on hospital waiting rooms, and Higuera, Montañana and Llinares (2017) on a neonatal unit.

On the other hand, in these user-centered architectural design studies, the stimuli usually employed are photographs, and although their use has been sufficiently validated (Stamps, 1990), there are two significant limitations: the use of a predefined viewpoint and the lack of physical presence. These limitations are particularly evident when assessing feelings or emotions associated with an individual's experience of the space. The validity of the responses is conditional upon the ability to recreate the space for individuals who often are incapable of imagining the space with sufficient realism to evoke the subtleties and sensations of the recreated environment. In this aspect, the new tools for immersive spatial representation are a great step forward.

In recent years, with the emergence of Head-Mounted Displays (HMD), immersive virtual environments have demonstrated their suitability for representing architectural environments, in a realistic way, under laboratory controlled conditions (Vince, 2004). The main advantages they provide in comparison to traditional systems are the representation of a space in a way that closely matches reality for users and the possibility of isolating, or modifying, the study variables (shape, color, lighting,…; Heydarian et al., 2015).

Broadly speaking, there are two types of virtual immersive environments. Interactive virtual environments generated in real time, usually known as Virtual Reality (VR) (Vince, 2004) enables user o move freely inside an environment, although at the cost of lower graphic photorealism. Spherical panoramic images visualized in HMD (Gledhill, Tian, Taylor, & Clarke, 2003) are half way between traditional rendering and VR, allowing spatial immersion and stereoscopy, but replaces continuous movement through space with greater photorealism. In this regard, virtual environments have already been validated in color appearance research (López-Tarruella, Llinares, Guixeres, & Higuera, 2016).

The general aim of the current study is to examine the impact of color hues on users' responses to a lactation room at a health center. This space was chosen because it has specific affective requirements (need for privacy and security). The analysis took place in the framework of KE, with two specific objectives: (a) to identify the set of affective factors behind users` assessments of a space in a lactation room and (b) to identify the influence of changes in color hue on users' perceptions and assessments. The analysis attempted to address the possible limitations noted above, and the fundamental contribution of this study lies in its methodology. In a first phase of the analysis, the semantic differential method in the framework of KE was used to identify the user's affective structure. Then, in a second phase, 360º images, which provide a complete immersive sensation for observers, were used to change the color of the room in an isolated, controlled way.

Materials and Methods

The methodological development focused on two field studies in accordance with the two proposed objectives: (a) identification of affective factors in lactation rooms and (b) obtaining users' affective responses and assessments based on the color hue of the room. These studies gathered interviewees' evaluations of the stimuli presented. Table 1 shows the most important characteristics of each field study.

[Place Table 1 approximately here]

Phase I - Identification of Affective Factors in Lactation Rooms

The general aim of this phase was to identify the affective factors that characterize a lactation room. A field study was conducted with the following characteristics:

Stimuli. The stimuli comprised a set of 20 images of lactation rooms (Figure 1). These pictures were taken from hospital and specialized websites. The main objective of the stimuli in this phase is to stimulate sensations and to achieve sufficient variability. Thus, photographs of real spaces were used, showing rooms with a wide range of layouts, equipment and finishes. A sample of 36 lactation rooms from 35 public buildings was selected. This sample was reduced by the affinity diagram technique (Terninko, 1997) to find affinities between the previously chosen pictures to guarantee that the final, smaller sample had sufficient variability. Images were displayed in a randomized way because it was not possible to isolate design elements in real rooms. This methodology is described by Kish (1995) as a way of controlling an experiment by including variables randomly, on the basis that chance will generate equivalent distributions of the units in the variables under study. Thus, the remaining bias is smaller.

[Place Figure 1 approximately here]

