Frontiers of Architectural Research (2020) 9, 739–750

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.keaipublishing.com/foar

Research Article

Color preference cool versus warm in nursing homes depends on the expected activity for interior spaces

Ana Torres*, **Juan Serra**, **Jorge Llopis**, **Anna Delcampo**

Instituto de Restauración Del Patrimonio, Universitat Politècnica de València, Valencia 46022, Spain

Received 16 March 2020; received in revised form 5 June 2020; accepted 16 June 2020

KEYWORDS
Color;
Elderly;
Preference;
Arousal;
Architecture

Abstract This study explores the color preferences of elderly residents of nursing homes based on the expected activities for different rooms, activity rooms, and bedrooms and compares the results with the arousal level induced by each color. Two experiments were conducted, one with elderly people living in nursing homes in the Valencian Community, and the other in a laboratory with virtual reality and physiological markers (i.e., heart rate variability). Individuals assessed six colors in two groups of warm and cool. Results demonstrate that preferences for warm and cool colors depend on the room type. For the activity room, warm colors were preferred over the cool colors by both genders, fitting the higher arousal levels induced by warm versus cool colors. For the bedrooms, cool colors were preferred by both genders, fitting the lower arousal levels induced by cool colors in females and the other models that suggest a U-shaped relation between the arousal level and the visible spectra of colors. Therefore, the color preferences for interior spaces in nursing homes depend on the room type and are related to the arousal level for the expected activity in them.
© 2020 Higher Education Press Limited Company. Publishing Services by Elsevier B.V. on behalf of KeAi. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

In recent decades, the average age of the population has progressively increased, and one in nine people worldwide is currently over 60 years old (UNFPA, International, H., 2012). Thus, the design of the interior spaces of nursing homes has received special interest toward improving the quality of life of the elderly (Lawlor and Thomas, 2008; Torrington, 2003; Weal, 1988). Color is one of the design variables that have a great impact on well-being and an easy feature to update in old architectural structures (Bosch et al., 2012; Perkins, 2013; Tofle et al., 2004).

* Corresponding author.
E-mail address: atorresb@ega.upv.es (A. Torres).
Peer review under responsibility of Southeast University.

https://doi.org/10.1016/j.foar.2020.06.002
2095-2635/© 2020 Higher Education Press Limited Company. Publishing Services by Elsevier B.V. on behalf of KeAi. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Several studies have demonstrated the disadvantages of exclusively white architectural spaces (Dalke et al., 2006). In urban colorscape, low color contrast affects visual comfort (Liu et al., 2016), while monotony and lack of sensory stimulation in interior spaces can hinder users' orientation as the visual cues needed to identify architectural elements are absent (Camgöz et al., 2004; Goodman et al., 2005; Lee, 2010; Read, 2003). This is particularly important in the design of nursing homes because the elderly has low visual health (Baget i Bernàldiz and Fontoba i Poveda, 2013) and many limitations in autonomy (Powell, 1985). Most elderly people in nursing homes are affected by a range of impairments due to the progress of biological aging. These impairments affect the perception of the built environment in many ways: (1) a shift in hue sensitivity exists, particularly with short wavelengths blue-green that become more yellowish, (2) a loss in the sensitivity to chromatic contrast, (3) a loss in the saturation of the colors perceived, (5) more difficulties in adapting the vision with low level of lighting and dark colors, (6) more reaction time to discriminate signs of the visual scene, (7) more vision deficits in depth perception, and (8) a general loss in visual acuity (Delcampo-Carda et al., 2019). Color is an important cue for cognitive reasons to differentiate visual information (Sloan, 1980). Moreover, colored rooms have a significant influence on the performance of intellectual activities compared to white (AL-Ayash et al., 2016; Kwallek et al., 1996; Öztürk et al., 2012). Evidence suggests that too much light and reflection from architectural surfaces cause anxiety and have a negative impact on well-being (Winterbottom and Wilkins, 2009, p. 56).

In the case of healthcare facilities and nursing homes, many studies have been conducted on the impact of physical features on well-being (Joseph et al., 2016), but few studies have specifically addressed color (Tofle et al., 2004). Despite the possible benefits of a good color palette in architecture, neutral architectural design, commonly known as "hospital aesthetic," is common in the interior of health and well-being spaces, such as nursing homes for the elderly (Dalke and Matheson, 2003). Instead of a neutral institutional aesthetic (López-Tarruella et al., 2018), the general purpose of the design should be to convey a sense of home (Eijkelenboom et al., 2017), and color can be one of the most useful features for this purpose (Delcampo Carda and Torres Barchino, 2016). Moreover, color can be used to emphasize the difference between quiet and more stimulating spaces (Barnes, 2006) and help elderly people in wayfinding (Passini et al., 2000). An appropriate color palette compared to white can be a key factor to enhancing the quality of living in nursing homes.

A color is described by three perceptual variables, namely, *hue*, *value*, and *saturation*. *Hue* is the color attribute that distinguishes a red from a blue or green and corresponds to the dominant wavelength of the physical stimulus (Sanz and Gallego, 2001, tono). In many experiments on the influence of different color hues on individuals, grouping them in two color palettes (i.e., warm and cool) and comparing red and blue are common (Ou et al., 2004a, p. 236). Some of these experiments have obtained statistically significant results in architectural spaces on the basis of the differentiation between cool and warm colors (Ainsworth et al., 1993; Hamid and Newport, 1989; Kwallek et al., 2007, 1996; Yildirim et al., 2007). In Itten's chromatic circle (Itten, 1987), cool colors (e.g., purple, bluish-purple, blue, bluish-green, green, and yellowish-green) are close to blue, while warm colors (e.g., yellow, yellow-orange, orange, red-orange, red, and red-violet) are close to red (Serra Lluch, 2019, p. 20). This distinction between cool and warm (blue and red) was used by Le Corbusier who assigned different architectural properties to blue and red (Heer, 2009; Serra et al., 2016). Although the differentiation between warm and cool colors is an emotional assessment, it seems to be quite universal among individuals of different cultures and genders (Lee, Luo, and Ou, 2009) and depends mainly on the perceptual variable of color *hue* (Ou et al., 2004a). Therefore, the distinction between cool and warm color hues, linked with the opposition blue versus red or short versus long wavelengths, is a reliable way of studying architectural color.

Studies on color preference must focus on specific building types and final users. Thus, color preference has been studied with specific architectural spaces, such as cafés/restaurants (Yildirim et al., 2007), living rooms (Yildirim et al., 2011), children's classrooms (Read et al., 1999; Yildirim et al., 2015), lactation rooms (López-Tarruella et al., 2018), and office spaces (Kwallek et al., 2007), but not with the rooms of nursing homes. Some studies demonstrate a connection between color preference and different building types. US respondents (mean age = 21) related cool colors and blue with residences, hotels, and hospitals, and warm colors and red with entertainment buildings, such as restaurants, theatres, and shopping malls (Kaya and Crosby, 2006). Considering the different rooms in a residence, Turkish respondents (mean age = 32) prefer pink for their sleeping rooms, light blue for their living rooms, and light yellow for their dining areas (Manav, 2007); violet is preferred over yellow for cafés/restaurants (Turkish, age 18—60) (Yildirim et al., 2007). Therefore, the expected activity to be developed in a specific room and building type implies a color preference as expectations and memory of previous experiences influence preferences (Guan and Hung, 2010; Whitfield and Slatter, 1978). In addition, evidence suggests that color preferences are different between young and old observers (Beke et al., 2008), so the findings cannot be transferred from one context to another. For these reasons, studying the color preference for the interior rooms in a nursing home for elderly people is important.

