THE PERCEPTION OF LIGHT AFFECTED BY COLOUR SURFACES IN INDOOR SPACES

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ABSTRACT

Visual comfort in indoor spaces depends on the amount and quality of light available and also on space characteristics. One of the most influential aspects is the colour of surfaces defining a space. Each colour has a reflectance coefficient resulting from how much light is reflected back from the coloured surface. However, from the observer's point of view, there are other factors that may affect visual perception of a space painted with colours. Some of them are psychological and depend on the background of the observer while other factors are physiological and are strongly connected to the sense of sight. According to this theory, architectural spaces could take advantage of the benefits of colour to improve visual responses for users.

In this paper, we present a case study in which three coloured spaces with different lighting conditions were assessed by a sample of observers. At the same time, luminance and illuminance measurements were taken so as to compare these values with light perceived in the spaces. The results of this field work show the influence that colour has on the perception of light in three-dimensional spaces and contribute to the study of colour in architecture.

Keywords: architecture, colour, visual comfort, light

INTRODUCTION

Dealing with visual comfort implies keeping in mind features of light and space configuration. Although attention is usually focused on light, space characteristics are vital to the visual response. One of the most important characteristics is the colour used on surfaces shaping a space. As a physical phenomenon, colour is a consequence of interaction between the reflecting properties of materials and the nature of incidental light. However, we can also explain colour from a perception standpoint, connected to psychological factors such as culture, age or education, and to physiological factors as well. These are influenced by the human visual system which shows a different degree of sensitivity based on light wavelength and objects. According to the photopic V (λ) and scotopic V' (λ) human response curve [1], maximum sensitivity corresponds to 555 and 505 nm, respectively. In photopic vision, this value is perceived as a greenish yellow.

In consequence, under the same lighting conditions, spaces can be perceived in a different way depending on the colours they are painted. On the one hand, the physical value which represents the amount of light returned by surfaces is luminance. It depends on incidental light and the reflection index of the colour. On the other hand, it has been noted that surfaces with the same luminance value but different colours are actually seen as having different brightness. In fact, brightness is the subjective perception of luminance [2]. Several studies have been done in the field of brightness and colour, but most of them compare small samples of colour among them as well as in contrast to a lighter or darker background [3].

Nevertheless, from the point of view of architectural spaces, which corresponds to a three-dimensional experience, little research has been conducted.

The aim of this study is to compare the physical phenomenon of colour and light with the human perception of it in order to determine if they coincide. As colour and brightness are the main parts of the theory of light and space in architecture [4], the results of the study can be applied to architecture, especially in the field of interior design where using colour can enhance perception of light in spaces.

METHOD

With this purpose in mind, three spaces were built in a controlled set. The set was appropriate because there was room enough to move in front of the spaces as well as because lighting conditions could be adjusted. The spaces, A, B and C, were of the same dimensions; 2m wide, 1.5m deep and 3m high, with no ceiling, as we see in Figure 1 and Figure 2.