Questionnaire. A questionnaire was designed to gather users´ responses during visualization of the stimuli. The questionnaire included: (a) filter questions to reject users who replied negatively: *Do you know what a lactation room is and what it is used for?* (b) questions related to participants' characteristics; and (c) 25 questions related to affective impressions of the room for assessment (E.g: *Do you think this room is comfortable?*) on a Likert scale from -2 (strongly disagree) to 2 (strongly agree). These items were pre-selected by 2 architects, 2 hospital staff members and 2 users of lactation rooms following the process established by Schütte, Eklund, Axelsson, and Nagamachi (2004). The first step in obtaining the set of expressions involves collecting as many adjectives (kansei words) as possible to describe the product domain. To obtain the most comprehensive set of words, all available sources must be searched. In our case, the highest number of expressions related to this field was found on specialized websites, journals and magazines. The process is completed when no new words appear. In our study, the work team gathered a total of 112 expressions. However, this set of words was too extensive to be included in a questionnaire. To decrease this set of adjectives the affinity diagram technique (Terninko, 1997) was applied. This technique consists of forming groups of words similar in meaning and assigning one significant word to embrace all the expressions in the group. The grouping process was as follows: (a) the kansei words were written on post-it notes, each note containing only one expression; and (b) the notes were grouped by similarity or affinity. The grouping took into account criteria that guarantee a representation of the initial semantic variability. These criteria were to remove: (1) adjectives requiring additional context to be understood; (2) adjectives and expressions related to specialized terms; (3) terms that are clear synonyms and antonyms of other terms on the list; and non-gradable adjectives. The grouping process ended when all the ideas or words were grouped, and (c) each group was given a title, or heading, that represented all the kansei words in the group. In the final event, the affinity diagram reduced the initial list to 25 adjectives. The questionnaire was disseminated with the collaboration of hospital staff and various infant, and breast-feeding associations provided a link to an online questionnaire.

Subjects. The final sample was comprised of 77 Spanish women, users of the space to be analyzed. The subjects were aged between 21 and 47 years (Mean=36.53; Standard deviation [SD].=4.36). Seventy-two (93.5%) had children, and 51 (66.2%) were regular users of lactation rooms. The sample size was chosen with the criterion of having a minimum of 6 observations for each variable to be included in the factor analysis, indicated as sufficient in Field (2005).

Data Analysis. The statistical analysis was carried out using the SPSS v.22.0 package. For analysis of significant differences in relation to the individual's profile, the questionnaire was examined for significant differences in responses based on the individual's profile, using the Mann-Whitney U-test and the Kruskal-Wallis test.

To obtain individuals' perceptual space, a principal components factor analysis provided a set of independent concepts or semantic factors that the women used to describe their sensations in relation to the lactation room (Basilevsky, 2009). We selected only those principal components with Eigenvalues greater than one and used a Varimax rotation to obtain the semantic axes factors. Finally, the internal consistency of the dimensions was evaluated by Cronbach’s alpha coefficient (Streiner, 2003).

Phase II - Analysis of the Influence of Changes in Color Hue in the Lactation Room on Users' Responses

The main objective of this stage was to identify how the variable color affects users' affective responses and their global assessment of a lactation room. For that purpose, a field study was conducted with the following characteristics:

Stimuli. The stimulus for assessment was a set of 360º panoramic renders of a lactation room, presented in nine different color palettes and visualized through a Samsung Gear VR Head-Mounted Display. The space designed consisted of a set of elements characteristic of this type of room: an area with breast-feeding stations, armchairs and auxiliary tables; a more private, independent station and a bench with an area for preparing bottles, washing hands and changing diapers. Nine color palettes were created and defined with the Natural Color System (NCS) as noted in Table 2. NCS characterizes colors on the basis of three perceptive variables (hue, blackness and chromaticness), whose values are given as percentages. Each color palette contains three colors with the same hue and chromaticness (30%) and differences in blackness: 5%, 30% and 60%. The set of nine tones chosen included desaturated (white plus two greys) and eight equidistant hues in the NCS color circle. The color with least blackness was used on walls, medium on the floor and one column and the color of most blackness on doors and under counter furniture. Ceilings, curtains and other elements were kept in white or neutral, desaturated hues. NCS colors were translated to the sRGB color space using the NCS Navigator Premium tool in order to reproduce them correctly on the display device.

[Place Table 2 approximately here]

The three-dimensional model of the room was created using SketchUp 2015 software. Colors, materials and lighting were applied using the Vray rendering engine. Then, 27 equirectangular 360º panoramic renders with 5000x2500 pixels depicted the lactation room (Figure 2), covering three viewpoints for each of the nine color palettes to be assessed, so that all of the space could be accessed visually (Figure 3).

[Place Figure 2 approximately here]

[Place Figure 3 approximately here]

Images were loaded in a Samsung Gear VR Head-Mounted Display. This system was used in the experiment because of its mobility and ability to natively admit spherical panoramic images. The system consists of a mobile Virtual Reality headset with a stereoscopic screen of

1280 x 1440 pixels per eye, a 96º field of view and a head position tracked with gyroscopes and accelerometers. The virtual experience is generated by a Samsung Note 4 mobile telephone with a 2.7GHz quad-core processor and 3GB of RAM.