Some of the experiments about color preference in architecture attempt to find the relationship between color preference and color emotion associations by self-reporting. In different experiments about color emotions and color preferences with color samples, Ou identified four color-emotion models, which are culture-independent across countries, namely, the warm—cool, heavy—light, active—passive, and hard—soft models (Ou et al., 2004a). Interestingly, warm—cool was found dependent on like—dislike for British observers (Ou et al., 2004b). In experiments about color emotions in interior spaces, blue is usually reported for relaxation, peace, and calm (AL-Ayash et al., 2016; Heller, 2004), while red is reported for activity and arousal (Kaya and Crosby, 2006). Despite some contradictions, such as colors self-reported negatively but

recommended for residence interiors (Manav, 2007), a significant relationship exists between architectural color preference and color emotions (López-Tarruella et al., 2018). That is, the colors associated with "calmness" are the most preferred for a study room in experiments with Italian students (mean age = 23.91) (Costa et al., 2018) and Australian students (age 20–38) (AL-Ayash et al., 2016). Therefore, the arousal level of the expected activity might influence the color preference for the rooms in a nursing home.

A more accurate way to assess the relationship between color and arousal level instead of self-reporting is through physiological measures, such as the heart rate variability (HRV). Experimental studies demonstrate that long-wavelength colors, red and yellow, are more arousing than short-wavelength colors, blue and green (Valdez and Mehrabian, 1994). Later studies comparing red and blue environments with physiological recordings confirm that red induces a more excited state (AL-Ayash et al., 2016; Küller et al., 2009). Given that colors influence arousal, some authors consider an intermediate level of color in architecture optimal for well-being, following the Yerkes and Dodson (1908) principle that a curvilinear relationship exists between arousal and performance (Küller et al., 2009; Kwallek et al., 2007). In brief, physiological measures, such as HRV, are reliable cues for identifying the arousal level induced by space colors.

Considering the influence of gender on color preferences, some studies have reported no significant differences between men and women in terms of their color preferences (Hsiao et al., 2008; Jadva et al., 2010; Ou et al., 2004a; Yener and Gu, 2002), while others have reported differences in hue preferences (Fortmann-Roe, 2013; Ou et al., 2004b), particularly in the built environment (Cubukcu and Kahraman, 2008) and in the use of black in homes (Manav, 2007). Some authors have suggested that gender differences in color preference could be due to biological differences in color vision (Bimler et al., 2004), such as the differences between the S–(L+M) (blue–yellow) and L-M (red-green) neuronal mechanisms, which encode colors for both genders (Hurlbert and Ling, 2007). However, this biological difference has not always been supported in later studies (Al-Rasheed, 2015, pp. 4–5).

The literature review confirms that an appropriate color palette compared to white can be a key factor to enhancing the quality of living in architecture, particularly in nursing homes where elderly people have many limitations in autonomy. In addition, color research shows that experiments must adapt to the specific architectural typology under study, the function of the rooms, and to end-users' profiles. Previous works demonstrate that the color preference in a particular environment is related with the color emotion associations to the place. Moreover, evidence indicates that color influences the arousal levels of individuals. Therefore, the expected arousal level of the activity to be developed in a room might determine the color preference for that interior. Physiological measures, such as HRV, are more reliable cues than self-report emotions for evaluating the arousal level induced by space colors. Finally, the distinction between cool versus warm color hues is an appropriate and commonly used classification for the stimuli.

Thus, the main objective of the present study is to identify the color preferences of elderly residents for the interior spaces of nursing homes based on the activities carried out in different rooms and their expected arousal level. Thus, we attempt to answer three questions. (1) What is the color preference of elderly residents in nursing homes? (2) What is the arousal level induced by colors in nursing homes? (3) What is the relationship between color preference and arousal level in nursing homes? To achieve the main objective, we take as case studies two rooms in an existing nursing home in Valencia (Spain), namely, a bedroom devoted to calm and relax and an activity room devoted for social relationships. We make two experiments (Fig. 1):

1) Experiment 1 aims to assess the color preferences for activity rooms and bedrooms by individuals living in publicly owned nursing homes in the Valencian Community (Spain). This experiment is developed on site with photographs.
2) Experiment 2 aims to assess the relationship between the wall colors for activity rooms and bedrooms and individuals' arousal level. This experiment is developed in a laboratory with virtual reality (VR) and the physiological measurement of HRV.

2. Material and methods

2.1. Experiment 1. color preferences for activity rooms and bedrooms by residents in nursing homes

2.1.1. Participants

The first study involved 134 elderly Spanish nationals, aged between 75 and 97 (mean age = 80.9), 78 women and 56 men, and living in 11 nursing homes in the Valencian Community (Table 1). The cultural level of the participants was medium-low, without university education. The participants were divided into small groups of 12 people or less, with a roughly equal distribution between men and women. They were randomly selected by knowledgeable staff in each of the nursing homes from residents who had relatively good cognitive abilities; were not suffering from any serious diseases, Alzheimer's, or dementia; and exhibited no color-blindness. The participation in the study was voluntary, and the seniors showed a good predisposition to collaborate. Those tired or with bad humor directly rejected the invitation to participate. The test was conducted in the morning during their spare time before lunch and took 30 min to 50 min.

2.1.2. Stimuli

The stimuli were images printed on DIN A3-sized panels. The images were photographs of existing activity rooms and bedrooms in a nursing home (Fig. 2). These images were edited with Adobe Photoshop CS6 to modify the colors of the walls. The 6 colors selected according to the Natural Color System (NCS) notation had the same level of blackness (30%) and chromaticness (30%) and just varied in hue. The set of warm-colored images consisted of three stimuli with colors red NCS S3010- R, yellow NCS S3010-Y, and

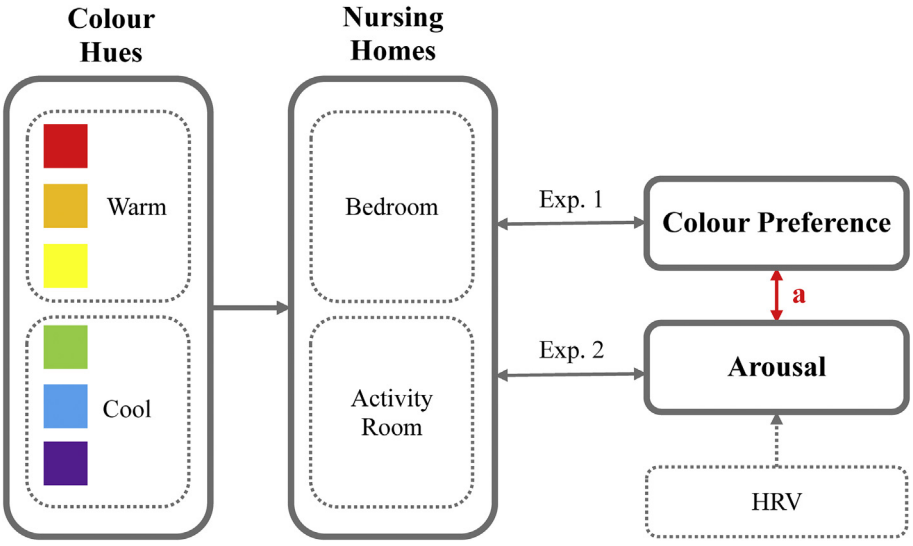

Fig. 1 Scheme of the methodology.