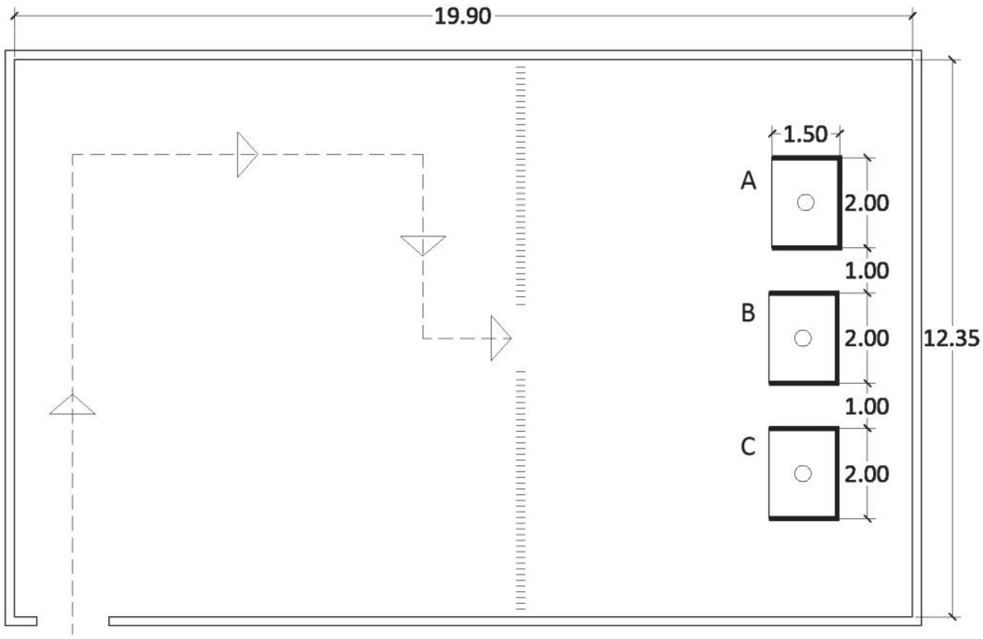

Figure 1: Plan of the set and Spaces A, B, C.

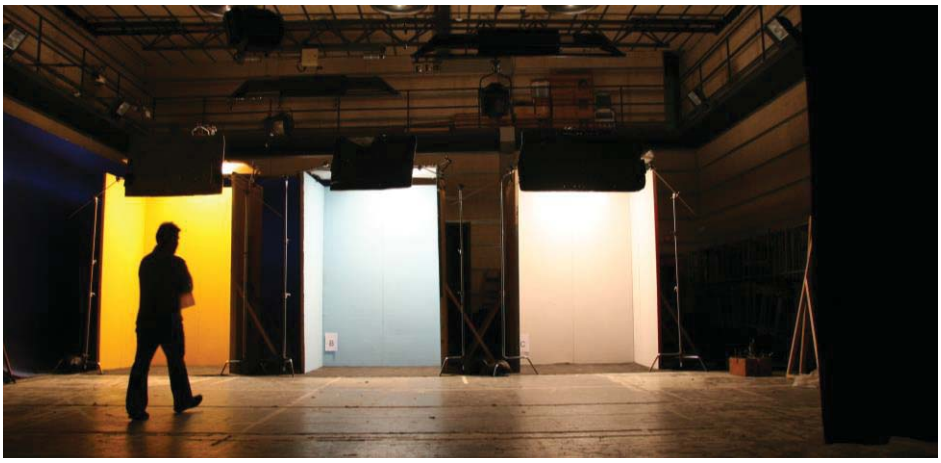

Figure 2: Front view of the set and spaces A, B, C

Each space was painted in a different colour: yellow (NCS S 1070-Y10R) for space A, blue (NCS S 1030-B) for space B, and grey (NCS S 1500-N) for space C. The choice started with a bright yellow because it is associated with a sensation of lightness. Besides, its wavelength is close to the point of highest sensitivity in the eye, according to the human response curve. The purpose was to compare an intense yellow with a grey with the same reflection index and with a slightly darker blue. The reflection index of each colour was calculated from the measurements of luminance and illuminance taken later on in the experiment. The equation (1) was used based on the assumption that all the surfaces were Lambertian. As a result, the experimental reflection indexes for each colour are: 0.64 for A (yellow), 0.50 for B (blue) and 0.66 for C (grey).

$$E \cdot r = \pi \cdot L \tag{1}$$

In order to compare the colours, two lighting arrangements were staged, combining two intensities of light; a starting intensity (I_1) and a modified intensity (I_2) which was half of the previous by means of a neutral filter. To these ends, the lighting fixtures were positioned in order to provide an illuminance level of approximately 900 lux at ground level for I_1. Using a filter, the intensity was reduced to I_2, becoming about 450 lux. A combination of both intensities led to the design of two lighting arrangements: in Arrangement 1, all the spaces had the same intensity (I_1), while in Arrangement 2 the intensity in Space A was reduced (I_2) and spaces B and C remained with I_1. The same lighting fixtures were used in each space: a Quars halogen lamp (2000W) in zenithal position filtered with a 50% Diffuser Frame so as to provide a diffuse and even light. A white board was placed in the upper part of the front side of each space to diffuse light and hide the lamps. The colour temperature and the lamps remained the same during the experiment.