Questionnaire. A questionnaire was designed, using a Likert-type scale from -2 (strongly disagree) to 2 (strongly agree) to assess the stimuli presented during visualization. The questionnaire contained (a) the set of affective impressions, or representative factors from the users' subjective responses obtained in Phase I, and (b) the global assessment of the room based on the statement: “If I had to use a lactation room, I would like it to be this one.”

Subjects. The sample for this analyzed was comprised of 106 Spanish women aged between 24 and 52 years (Mean=37.21; SD.=4.67). Seventy-eight (74.6%) had children, and 62 (58.5%) were regular users of lactation rooms. The sample size was determined considering an effect size f=0.4, α error=0.05 and power=0.8 (Faul, Erdfelder, Buchner, & Lang, 2007). At least 10 visualizations per color were considered.

Data analysis. Statistical analysis was carried out using the SPSS v.22.0 package.
Firstly, questionnaire responses were examined for significant differences based on the individual's profile, using the Mann-Whitney U-test and Kruskal-Wallis test. Then, the influence of the different colors on affective impressions or factors obtained in Phase I were analyzed with Spearman's correlation coefficients and the existence of significant differences in responses according to the color visualized using the Kruskal-Wallis non-parametric test.

Then, the influence of affective factors on the global assessment of the room was analyzed with linear regression. Finally, after measuring the influence of the different colors on the affective factors or impressions and their influence on the global assessments, the weight of each hue was obtained for the global assessments of the room.

Results

Phase I - Identification of Affective Factors in Lactation Rooms

The results of this phase are classified in two parts. On one hand, the analysis of significant differences in relation to the individual's profile. On the other hand, obtaining the subjects' perceptual space.

Analysis of significant differences in relation to the individual's profile. Both the Mann-Whitney U-test and the Kruskal-Wallis test show no statistical differences at a significance level of 0.05 in any response in relation to demographic factors (Table 3).

[Place Table 3 approximately here]

Obtaining individuals' perceptual space. Factor analysis reduced the initial set of 25 expressions to 6 independent factors, able to explain 70.72% of the variance (see Table 4).

[Place Table 4 approximately here]

Factor 1 represents the sensation of safety in the room, with safe, functional, accessible, and well-equipped as main concepts. Factor 2 covers the adjectives related to elegance, originality, modernity, and the unique style of the room. Factor 3 corresponds conceptually to the sensation of a cozy, warm, familiar room. Factor 4 refers to the spaciousness of the room. Factor 5 represents the simplicity of the design. Finally, factor 6 refers to the light, sunny aspect of the room. Cronbach's alpha values for 6 dimensions ranged from 0.656 to 0.911, showing that these scales have considerable reliability (Streiner, 2003).

Phase II - Analysis of the Influence of Changes in Color Hue in the Lactation Room on Users' Responses

The results of this phase are classified in five parts. Firstly, the possible existence of significant differences in relation to the individual's profile was analysed. Then, the influence of the different colors on the emotional impressions and the relevant differences based on the color of the room were analysed. Finally, the impact of affective factors on the global assessment of the room was analyzed and the color ranges were ordered.

Analysis of significant differences in relation to the individual's profile. No statistical differences at a significance level of 0.05 were found in any response in relation to demographic factors (Table 5).

[Place Table 5 approximately here]

Impact of the different color palettes on affective impressions. The analysis of Spearman's correlations shows that (Table 6) hues 1 (white) and 4 (orange) generally obtain the highest scores. In contrast, hues 5 (red) and 8 (cyan) accumulate significant negative correlations. Figure 4 shows the values obtained by each color for each affective impression between the axis -0.4 and 0.4.

[Place Figure 4 approximately here]

[Place Table 6 approximately here]

Analysis of significant differences in affective impressions based on the color of the room. The above differences are quantified by Kruskal-Wallis non-parametric analysis. This analysis shows statistically significant differences in the sensation of coziness ($H=17.69$ $p=.024$) and between orange versus red ($H=3.54$ $p=.01$); simplicity ($H=25.67$ $p<.001$), between white versus red ($H=3.78$ $p<.001$) and white versus cyan ($H=3.56$ $p=.01$); and luminosity ($H=31.48$ $p<.001$), between red versus orange ($H=3.45$ $p=.02$), cyan versus orange ($H=3.42$ $p=.02$), red versus white ($H=3.21$ $p=.05$) and cyan versus white ($H=3.17$ $p=.054$).