Table 1 Description of the sample of participants.

Residence Location	Females	Males	Total	Age Average	Years in residence
Palacio de Raga, Valencia	9	4	13	85.2	3.77
Velluters, Valencia	5	5	10	81.6	3.7
Silla	8	4	12	77	2.58
La Canyada	7	4	11	80.1	6.83
Torrent	5	5	10	80.8	7.5
Massamagrell	6	5	11	78.1	3.45
El Pinar	12	4	16	82.9	5.27
Segorbe	6	7	13	84	7
Fontilles	10	8	18	80	4.78
Chiva	4	6	10	81	3.7
Buñol	6	4	10	79.3	263
TOTAL	**78**	**56**	**134**	**80.9**	**4.66**

orange NCS S3010- Y50R. The set of cool-colored images also consisted of three stimuli with colors blue NCS S3010-B, green NCS S3010-G, and purple NCS S3010- R50B. Notably, the perceptual conditions of these colors painted on real architecture might shift depending on the lighting conditions, that is, natural or artificial. We chose a daylight vision for the bedroom because elderly people spend quite an amount of time during the day in these places as the bedroom is the most private room in a nursing home, and its use is not just limited to the nighttime. Moreover, a reduction in vision sensitivity to dark colors or environments with low levels of lighting start to manifest at the age of 60 (Owsley, 2011; Suzuki et al., 2012). This might bias the results of our study if the simulated lighting was different between bedrooms and activity rooms. The accuracy of the final printed colors was verified by measuring specific points of the images using a spectrophotometer and with the help of three color experts with normal vision to assess the consistency of the printed colors with their NCS descriptions observed under the D65 standard lighting.

2.1.3. Method

The test was conducted in the nursing homes due to limitations in the mobility of the elderly. The experiment was performed in 2018 between 10.00 h and 14.00 h for a period of 8 months in a room with good natural light on sunny days. The same researchers (two people) conducted the trials. Social workers and psychologists from the centers were present. Each participant completed a questionnaire with three distinct parts:

(1) General information about the individual: name, age, gender, level of education, and years living in the residence (see Section 2.1.1.).
(2) Color preferences for the activity room. Participants responded to the following. "Of the activities you undertake in the residence, think of the one you like the most. Choose which of these rooms you think is the most appropriate for that activity." This instruction was followed independently for the set of 3 cool-color stimuli and for the set of 3 warm-color stimuli. The final most preferred stimulus was chosen from the two pre-selected images.
(3) Color preferences for the bedroom. The participants answered the following question. "Imagine that you are arriving at the residence for the first time and you have been given a choice between one of these rooms. Which one do you think is most appropriate?" This question was answered independently for the set of 3 cool-color stimuli and for the set of 3 warm-color stimuli. The final most preferred stimulus was chosen from the two pre-selected images.

The groups of stimuli were presented randomly by Researcher 1, while Researcher 2 wrote down the results in the corresponding template (Fig. 3).

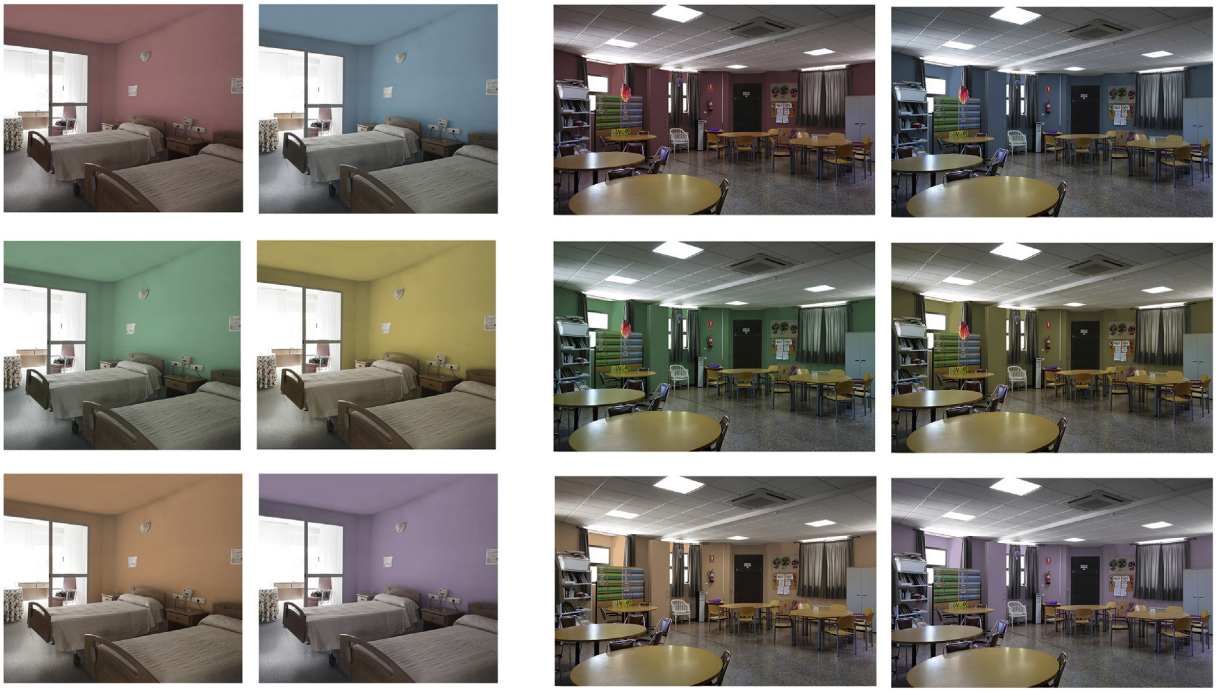

Fig. 2 Stimuli shown for (a) the bedroom and (b) the activity room, with the colors arranged from top to bottom and from left to right: red, blue, green, yellow, orange and purple.

Fig. 3 Experiment 1. Surveys conducted in residences for the elderly in the Valencian Community.

2.1.4. Results

2.1.4.1. Color preference for the activity room. The participants slightly preferred warm colors (54%) over cool colors (46%) for the activity room, with no significant differences between genders (Fig. 4). The most preferred warm-color choice of both genders for the activity room was yellow (29%), followed by red (14%) for women and orange (15%) for men. The preferred cool-color choice of both genders for the activity room was green (24%), followed by blue (15%) and purple (7%). We conclude that the elderly prefers activity rooms with colors located in the center of the visible spectrum (green-yellow), with a tendency toward longer wavelengths (red and orange), that is, warm colors over colors cool colors with shorter wavelengths (purple and blue).