Figure 3: Observer assessment

The spaces were assessed by a sample of observers (Figure 3). A total of 25 participants took part in the test, 9 males and 16 females, from 18 to 39 years old, with an average age of 25. All of them had normal vision with the exception of one, who had Daltonism. The participants were all students with basic knowledge of lighting. They were organised in groups of 3-5 that entered the set twice, each with a different lighting arrangement, and answered some questions about the perception of light. All the groups had a 15 minute gap between Arrangement 1 and 2. On entering the set, they were asked two questions: which space seemed to be lighter and which seemed to be darker. Furthermore, they had to estimate the difference of light in the spaces as “almost equal”, “slightly different” or “very different”.

Apart from the observer assessment, physical measurements were taken in each arrangement. While the measurements give quantitative data, the assessment offers a qualitative evaluation [5]. The measured parameters were illuminance and luminance. Illuminance was measured at ground level and in the middle of each vertical surface, 1.5m from the ground, half width. Luminance was measured in the middle of each vertical surface as well. The instruments used were a Konica Minolta LS-110 luminance meter and a Lutron lux meter.

RESULTS

The results of the measurements are divided into illuminance and luminance values. The first results were used to establish intensities in the lighting arrangements by placing the lighting fixtures and filters, as well as to calculate the reflection index of the colours. The luminance measurements were used as physical and objective data to assess the amount of light coming from vertical surfaces, although other studies take different parameters into consideration [3, 6]. Given that the observers could move freely throughout the set, an average value of luminance was considered to be most suitable. The value for each space resulted from the mean of luminance in the vertical surfaces. The results are shown in the tables and graphs below:

Luminance (cd/m^2)	**Space A**	**Space B**	**Space C**
Arrangement 1	124.0	109.0	149.7
Arrangement 2	65.5	109.0	149.7

Table 1: Average wall luminance values at 1.5m from ground level (cd/m^2) in each space, Arrangement 1 and Arrangement 2

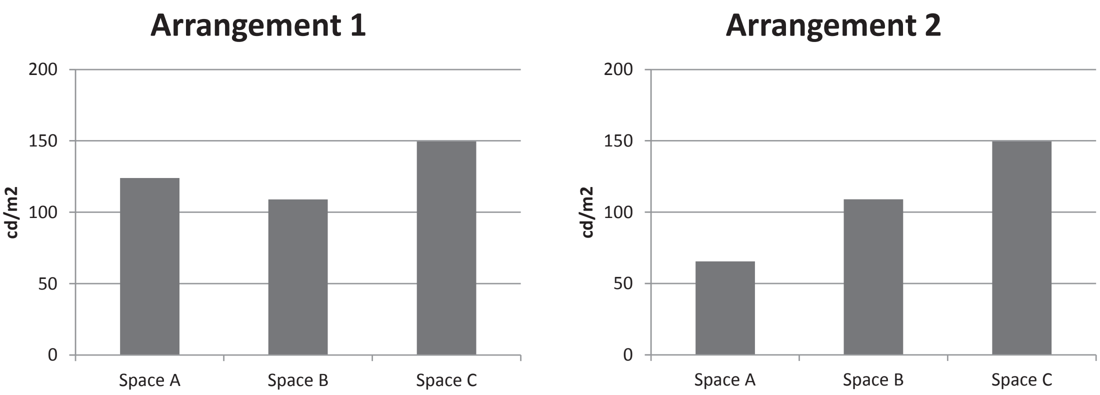

Figure 4: Average wall luminance values at 1.5m from ground level (cd/m^2) in each space, Arrangement 1 and Arrangement 2

Although the lighting conditions in Arrangement 1 were the same for all spaces, the measurements show that luminances are not equal, due to different reflection indexes in the colours. In the second arrangement, when darkening Space A, the measurements show that Space C is clearly the lightest and Space A is obviously the darkest.

The observer assessment comes in two parts. The first part contains the answers to questions about the quantity of light perceived in each space (Figure 5); the second part presents the degree of difference perceived in terms of light (Table 2). In the first part, there is a graph for each lighting arrangement showing the answer percentage. The answers are divided into three blocks, one for each space, containing two columns. The first column corresponds to answers about the brighter space and the second column shows answers to question about the darker space.

