Effect of Area on Color Harmony in Simulated Interiors

Seden Odabaşıoğlu; Marmara University Department of Interior Architecture; İstanbul, Turkey
Nilgün Olguntürk; Bilkent University Department of Interior Architecture and Environmental Design; Ankara, Turkey

Abstract

The main aim of this study is to examine the effect of area on color harmony in simulated interior spaces. Area in color harmony is the relative amount of different color areas represented as a proportion, on which color harmony depends. Colors in the color scheme of an interior space are usually not applied in equal proportions of surface areas. Considering the complex relations of colors in interiors, it is important to search for the principles of color harmony and area effects. The secondary aim of the study is to investigate how the term color harmony is defined and the link between color harmony and related terms used to define it. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious. In this study, three primary (red, blue, yellow) and three secondary (green, purple, orange) colors of Itten's color wheel were studied in a simulated office interior with three-color schemes emphasizing different proportional use of each color. There were four color combinations, each consisting of six images differing in areas of the constituent colors. Firstly, participants evaluated the harmony content of the images by comparing them in pairs. Secondly, they evaluated each image regarding the thirteen terms related to color harmony. Findings indicated that area had an effect on color harmony for two of the color combinations (warm and cool color schemes). However, there were no strong but rather moderate and weak correlations between color harmony and the terms.

Introduction

Color harmony has been a focus of interest for many researchers for two centuries. Many theorists have defined color harmony with the principles they posited based on their experiences to create harmony [1-4]. There are also theories predicated on indicating the degree of color harmony with a mathematical formula [5-10]. These studies developed universal formulas for predicting color harmony, however it still needs to be tested for different conditions and cultures and they also have some features missing that should be considered, such as area effect and complex environments.

There have been a few theories about the influence of area on color harmony [11-14] and studies investigating color harmony in interior spaces [10, 15-16] are also few in number. These studies do not combine both the concepts of area and color harmony in the scope of interior spaces. However, area in color harmony is an important factor in interior spaces since colors usually are applied in different proportions in interiors on furniture, walls, floor and ceiling. All these aspects of interiors may be differently colored and accordingly the surface areas and relations of the colors may differ.

Method

This study mainly aims to examine the effect of area on color harmony in simulated interiors. Additionally, it also aims to investigate how the term color harmony was defined and the link between color harmony and related terms used to define it. The term color harmony is defined differently by different authorities and in experimental studies researchers prefer to use one of these definitions to inform the evaluators. However, it is also important to know how the evaluators define color harmony and according to what they evaluated a color scheme as harmonious. The related terms that are used to define color harmony can explain why a color scheme is evaluated as harmonious.

The hypotheses of the study are as follows:

1. Color harmony evaluations differ depending on the proportions of constituent colors' areas in interior spaces.
2. There is a strong and positive relationship between color harmony and the terms (proportion, balance, placement, similarity, lightness, liking, association, naturalness, warmth, relaxation, spaciousness, effect, pleasantness) used to define it.
3. There is a strong and positive relationship between all the terms (proportion, balance, placement, similarity, lightness, liking, association, naturalness, warmth, relaxation, spaciousness, effect, pleasantness) used to define color harmony.

Sample

The experiment was conducted with the participation of 60 subjects. The majority of the participants were university students (95%). Subjects had taken no color courses and had no knowledge of color. There were four sets of color combinations used in the experiment (see Specifying the Colors Section) and different subjects participated in the experiment for each four sets. Age ranges of the subjects for each set were 18-24 (M:20,20) for Set 1, 18-29 (M:20,13) for Set 2, 18-27 (M:20,20) for Set 3, and 18-44 (M: 22,13) for Set 4.

Experiment Room

The experiment was conducted in Color Laboratory of Faculty of Technical Education, at Marmara University. The laboratory had no windows and had a viewing condition appropriate for the standard ISO 3664:2009. This standard specifies viewing conditions for images as prints or images displayed on color monitors. The walls and all the furnishing were gray having a Munsell notation of N8. Additionally, the room had fluorescent lamps that simulate Illuminant D50 for illumination.