Influence of affective impressions on the global assessment of the room. Linear regression analysis identified the relevant factors in the global assessments of the lactation room

(R=0.790; Table 7). The factor with the greatest influence is coziness, followed by aspects related to spaciousness and safety. Perceptions of elegance, simplicity and luminosity were not statistically significant.

[Place Table 7 approximately here]

Order of the color ranges in the global assessment of the room. Correlations of the different color ranges on users' affective responses (Table 6) and the influence of that on the global assessment (Table 7) are used to obtain the order of the different hues in the global assessment (Figure 5).

[Place Figure 5 approximately here]

The results show that orange has a very significant weight in the global assessment, followed by yellow, as they mainly influence coziness, the most influential factor in the global assessment. White compensates its low score in coziness with a high contribution to safety, and finally, generates a neutral assessment. Finally, red obtains a negative assessment due to the sum of negative assessments in the set of impressions.

Discussion

This study attempts to achieve two main aims. Firstly, to identify the set of affective factors behind the assessments of lactation rooms. Secondly, to identify the influence of color hue changes in the perception and assessments of a particular lactation room. The results show significant implications on two levels, contributing to methodology and practice. From the methodological point of view, the most important contribution is the application of the Semantic Differential method to identify the user's affective structure, as a phase preliminary phase to the subsequent study of the influence of the characteristics of the space on the user's emotional response. If assessment scales are based on attributes that evaluators cannot appreciate, or concepts that use overlapping information, it is very difficult then to find statistical evidence for the relation between specific design parameters and that group's perception. There must be a large enough homogeneous sample of subjects for the results obtained in the first phase to be considered as representative, and a set of stimuli that provides a broad range of different assessments.

The semantic differential method has been previously applied in environmental psychology. The works by Küller (1980) focus on determining semantic environmental descriptions (SMB) by limiting the study area to an architectural environment. The novelty of our approach is to use the methodology as a first step within the Kansei Engineering framework. This step is fundamental for studying the relationships between color hues and subjective judgements in subsequent phases.

Furthermore, the use of 360º panoramic computer-generated images (CGI) helps to show the possibilities of highly realistic immersive environments in User-Centered architectural design studies (Bullinger, Bauer, Wenzel, & Blach, 2010).

From the point of view of the results of the experimental work, in a first phase, factor analysis identified 6 independent factors that explained 70.72% of the original variables. These factors are: safety, elegance, coziness, spaciousness, simplicity and luminosity. Only coziness, spaciousness and safety influence the final evaluation. In other works relating to Evidence-Based Design (EBD), similar factors have been proven to be desirable for healthcare facilities (Malenbaum, Keefe, Williams, Ulrich, & Somers, 2008).

The factor coziness, which has proved more influential in the assessment of lactation rooms, refers to the affection for or the friendliness of the space (it includes cozy, homey, youthful and warm). Previous studies (Ulrich, 1991) refer to the importance of generating an environment psychologically adapted to users' needs to counteract the stress inherent in hospital environments. In the sphere of EBD, a variety of factors influencing the perception of coziness of a space have been studied, such as privacy (Leino-Kilpi et al., 2001) and homey (Shin, Maxwell, & Eshelman, 2004).

Spaciousness (includes spacious and not claustrophobic) is also found as an EBD design factor in previous literature (Mourshed & Zhao, 2012). Some studies suggest that a lack of spaciousness could be an ambient stressor (Stamps, 2007).

The concept safety (safe, functional, accessible…) has been studied as a design factor by, among others, Clarkson et al., (2004) and Codinhoto, Tzortzopoulos, Kagioglou, Aouad and Cooper (2009). Ulrich (1991) notes that the stress inherent in health care facilities can be reduced if the environment promotes a sensation of control and safety.

The concept elegance (elegant, modern, original…), in the sense of attractiveness or aesthetics, was proposed as one of the four factors that define color, in the works of Wright and Rainwater (1962).

Simplicity (simple and unornamented), considered as an aesthetic factor, has been shown to influence preferences (Herzog & Shier, 2000). Finally, the factor luminosity (sunny and bright) has also been widely studied in both EBD and ergonomics in relation to users' psychological responses (Dalke et al., 2006).