2.1.4.2. Color preference for the bedroom. The participants preferred cool colors (64%) to warm (36%) in the bedroom, with similar percentages between the genders (Fig. 5). The most preferred cool-color choice of both genders for bedrooms was green (26%), followed by blue for men (24%) and purple for women (21%). The preferred warm-color choice of both genders for bedrooms was yellow (17%), followed by orange (10%) and red (9%), again with similar percentages between genders for the latter two. We conclude that elderly people prefer bedrooms with colors located in the center of the visible spectrum (green-yellow) with a tendency toward cool colors with lower wavelengths (purple and blue) over warm colors with longer wavelengths (red and orange).

2.2. Experiment 2. physiological evaluation of colors for activity rooms and bedrooms in the laboratory setting

2.2.1. Participants

A total of 20 elderly people, 10 men and 10 women, with an average age of 73.5 ($\pm$3.1 SD), participated in the experiment. The Valencian Biomechanic Institute (IBV) staff recruited the participants via a personal telephone call following their user's panel and a support questionnaire. The individuals fitted the profile of potential users of nursing homes, that is, people over 70 years of age currently living at home. Each participant had visited a nursing home in the previous 12 months and did not suffer

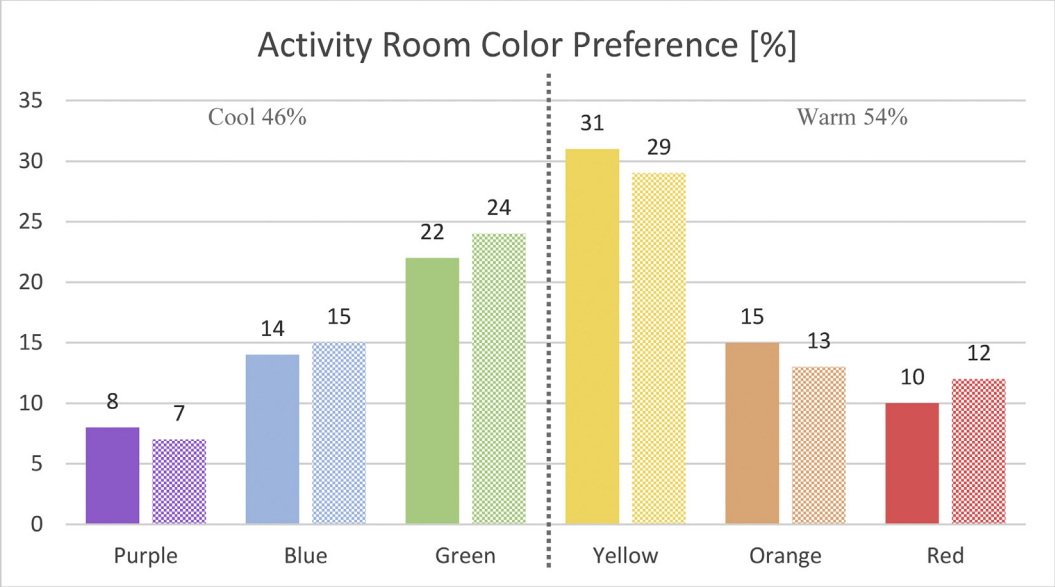

Fig. 4 Experiment 1. Color preference for the activity room for both genders: ■ Males and □ Females.

from any physical, cognitive, or visual limitations to complete the experiment.[1] In a pre-experiment step, individuals assessed their ability to discriminate colors through the Farnsworth—Munsell D-15 Dichotomous Color Blindness test, and those with color deficiencies were excluded.

2.2.2. Stimuli

Experiment 2 used the same stimuli as in Experiment 1, an activity room and a bedroom of an existing nursing home, with a set each of three cool and three warm-colored walls with the same NCS notations. Although the spaces depicted were the same as in Experiment 1, Experiment 2 used a display system with VR glasses with a 360° surrounding spherical panorama for the activity room, and a 50-inch TV screen for the bedroom (Fig. 6). The complete activity room was visible by gazing in any direction by moving the head from side to side. Two different display systems were used to prevent the elderly people from becoming dizzy from using the immersive glasses for an extended period (Kamińska et al., 2018). In both cases, the devices were pre-calibrated to ensure that the displayed color is consistent with the intended color. The stimuli were presented randomly for 10 s.

2.2.3. Method

Experiment 2 was conducted in the laboratory setting during the morning between 10:00 and 14:00 and used the same methodology as Experiment 1 to collect the following: (1) general information about the subjects, (2) their color preferences for the activity room, and (3) their color preference for the bedroom. Furthermore, the individuals' emotions were assessed through physiological measures of physiological variables, such as HRV. Although this variable depends on the autonomous nervous system, it is controlled by different subsystems, namely, sympathetic and parasympathetic, and can yield different results with certain stimuli (Ahuja et al., 2003).

2.2.3.1. Heart rate variability (HRV). HRV is a non-invasive tool for measuring the status of the autonomic nervous system and relates to the balance between the sympathetic and parasympathetic nervous systems when faced with physical and psychological challenges (Shaffer and Ginsberg, 2017). HRV is inversely related to emotional intensity and arousal. When the individual is facing high cognitive or emotional demand, the heart maintains a fixed rhythm with reduced cardiac variability to optimize performance. The HRV is high when the subject is relaxed or less activated (Appelhans and Luecken, 2006).

The HRV was measured during exposure to different chromatic stimuli using the standard deviation variable of NN intervals. This variable is defined as the standard deviation of the normal intervals between beats, excluding those outside the heart's sinus rhythm. This parameter is a reference pattern for cardiac variability.

2.2.4. Results

To study the influence of room colors on the individuals' arousal levels, the HRV was registered for the different

[1] The exclusion criteria for participants was: Cataracts, color blindness, vision problems, etc; use of progressive lenses; Drink coffee or stimulants in the 2 h prior to the test; Limitation for performing basic AVDs.; Vascular Brain Accidents (CVA); Motor disorders with derivatives of the nervous and/or peripheral system; Diagnosed anxiety, Severe heart disease and/or hypertension without treatment; Recent surgery (less than 3 months ago); Consumption of antidepressants, alcohol or other addictive substances; Depression; Cognitive impairment; Severe hearing loss; To be in a situation of serious or moderate high dependency; Progressive or terminal illness; Serious illnesses or interventions that have required hospitalization in the last 6 months; Epilepsy; Recent or unresolved fractures (less than 6 months ago); Muscular degenerative pathology; Polyneuropathies; Frequent problems of vertigo, dizziness or loss of balance in treatment (eg medication); or Severe neurological problems.