The monitor used in the experiments for showing the interior images was EIZO ColorEdge CG243W that was 24 inch wide format LCD and it had a monitor hood that prevents glare. The monitor was calibrated with i1-Pro2 spectrophotometer that measures detailed spectral information from LCD displays. The obtained values for black level, white point and brightness were 0.15 cd /m^2, 5016K and 80.2 cd/m^2 respectively. This data was saved as an ICC color profile to be used in the program that was utilized in the experiments for showing the images randomly.

Selecting the Function

Function of the interior space was specified as an office since in office environments furnishings, wall coverings, floor coverings are kept identical for all users and users are obliged to stay in these spaces. Plan of the office used in the visuals is given in Figure 1.

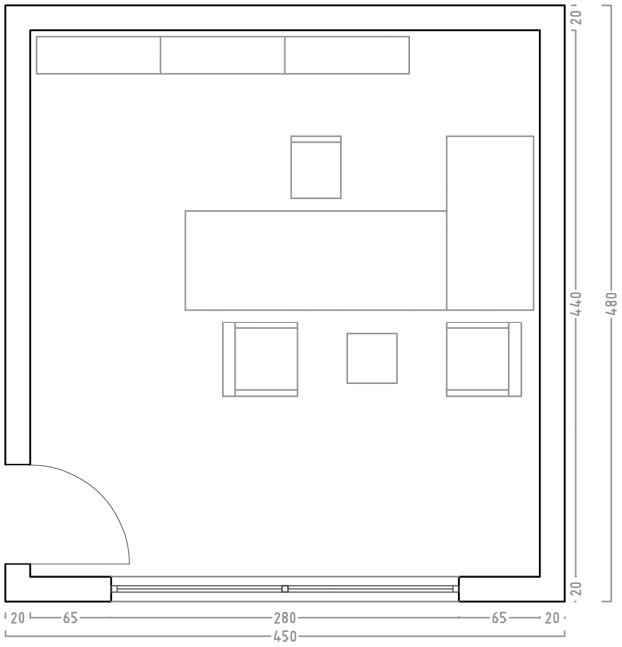

Figure 1. *Plan of the office.*

Specifying the Colors

Colors used in the experiments were selected as the three primary colors (red, blue, yellow) and three secondary colors (green, purple, orange) on Itten's color wheel. Four sets of three-color combinations were created by using these colors (see Table 1). Sets of three colors were applied to walls, table-bookshelf-coffee table, and to seating units. Floor and ceiling were gray.

Hue differences were searched in these experiments. Therefore, saturation levels of the selected colors were equal. The reflectance values of the ceiling, walls and furniture, and floor of offices were adjusted as 80%, 50% and 20% respectively, according to the recommendations of IESNA [17]. Since the colors that were subject to the harmony evaluations in the experiments were applied to walls and furniture, they had reflectance value of 50%.

Table 1. Four sets of three-color combinations and RGB values of the colors.

SET 1 (triadic color scheme 1)	Red: (R: 0.76 G: 0.38 B: 0.38) Blue: (R: 0.45 G: 0.45 B: 0.9) Yellow: (R: 0.5 G: 0.5 B: 0.25)
SET 2 (triadic color scheme 2)	Green: (R: 0.27 G: 0.56 B: 0.27) Purple: (R: 0.72 G: 0.36 B: 0.72) Orange: (R: 0.62 G: 0.46 B: 0.3)
SET 3 (warm color scheme)	Yellow-Red-Orange
SET 4 (cool color scheme)	Blue-Green-Purple

Creating the Interior Space

Interior spaces for the experiment were created in RADIANCE. The reason for using RADIANCE is that it is a physically based rendering software allowing accurate estimation of the properties of light to produce photometric models. It is important to obtain colors seen physically accurate since in 3D environments shadows and interreflections have an influence on perception of colors.

OSRAM Mira Led (CRI > 85, CCT 4000) was selected for the light source used in the simulated offices and the photometry file of this luminaire was used in RADIANCE for rendering. The horizontal illuminance level that was maintained at working level was approximately 400 lux.

Related to the areas of the perspective of the office, the proportions of the areas of walls, table-bookshelf-coffee table, seating units were as 9: 3: 1 respectively. Accordingly, the proportions of the three-color combinations were 9: 3: 1.