Furthermore, the second stage of KE identifies the colors associated with individuals' assessments.

Firstly, the final order of colors in relation to their influence on the global evaluation of the space is almost identical to that obtained in the affective response of coziness. This is due to the significant weight of this attribute in the model, almost double that of the other significant impressions, safety and spaciousness. The importance of the cozy and pleasant sensations of a hospital space has also been highlighted in previous studies (Ulrich, 1991).

Red (NCS Y80R) is the color with the worst assessment and it also has negative scores for coziness and safety. In the hospital context, red is an undesirable color, perhaps because of its iconographic link to blood or because it has commonly been used as a visual code for expressing danger in various cultures (Heller & Chamorro, 2004). Küller, Mikellides and Janssens (2009) also show that, in a physical space colored in red, individuals feel more excited.

Red is followed in the other global negative assessments by cyan (NCS B30G), turquoise (NCS B90G) and green (NCS G30Y), correlating negative scores for coziness. These are hues commonly found in hospital operating theaters and are particularly associated with health care facilities (Kaya & Crosby, 2006). Thus, hues close to green are not considered cozy. Other works report similar results (Dalke et al., 2006; Higuera et al., 2017).

White (NCS N) and pink (NCS R30B) receive intermediate assessments. White is assessed lower in the cozy factor because it is a neutral, or achromatic color, that can be very monotone. In comparison to achromatic colors, variations in hue have a positive influence on the sensation of well-being (Mahnke, 1996). Pink has negative assessments only in the elegant sensation, perhaps because it is linked to children (Heller & Chamorro, 2004) and does not match well with concepts like modern, elegant and exclusive.

Finally, **the colors with the highest assessments are also those considered the most homey and correspond to orange (NCS Y30R) and yellow (NCS G90Y), followed by blue (NCS G80B).** The color palettes linked to hominess match the colors characteristic of traditional architecture, as previous studies have shown (Garcia-Codoñer, Verdú, Barchino, Guillén, & Lluch, 2009).

Of the three perceptive variables that define a color, hue, lightness and saturation, this work analyzes the relationship between hues and emotional response in lactation rooms. Although these relations are statistically significant, their value is not always very high. This result is consistent with previous research into color and perception, which shows that changes in saturation and luminosity have more influence on individuals than changes in hue (Küller et al., 2009; Manav, 2007). When Valdez and Mehrabian (1994) studied the effect of hue on emotions, they found that the relationship of hue to emotions was much weaker than anticipated. Other studies (Gao & Xin, 2006; Manav, 2007) also show that the influence of luminosity and chroma are more important than hue in the relationship between emotions and colors.

This study argues for the need to evaluate color emotions evoked by specific architectural spaces and not in an abstract way. Finally, as regards the limitations of the study, it should be taken into account that the work was carried out in a very specific environment and with a very specific population segment. The proposed methodology, however, has general validity and could therefore be applied to evaluate different design elements, spaces, uses and population segments.

Conclusions

The present study shows that color hues in lactation rooms evoke different emotional responses in users and that those emotions influence the global assessment of the space. The Semantic Differential method can be used to identify the affective factors behind assessments of a particular building typology. Thus, assessment scales, adapted to the conceptual scheme of the users, might be created to quantify their subjective perceptions, which can then be related to their global assessments. Furthermore, the use of photorealistic 360ºx180º panoramic CGI, visualized though an immersive Head-Mounted Display system, seems an appropriate visualization tool for studies that require an isolated, controlled analysis of the effect of one design parameter without altering the others.

Lactation rooms tend to be assessed in relation to six factors: safety, elegance, coziness, spaciousness, simplicity and luminosity, of which coziness has the most impact on the assessment of the space. Furthermore, warm colors (yellow and orange) tend to score well for coziness which puts them ahead in the general assessments. Although white scores well in almost all aspects its final assessment is dragged down by its lack of coziness. Greenish and bluish hues tend to remain in slightly negative positions, as reported in other works on healthcare spaces, and red gets bad assessments in practically all aspects.

Although the chromatic results of this study can be applied only to a specific environment and population, this work suggests that it should be possible for designers to establish an effective method to anticipate users' emotional responses to color. Thus, designers might plan facilities that take into account the specific affective requirements of the space.

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