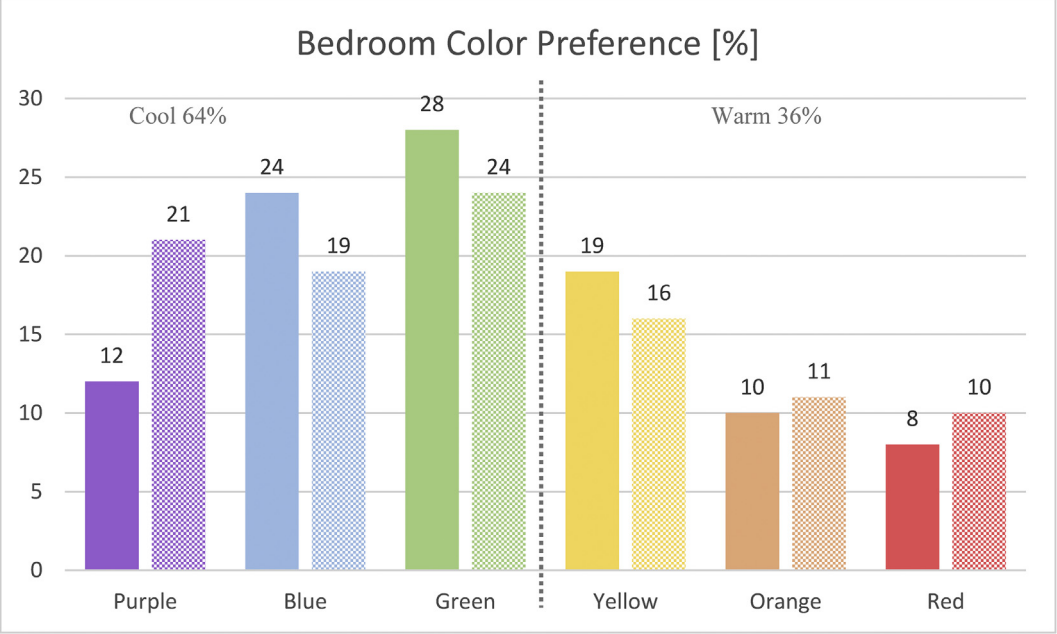

Fig. 5 Experiment 1. Color preference for the bedroom for both genders: ■ Males and □ Females.

chromatic alternatives. Statistical tests were performed to discover whether or not differences exist in the subjects' arousal levels based on room color (Kruskal—Wallis Test). The differences in the subjects' arousal due to room color were analyzed by gender, segmenting the sample between males and females. In addition, for each of the colors, we analyzed whether or not any statistically significant differences exist in the arousal level in the males' group compared with the females' group (Mann-Whitney *U* test).

2.2.4.1. Physiological evaluation of color in the activity room. In the activity room, statistically significant differences in HRV levels were identified based on room color in the analysis of the individuals as a whole and in the females' group, but not in the males' group. Fig. 7 shows the HRV for the activity room colors. The order of the colors from the most to least arousing based on the HRV is yellow, purple, orange, green, red, and blue. As previously discussed, an individual's arousal level is inversely related to the HRV. For both genders, the group of warm colors is more arousing than the group of cool colors. The yellow activity room caused the highest arousal based on the HRV, and the arousal was higher in females than in males, whereas the blue activity room caused the lowest arousal level in both males and females.

The main results in terms of the arousal levels caused by the different colors are as follows:

- The activity rooms with warm colors caused greater arousal levels than the cool colors in both genders, but statistically significant in females only.
- The yellow activity room was the most arousing for both genders based on the HRV, and the arousal was higher in females than in males.
- The blue activity room was the least arousing for both genders based on the HRV, and the arousal was lower in females than in males.

2.2.4.2. Physiological evaluations of color in the bedroom. In the bedroom, no statistically significant differences in HRV levels were identified based on room color in the analysis of the individuals as a whole, and by gender.

Fig. 6 Experiment 2. Display systems used to evaluate (a) the activity room and (b) the bedroom.

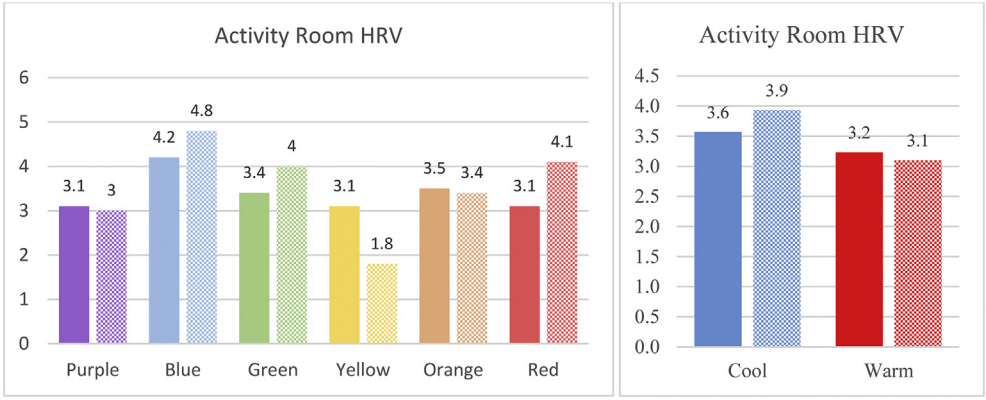

Fig. 7 Experiment 2. Activity room HRV induced by colors, for both genders: ■ Males and □ females.

Fewer differences in physiological markers based on bedroom color than the activity room color were observed, with the biggest difference in the level of HRV in the males' group. Fig. 8 shows the HRV for the bedroom colors. Interestingly, the order of the colors from most to least arousing based on the HRV for the males' group matches the visual spectral order: purple, blue, green, yellow, orange, red; the order for the females group is red, blue, purple-green-orange, yellow. For males, the group of cool colors is more arousing than the warm colors. For females, warm colors are more arousing than cool colors.

The red and purple bedrooms caused considerably different arousal levels in males and females based on the HRV. The red bedroom caused higher arousal levels in the females than in the males. The purple bedroom caused higher arousal levels in the males than in the females. Therefore, although no statistically significant differences in the physiological responses to colors was observed among the females, we can confirm different trends between the female and male groups in terms of the arousal generated by the colors.

The main results in terms of the arousal level caused by the different bedroom colors and according to the HRV are as follows:

- The bedrooms with warm colors caused higher arousal levels than the cool colors in females, but not in males.
- The red bedroom had different effects on males and females, being the most arousing for females and the least arousing for males.
- The purple bedroom had different effects on males and females, being the most arousing for males, but not for females.