Preparing the Questionnaire

In a study previously conducted by the authors, the definition of color harmony was asked to 30 subjects in order to understand how they determine a color combination to be harmonious. The subjects responded to the questions 'What is color harmony according to you? How can a color combination be evaluated as harmonious?' and the content of their answers was analyzed. While analyzing the answers, words were accepted as a unit of analysis. The words that were used by the subjects to describe color harmony were counted. These words, the number of subjects using them and how many times they were repeated are shown in Table 2. For the reliability of the terms obtained and their categorization related to their content, another researcher also counted and categorized the terms independently from the authors. Data obtained from all of the researchers coincided 100%.

The terms derived from the answers of the subjects were transformed into a questionnaire by forming them into word pairs. This questionnaire consisted of 13 word pairs (proportional/not proportional, like/dislike, positive association/negative association, natural/unnatural, warm/cool, relaxed/tense, spacious/cramped, positive effect/negative effect, pleasant/unpleasant, well placed/not well placed, analogous/contrast, light/dark, balanced/imbalanced) was used in the third phase of the experiment (see Phases of the Experiment Section).

Table 2. The terms related to color harmony derived from the previously conducted study.

Word	Number of subjects using the word	%	Repetition of the word	%
Pleasing	16	19.5	16	16
Contrast/Analogous	14	17.1	15	16
Like	10	12.2	15	15
Balance	8	9.8	12	12
Tints & shades	8	9.7	9	9
Warm/Cool colors	7	8.6	7	7
Proportional	5	6.1	5	5
Spaciousness	4	4.9	5	5
Calmness	4	4.9	4	4
Natural colors	2	2.4	6	6
Association	2	2.4	4	4
Positive effect	1	1.2	1	1
Proximity & Distance	1	1.2	1	1

Phases of the Experiment

The experiment was conducted in three phases for all sets of color combinations. The participants entered the laboratory where the experiments were conducted one by one and the lights were on during the experiments. The reason for this was that the laboratory had a lighting condition appropriate for the standard ISO 3664:2009 that specifies viewing conditions for images as prints or images displayed on color monitors. The appropriateness of the ambient lighting level to this standard was checked with Eye-One Match program and it was close to the recommended illuminance level.

In the first phase, subjects were given Ishihara's Tests for Color-Blindness before participating in the experiment. Participants, who passed these tests, were allowed to attend the other phases.

In the second phase, there were 4 sets of three-color combinations applied to a created 3D office. Each set of combination had 6 images since the place of the colors were permutated (see Figure 2 for set 1). Each participant was shown the six possible combinations of the three-color combinations differing in their applied surfaces in the same space with a ratio of 9:3:1 which were paired up with each other for the comparison of their color harmony content. A computer program was used for mixing the images randomly.

In the third phase, all the six images used in the second phase were evaluated by the participants considering the related terms of color harmony in the questionnaire. Subjects evaluated the six images, one by one, by selecting one of the word pairs told to them for indicating which word is more closely associated with the color combination presented. The randomly-shown six images were assessed regarding the randomly asked word pairs.

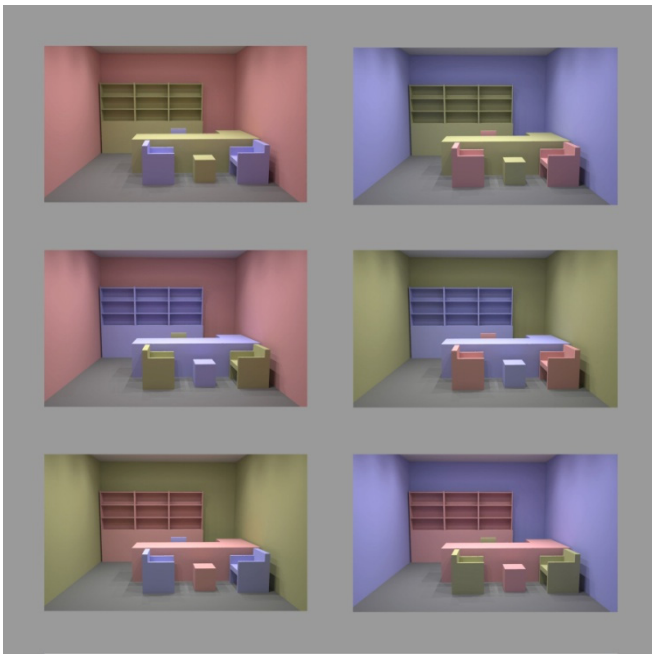

Figure 2. *Six images of Set 1.*

Results

After all the phases were finished, the collected data was firstly gathered as preference matrices formed by the choices of the subjects. The ranks obtained from the matrices were used for consistency, comparison and correlation analysis.

Consistency Analysis

As mentioned, in the second phase of the experiment harmony evaluations were conducted with paired comparison method. Although paired comparison is a time consuming task, it is the most direct and simple task for the observer that has clear and simple goals [18]. However, reluctance of the participants or the difficulty of the experimental task may cause inconsistencies in the final ranking. Thus, it is important to check the consistency of the evaluations of the observers, before conducting further analysis. The consistency coefficients were calculated for each participant according to the formula developed by Kendall & Smith [19]. The evaluations of the subjects who have higher coefficients of consistency over 0.3 were accepted as consistent. After the exclusion of the inconsistent subjects, further analysis of the data was done in SPSS 20.

Comparison Analysis

Following the consistency analysis, a Friedman test was conducted to understand whether or not there were significant differences in harmony between the color combinations in each set depending on the differences in area coverage. According to the Friedman test results, there were no significant differences between the images depending on the differences in the area coverage of the colors in the combination in Set 1 [$X^2(5)=7.117$, $p=0.212$] and Set 2 [$X^2(5)=5.249$, $p=0.386$]. Whereas there were significant differences between the images in Set 3 [$X^2(5)=13.291$, $p=0.021$] and Set 4 [$X^2(5)=11.508$, $p=0.42$]. In order to examine where the differences actually occurred in Set 3 and 4, post hoc tests were conducted. According to the results

there were significant differences between Office 5 and Office 2 (p=.018), Office 5 and Office 3 (p=.018), Office 5 and Office 4 (p=.005), and Office 1 and Office 4 (p=.028) in Set 3 (see Figure 3). In Set 4 there were significant differences between Office 1 and Office 4 (p=.015), Office 2 and Office 4 (p=.0008), and Office 2 and Office 5 (p=.032) (see Figure 4).

Considering these differences, when the mean ranks of these images were examined, it was found that in Set 3 (warm color combination), orange was the leading color that influenced the harmony evaluations of the subjects. The order of the harmony content of the combinations changed depending on the area covered by orange.

According to the mean ranks of the harmony evaluation of the images in Set 4 (cool color combination), it was found that blue was the leading color that influenced the harmony evaluations of the subjects. The order of the harmony content of the combinations changed depending on the area covered by blue.