3. Discussion

After Experiment 1, to assess the color preferences for activity rooms and bedrooms of individuals living in publicly owned nursing homes in the Valencian Community (Spain), we demonstrate that elderly people considered warm hues rather than cool as more appropriate for the activity room and preferred cool colors over warm colors for the bedroom. Therefore, we confirm that the color preference in an architectural space varies depending on the type of activity for which it is intended, which is consistent with the reports of other researchers (Manav, 2007; Slatter and Whitfield, 1977). The preference for warm colors in the activity room is consistent with the results of previous studies about color preferences for living rooms in Western European countries, like Holland (Bakker et al., 2015, p. 5). Nevertheless, this color preference for interiors might be cultural because in other countries, like Turkey, people

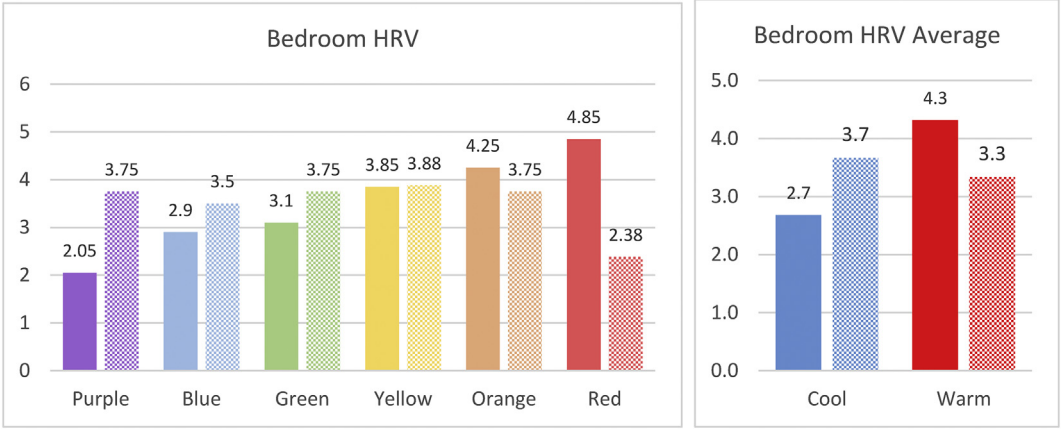

Fig. 8 Experiment 2. Bedroom HRV induced by colors, for both genders: ■ Males and □ Females.

prefer a cool light or blue color instead of warm colors for living rooms (Manav, 2007).

No significant gender-based differences were found, although the preference for warm colors in the activity room was more evident in males than in females. This result is consistent with those of previous studies that reported no significant differences between males and females in terms of color preferences (Hsiao et al., 2008; Jadva et al., 2010; Ou et al., 2004b; Yener; Gu, 2002). In our study, among the warm colors, the preference order of both genders was yellow, orange, and red. Among the cool colors, both genders preferred green, followed by blue and purple, although the females preferred purple over blue for the bedroom. This slight difference in female's preference for bedroom colors is consistent with other studies that found gender differences in color preferences for bedrooms and work areas, but not for other rooms (Bakker et al., 2015). In our study, for both warm and cool hues, the preference for a color increases when it approaches the center of the visible spectrum (yellow and green hues), and vice versa (purple or red).

Experiment 2 was developed to assess the arousal level induced by activity room and bedroom colors in elderly people using VR in a laboratory and the physiological measurement of the HRV. Warm colors caused higher arousal levels than cool colors in both genders for the activity room and in females for the bedroom, and the results were statistically significant for the activity room in females. The yellow activity room was the most arousing, while the blue activity room was the least arousing for both genders based on the HRV. These results are consistent with those of previous studies demonstrating that warm-colored rooms evoke higher arousal than cool-colored rooms (AL-Ayash et al., 2016; Goldstein, 1942; Jacobs and Hustmyer, 1974; Küller et al., 2009). On the contrary, for the bedroom, we found that warm colors induced high arousal levels just for females, but not for males. In our study, lower emotional reactions were recorded for the bedrooms than for the activity rooms, which might be explained by the fact that a different display system was used in each case study. The flat screens used for the bedrooms reduced the emotional reaction of the subjects to different chromatic stimuli compared to observation through the immersive virtual reality used for the activity rooms, what is consistent with other studies (Ding et al., 2018). Interestingly, the order of the bedroom colors from most to least arousing for the males' group matches the visual spectral order: purple, blue, green, yellow, orange, red ($P < B < G < Y < O$). As mentioned, experimental studies demonstrate that long-wavelength colors, red and yellow, are more arousing than short-wavelength colors, blue and green (Valdez and Mehrabian, 1994). Nevertheless, other authors suggest a possible U-shaped relation with arousal in the visible spectrum, with the colors at the ends (i.e., red and purple) being more arousing than the colors at the center (e.g., green); thus, the arousal levels of the colors might follow $R > O > Y > G < B < P$ (Wilson, 1966, p. 949). In our study, the arousal levels induced by the colors at the ends of the visible spectrum (i.e., purple and red) have significant differences between genders.

The comparison of the results of Experiments 1 and 2 shows that, for the activity rooms, the color preference of warm over cool colors matches with the high arousal levels induced by warm colors over cool colors for both genders. The yellow activity room is the most arousing for both genders and the most preferred. The expected activity to be developed in the activity room, which is social and thus requires high activation, might determine the selection of colors that induce high arousal levels. On the contrary, in the case of the bedroom, the cool colors preference over warm colors by both genders just matches the low arousal levels induced by cool colors over warm in females, but not in males. For females, the red bedroom was the most arousing and also the least preferred, but for males, the purple bedroom was the most arousing but not the least preferred. The expected activity to be developed in the bedroom, which requires low activation, might determine the tendency to select colors that induce low arousal levels. However, in our study, this was only true for females and not for males. Nevertheless, Wilson's proposed hue order based on a U-shaped arousal level ($R > O > Y > G < B < P$) perfectly fits with the bedroom color preferences in our study ($R < O < Y < G > B > P$) albeit in reverse order. Thus, according to Wilson's results, the elderly people in our study would prefer less-arousing colors for the bedroom.

The present research has some limitations. On one hand, among the three perceptual variables to describe a color, namely, hue, value, and saturation, our study focused on the influence of hue in the preference for nursing homes' interior spaces. Furthermore, some researchers conclude that saturation can be more important than hue in emotional response (Gao and Xin, 2006; Gao et al., 2007) and also suggest that the value of color is crucial in the design of nursing facilities for seniors with visual impairments (Owsley, 2011; Suzuki et al., 2012). In this sense, future research is necessary to analyze the influence of saturation and value on color preference for nursing homes. On the other hand, the preference between warm and cool colors might be oriented by other aspects, such as the expected thermal comfort in each room, as the emotional relationships red-warm and blue-cool are quite universal (Lee et al., 2009). In future research with real environments, the temperature of a setting may be included to observe how far participants react to warm and cool temperatures and analyze this influence in the red versus blue color preference. Finally, given that our study is culturally framed in a specific population located in Spain, we must indicate that many cultural issues might be influencing our results, so intercultural comparisons would be very interesting. Other aspects, such as the relationship between color preference and the visual complexity of a space, are outside the scope of our study but worth studying in future research.

4. Conclusions

The main objective of the present study was to identify the color preferences of elderly residents for the interior spaces of nursing homes on the basis of the expected activities in different rooms, activity rooms, and bedrooms and compare the results with the arousal level induced by each color. Two experiments were carried out, one with

elderly people living in a nursing home, and the other in a laboratory setting with VR and physiological markers (e.g., HRV). In both cases, individuals assessed 6 colors in two groups of warm (red, orange, yellow) and cool colors (purple, red, green).