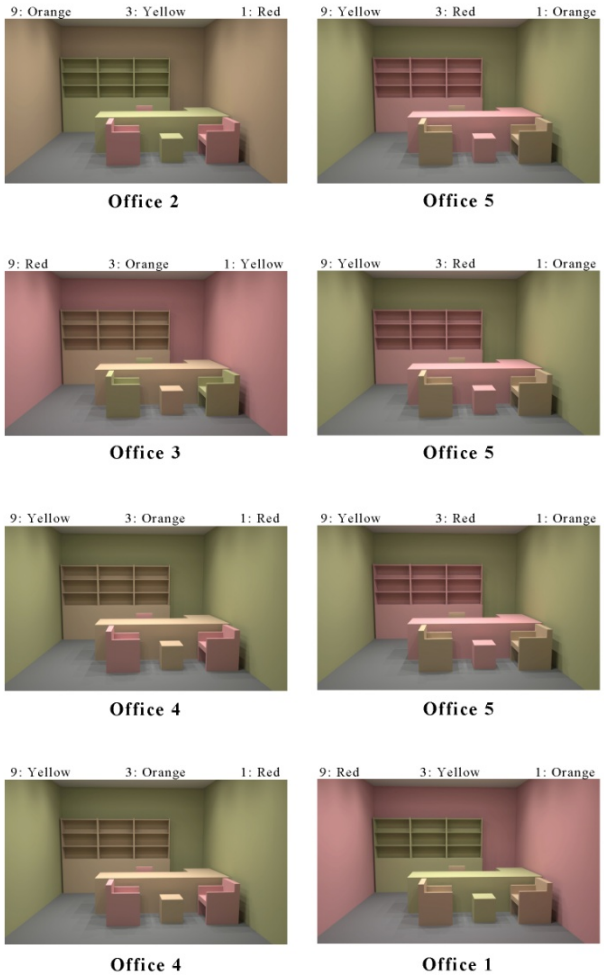

Figure 3. *Images having significant differences regarding color harmony in Set3. (The proportions of the colors is shown on top of each image. Mean ranks of harmony evaluations of the images from the lowest to the highest are Office 5: 2.35; Office 1:2.81; Office 6: 3.27; Office 2: 4.08, Office 3: 4.08; Office 4: 4.42).*

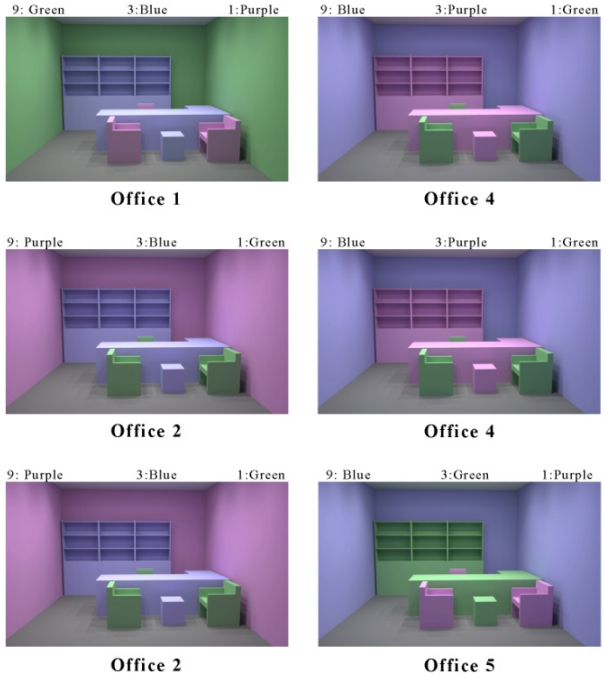

Figure 4. *Images having significant differences regarding color harmony in Set4. (The proportions of the colors is shown on top of each image. Mean ranks of harmony evaluations of the images from the lowest to the highest are Office 4: 2.57; Office*

Correlation Analysis

The items of the questionnaire used in the second phase of the experiment were expected to measure the same property, namely harmony. Thus, the reliability of the data obtained in the second phase of the experiment was tested using Cronbach's alpha. The reliability of the coefficient of the 13 items was 0,87. Since the acceptable reliability coefficient is above 0,70 [20] the scale was accepted as reliable and was used for further analysis.

Firstly, correlations of the harmony values of the images obtained in the first phase and the values of the related terms of the color harmony obtained in the second phase (summed for each image in all the sets) were analyzed to understand the relation with harmony and the terms used to define it. The findings showed that there were positive correlations between harmony and its related terms for fourteen of twenty-four images with a coefficient above 0.2, which is acceptable. Only one image, of these fourteen images, had strong correlations with the terms (r_s=.72), others had moderate, weak and very weak correlations.

Secondly, the correlations of the 13 word pairs were analyzed. The findings showed that the terms that had a strong correlation were pleasantness & association (r_s=.75), effect (r_s=.72), liking (r_s=.71) and association & effect (r_s=.70). The terms that had a moderate correlation were liking (r_s=.67), relaxation (r_s=.68), spaciousness (r_s=.67) & association; effect (r_s=.69), liking (r_s=.66) pleasantness (r_s=.63) & relaxation; effect (r_s=.67), liking (r_s=.59), pleasantness (r_s=.60), relaxation (r_s=.68) & spaciousness; effect (r_s=.69) & liking (see Table 3). Correlations between other terms ranged from weak to very weak.

Table 3. The correlations (Spearman) of the 13 word pairs.