Findings indicate that preferences for warm and cool colors depend on the room type. For the activity rooms in nursing homes, which are places for social activities and require higher activation, elderly people of both genders prefer warm colors over cool, with the biggest preference for the warm hue nearest the center of the visual spectra, that is, yellow. This color preference in the activity room fits the high arousal levels induced by warm colors versus cool colors. In the case of the bedrooms in nursing homes, which are places to rest and require low activation, elderly people of both genders prefer cool colors over warm colors, with the highest preference for the cool hue nearest the center of the visual spectra, that is, green. This color preference in the bedrooms fits the low arousal levels induced by cool colors in females and the other models that suggest low arousal levels in the colors of the center of the visual spectra (i.e., green) and high in the ends (i.e., red and purple) (e.g., Wilson, 1966). Therefore, the color preferences for interior spaces in nursing homes depend on the room type and are related to the arousal level expected for the activity conducted in them.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgements

This paper is part of the research project, "Modifications of the Visual Comfort in Residential Centers to Improve the Quality of Life for the Elderly," funded by the Ministry of Economy and Competitiveness (Ministerio de Economía y Competitividad), Spain [Grant Number BIA2016-79308-R]. We thank Dr. Begoña Mateo, D. José Francisco Serrano and D. Carlos Planells, members of the IBV, for their assistance in the development of Experiment 2.

References

Ahuja, N.D., Agarwal, A.K., Mehta, N.H., Mahajan, N.M., Kapadia, H.N., 2003. GSR and HRV: its application in clinical diagnosis. In: Proceedings of the IEEE Symposium on Computer-Based Medical Systems, pp. 279—283.

Ainsworth, R.A., Simpson, L., Cassell, D., 1993. Effects of three colors in an office interior on mood and performance. Percept. Mot. Skills 76, 235—241.

AL-Ayash, A., Kane, R.T., Smith, D., Green-Armytage, P., 2016. The influence of color on student emotion, heart rate, and performance in learning environments. Color Res. Appl. 41 (2), 196—205.

Al-Rasheed, A.S., 2015. An experimental study of gender and cultural differences in hue preference. Front. Psychol. 6, 1—5.

Appelhans, B.M., Luecken, L.J., 2006. Heart rate variability as an index of regulated emotional responding. Rev. Gen. Psychol. 10, 229—240.

Baget i Bernàldiz, M., Fontoba i Poveda, B., 2013. Información y consejos para promover la salud visual en personas mayores, first ed. Institut de l'Envelliment UAB, Barcelona.

Bakker, I., Van Der Voordt, T., Vink, P., De Boon, J., Bazley, C., 2015. Color preferences for different topics in connection to personal characteristics. Color Res. Appl. 40, 62—71.

Barnes, S., 2006. Space, choice and control, and quality of life in care settings for older people. Environ. Behav. 38, 589—604.

Beke, L., Kutas, G., Kwak, Y., Sung, G.Y., Park, D.S., Bodrogi, P., 2008. Color preference of aged observers compared to young observers. Color Res. Appl. 33, 381—394.

Bimler, D.L., Kirkland, J., Jameson, K.A., 2004. Quantifying variations in personal color spaces: are there sex differences in color vision? Color Res. Appl. 29, 128—134.

Bosch, S.J., Cama, R., Edelstein, E., Malkin, J., 2012. The Application Of Color In Healthcare Settings. The Center for Health Design, EE.UU (Article).

Camgöz, N., Yener, C., Güvenç, D., 2004. Effects of hue, saturation, and brightness: Part 2: Attention. Color Res. Appl. 29, 20—28.

Costa, M., Frumento, S., Nese, M., Predieri, I., 2018. Interior color and psychological functioning in a university residence hall. Front. Psychol. 9.

Cubukcu, E., Kahraman, I., 2008. Hue, saturation, lightness, and building exterior preference: an empirical study in Turkey comparing architects' and nonarchitects' evaluative and cognitive judgments. Color Res. Appl. 33, 395—405.

Dalke, H., Little, J., Niemann, E., Camgoz, N., Steadman, G., Hill, S., Stott, L., 2006. Colour and lighting in hospital design. Optic Laser. Technol. 38 (4—6), 343—365.

Dalke, H., Matheson, M., 2003. Colour Design Schemes for Long-Term Healthcare Environments Arts and Humanities Research Council Colour Design Schemes for Long-Term Healthcare Environments. Kingston University, London.

Delcampo-Carda, A., Torres-Barchino, A., Serra-Lluch, J., 2019. Chromatic interior environments for the elderly: a literature review. Color Res. Appl. 44, 381—395.

Delcampo Carda, A., Torres Barchino, A., 2016. El uso del color como recurso para reforzar intenciones arquitectónicas: estudio de tres intervenciones en espacios para la salud y el bienestar. In: Michinel Álvarez, H. (Ed.), XI Congreso Nacional de Color. Sedóptica, Comité del Color., Orense, pp. 39—42.

Ding, N., Zhou, W., Fung, A.Y.H., 2018. Emotional effect of cinematic VR compared with traditional 2D film. Telematics Inf. 35, 1572—1579.

Eijkelenboom, A., Verbeek, H., Felix, E., van Hoof, J., 2017. Architectural factors influencing the sense of home in nursing homes: an operationalization for practice. Front. Archit. Res. 6, 111—122.

Fortmann-Roe, S., 2013. Effects of hue, saturation, and brightness on color preference in social networks: gender-based color preference on the social networking site Twitter. Color Res. Appl. 38, 196—202.

Gao, X.P., Xin, J.H., 2006. Investigation of human's emotional responses on colors. Color Res. Appl. 31 (5), 411—417.

Gao, X.P., Xin, J.H., Sato, T., Hansuebsai, A., Scalzo, M., Kajiwara, K., Guan, S.S., Valldeperas, J., Lis, M.J., Billger, M., 2007. Analysis of cross-cultural color emotion. Color Res. Appl. 32 (3), 223—229.

Goldstein, K., 1942. Some experimental observations concerning the influence of colors on the function of the organism. Am. J. Phys. Med. Rehabil. 21.