		Terms related to object					Terms related to person							
		balance	lightness	placement	proportion	similarity	association	effect	liking	naturalness	pleasantness	relaxation	spaciousness	warmth
Terms related to object	balance	1												
	lightness	0.18	1											
	placement	0.39	0.05	1										
	proportion	0.47	0.14	0.39	1									
	similarity	0.26	0.23	0.18	0.30	1								
Terms related to person	association	0.47	0.34	0.30	0.33	0.20	1							
	effect	0.42	0.44	0.30	0.36	0.28	0.70	1						
	liking	0.47	0.34	0.32	0.34	0.28	0.67	0.69	1					
	naturalness	0.37	0.28	0.24	0.27	0.21	0.40	0.38	0.36	1				
	pleasantness	0.46	0.39	0.30	0.29	0.27	0.75	0.72	0.71	0.36	1			
	relaxation	0.41	0.40	0.27	0.32	0.23	0.68	0.69	0.66	0.36	0.63	1		
	spaciousness	0.32	0.48	0.21	0.25	0.22	0.67	0.67	0.59	0.41	0.60	0.68	1	
	warmth	0.25	0.25	0.23	0.23	0.09	0.38	0.42	0.30	0.25	0.32	0.32	0.27	1

strong moderate weak

The correlation coefficient of the terms proportion, balance & lightness, placement & similarity were below 0.2 and therefore they could be considered to have no correlation. According to the findings, participants liked the color combinations which had positive effects on them and which they found relaxed, spacious and pleasant associating with positive emotions.

In order to detect other relations between the terms, they were grouped into two as the terms related to object and the terms related to person. According to this categorization, the strong and moderate correlations were not within the terms related to the object but within the terms related to the person.

5. 2.90; Office 6: 3.30; Office 3: 3.63; Office 1: 4.23; Office 2: 4.37).

Conclusion

In this study, four color schemes were evaluated for their harmony content and differences were found only for the images in warm and cool color schemes. The relationship between color harmony and its related terms was also examined. It was found that there were no strong but rather moderate and weak correlations between the two. Regarding the relationship between the terms related to color harmony, it was found that there were significant and strong correlations between some of the terms (pleasantness-liking, association, effect; effect-association) but not all of them and these strong correlations were between the terms related to person.

The implications of the findings of the study can be concluded as follows:

1. Harmonious three-color combinations obtained from equilateral triangles on twelve part color wheel are found to be harmonious regardless of area differences.
2. In modified triads (warm and cool color scheme), area differences should be considered while applying these colors to an interior space.
3. Related to the second item, while applying a warm color scheme (red, yellow and orange) to an interior space, orange should cover the medium area for obtaining the most harmonious combination.
4. Related to the second item again, while applying a cool color scheme (blue, purple and green) to an interior space, blue should cover a medium area for obtaining the most harmonious combination.

This study contributes to the literature as a study of area effect on color harmony in interior spaces since area effect on color harmony has not been studied in interiors before. The implications of the findings of this study stated above can be used by architects and interior architects/designers to obtain pleasant and aesthetic spaces for a wider range of users. The findings of the study also can be used by researchers working on color.

Despite some meaningful results, the study has some limitations. One of the limitations of the study is due to color selection. In this study only 4 three-color combinations (differing in hue) were investigated however in future research the number of combinations can be increased with different hues, chromas or values. As the number of combinations increases a guideline for harmony with a large number of color combinations can be created for interior designers. Moreover, in this study, area effect on color harmony was investigated in an office. In future research the same study can be repeated and tested with different kinds of spaces especially public ones such as restaurants, cafes, bars and

schools. Furthermore, in this study gender, age and cultural differences in color harmony evaluation were not investigated. Future research might profit from looking into these other avenues of determining the best forms of creating harmony. Additionally, the effect of material-color associations on color harmony can also be investigated since there might be common material associations for each of the surfaces tested in this study and these associations that might cause people to accept certain colors more readily than others for some of the surfaces might affect harmony evaluations of colors.

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Authors Biography

Seden Odabaşıoğlu received her PhD in interior architecture and environmental design from Bilkent University (2015). Her works have focused on lighting and color perception in interior spaces.

Nilgün Olguntürk received her PhD in interior architecture and environmental design from Bilkent University (2000). Her works have focused on color, lighting and universal design.