Goodman, J., Brewster, S.A., Gray, P., 2005. How can we best use landmarks to support older people in navigation? Behav. Inf. Technol. 24, 3—20.
Guan, S.S., Hung, P.S., 2010. Influences of psychological factors on image color preferences evaluation. Color Res. Appl. 35, 213—232.
Hamid, P.N., Newport, A.G., 1989. Effect of colour on physical strength and mood in children. Percept. Mot. Skills 179—185.
De Heer, J., 2009. The Architectonic Colour : Polychromy in the Purist Architecture of Le Corbusier. 010 Publishers.
Heller, E., 2004. Psicología del color: cómo actúan los colores sobre los sentimientos y la razón. Gustavo Gili, Barcelona.
Hsiao, S.W., Chiu, F.Y., Hsu, H.Y., 2008. A computer-assisted colour selection system based on aesthetic measure for colour harmony and fuzzy logic theory. Color Res. Appl. 33, 411—423.
Hurlbert, A.C., Ling, Y., 2007. Biological components of sex differences in color preference. Curr. Biol. 17, R623—R625.
Itten, J., 1987. Design and Form : the Basic Course at the Bauhaus. Thames & Hudson, London.
Jacobs, K.W., Hustmyer, F.E., 1974. Effects of four psychological primary colors on GSR, heart rate and respiration rate. Percept. Mot. Skills 38, 763—766.
Jadva, V., Hines, M., Golombok, S., 2010. Infants' preferences for toys, colors, and shapes: sex differences and similarities. Arch. Sex. Behav. 39, 1261—1273.
Joseph, A., Choi, Y.S., Quan, X., 2016. Impact of the physical environment of residential health, care, and support facilities (RHCSF) on staff and residents: a systematic review of the literature. Environ. Behav. 48, 1203—1241.
Kamińska, M.S., Miller, A., Rotter, I., Szylińska, A., Grochans, E., 2018. The effectiveness of virtual reality training in reducing the risk of falls among elderly people. Clin. Interv. Aging 13, 2329—2338.
Kaya, N., Crosby, M., 2006. Color associations with different building types: an experimental study on American college students. Color Res. Appl. 31, 67—71.
Küller, R., Mikellides, B., Janssens, J., 2009. Color, arousal, and performance - a comparison of three experiments. Color Res. Appl. 34, 141—152.
Kwallek, N., Lewis, C.M., Lin-Hsiao, J.W.D., Woodson, H., 1996. Effects of nine monochromatic office interior colors on clerical tasks and worker mood. Color Res. Appl. 21, 448—458.
Kwallek, N., Soon, K., Lewis, C.M., 2007. Work week productivity, visual complexity, and individual environmental sensitivity in three offices of different color interiors. Color Res. Appl. 32, 130—143.
Lawlor, D., Thomas, M.A., 2008. Residential Design for Aging in Place. John Wiley & Sons.
Lee, S., 2010. Understanding wayfinding for the elderly using VR. In: Proceedings of the 9th ACM SIGGRAPH Conference on Virtual-Reality Continuum and its Applications in Industry, VRCAI '10. ACM, New York, NY, USA, pp. 285—288.
Lee, W.Y., Luo, M.R., Ou, L.C., 2009. Assessing the affective feelings of two- and three-dimensional objects. Color Res. Appl. 34, 75—83.
Liu, Y., Kang, J., Zhang, Y., Wang, D., Mao, L., 2016. Visual comfort is affected by urban colorscape tones in hazy weather. Front. Archit. Res. 5, 453—465.
López-Tarruella, J., Llinares Millán, C., Serra Lluch, J., Iñarra Abad, S., Wijk, H., 2018. Influence of color in a lactation room on users' affective impressions and preferences. HERD. Health Environ. Res. Des. J. 193758671879659.
Manav, B., 2007. Color-emotion associations and color preferences: a case study for residences. Color Res. Appl. 32, 144—150.
Ou, L.-C., Luo, M.R., Woodcock, A., Wright, A., 2004a. A study of colour emotion and colour preference. Part I: colour emotions for single colours. Color Res. Appl. 29, 232—240.
Ou, L.C., Luo, M.R., Woodcock, A., Wright, A., 2004b. A study of colour emotion and colour preference. Part III: colour preference modeling. Color Res. Appl. 29, 381—389.
Owsley, C., 2011. Aging and vision. Vision Res. 51, 1610—1622.
Öztürk, E., Yilmazer, S., Ural, S.E., 2012. The effects of achromatic and chromatic color schemes on participants' task performance in and appraisals of an office environment. Color Res. Appl. 37, 359—366.
Passini, R., Pigot, H., Rainville, C., Tétreault, M.H., 2000. Wayfinding in a nursing home for advanced dementia of the Alzheimer's type. Environ. Behav. 32, 684—710.
Perkins, B., 2013. Building Type Basics for Senior Living, second ed. John Wiley & Sons.
Powell, M., 1985. The elderly in context: "perspectives from environmental psychology and gerontology. Environment 4, 501—519.
Read, M.A., 2003. Use of color in child care environments: application of color for wayfinding and space definition in Alabama child care environments. Early Child. Educ. J. 30, 233—239.
Read, M.A., Sugawara, A.I., Brandt, J.A., 1999. Impact of space and color in the physical environment on preschool children's cooperative behavior. Environ. Behav. 31, 413—428.
Sanz, J.C., Gallego, R., 2001. Diccionario del color, Diccionarios Akal. Akal, Madrid.
Serra, J., Llopis, J., Torres, A., Giménez, M., 2016. Color combination criteria in Le Corbusier's Purist architecture based on Salubra claviers from 1931. Color Res. Appl. 41, 85.
Serra Lluch, J., 2019. Color for Architects. Princeton Architectural Press, New York.
Shaffer, F., Ginsberg, J.P., 2017. An overview of heart rate variability metrics and norms. Front. Public Health 5.
Slatter, P.E., Whitfield, T.W.A., 1977. Room function and appropriateness judgments of color. Percept. Mot. Skills 45, 1068—1070.
Sloan, A., 1980. Housing for the elderly: cognitive considerations. Environ. Behav. 12, 451—465.
Suzuki, T., Okajima, K., Funai, T., 2012. Optical simulation of reduced retinal illuminance caused by senile miosis. Opt. Rev. 19, 174—181.
Tofle, R., Schwarz, B., Yoon, S., Max-Royale, A., 2004. Color in Health Care Environments: A Critical Review of the Literature. Coalition of Health. EE.UU, San Francisco, CA (article).
Torrington, J., 2003. Care Homes for Older People: A Briefing and Design Guide. Taylor & Francis.
UNFPA, International, H., 2012. Ageing in the Twenty-First Century: A Celebration and a Challenge (JOUR). United Nations Population Fund, New York & HelpAge International London.
Valdez, P., Mehrabian, A., 1994. Effects of color on emotions. J. Exp. Psychol. Gen. 123, 394—409.
Weal, F., 1988. Housing for the Elderly: Options and Design. Nichols Pub Co.
Whitfield, T.W.A., Slatter, P.E., 1978. The evaluation of architectural interior colour as a function of style of furnishings: categorization effects. Scand. J. Psychol. 19, 251—255.
Wilson, G.D., 1966. Arousal properties of red versus green. Percept. Mot. Skills 23, 947—949.
Winterbottom, M., Wilkins, A., 2009. Lighting and discomfort in the classroom. J. Environ. Psychol. 29, 63—75.
Yener, C., Gu, D., 2002. Effects of hue, saturation, and brightness on preference. Color Res. Appl. 27, 199—207.

Yerkes, R.M., Dodson, J.D., 1908. The relation of strength of stimulus to rapidity of habit-formation. J. Comp. Neurol. Psychol. 18, 459—482.

Yildirim, K., Akalin-Baskaya, A., Hidayetoglu, M.L., 2007. Effects of indoor color on mood and cognitive performance. Build. Environ. 42, 3233—3240.

Yildirim, K., Cagatay, K., Ayalp, N., 2015. Effect of wall colour on the perception of classrooms. Indoor Built Environ. 24, 607—616.

Yildirim, K., Hidayetoglu, M.L., Capanoglu, A., 2011. Effects of interior colors on mood and preference: comparisons of two living rooms. Percept. Mot. Skills 112, 509—524.