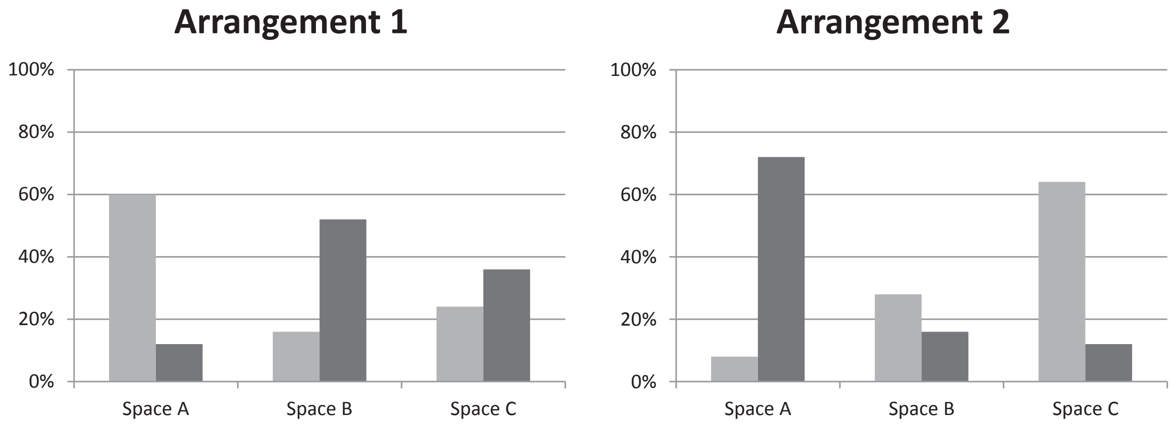

Figure 5: Graphs showing the percentage of responses in Arrangement 1 and Arrangement 2 to the questions: -Which space seems lighter? (light grey columns) -Which space seems darker? (dark grey columns)

In the second part of the results the observers estimated the degree of difference in perception of light in the spaces. It was important to highlight to what extent observers perceived differences in terms of light, because evaluating if this was easily perceived or not was significant. The answers are divided into three categories for each arrangement.

	Answers		
	Almost equal	**Slightly different**	**Very different**
Arrangement 1	44 %	56 %	0 %
Arrangement 2	48 %	48 %	4 %

Table 2: Percentage of answers to the question about the degree of difference in the perception of light in the spaces, Arrangement 1 and Arrangement 2.

DISCUSSION AND CONCLUSIONS

Once the measurements and the observer assessment were completed, the results obtained in both procedures could be compared. First of all, we see that the overall result of observer opinions in Arrangement 1 does not coincide with the measurements, while in Arrangement 2 it does. The assessment in Arrangement 1 concerns yellow and grey, which have a similar reflection index but do not give the same sensation to observers.

As mentioned above, the lighting conditions in Arrangement 1 were equal in all spaces. In Table 1 we see that the highest value of luminance was measured in Space C (149.7cd/m^2) while the lowest was in Space B (109cd/m^2). Space A is in the middle, with 124cd/m^2. Comparing these values with the observer assessment, we find that the majority of observers perceived Space A as the brightest instead of C. In regards to the darker space, opinions coincided with the measurements. The luminance is similar, but if we compare the values, Space C is 1.37 times lighter than B and 1.2 times lighter than A, which is not a big difference. According to the observer opinions (Table 2), none of them found the spaces “very different”; the opinions were divided between “almost equal” and “slightly different”. This corresponds to reality, because the measurements didn’t show prominent differences.

The results in Arrangement 2 are different. Here, the highest luminance value corresponds to Space C (149.7cd/m^2), while the lowest corresponds to Space A (65.5cd/m^2). The observer assessment coincided with the results, but not with the degree of difference perceived. If we compare the luminance values, we see that Space C is 2.28 times lighter than A, which means that the difference is noticeable. If we look at the observer assessment in Table 2, only 4% of observers perceived light in the spaces as “very different”, while 48% thought they were “almost equal”. The remaining 48% perceived them as “slightly different”. In this case, although Space C is much lighter than A, observers minimise the difference. It makes it clear that, from the observers’ point of view, yellow and grey do not offer the same sensation in terms of light.

We came to the conclusion that even though yellow and grey had the same reflection index, the surfaces painted with these colours offered a different sensation of light. While under the same lighting conditions the grey space looked dull and dark, the yellow space seemed brighter. What’s more, when the yellow space was darkened it was perceived as darker but to a lesser extent than what the measurements showed.

These results can be taken into account when designing a building, because the perception of light in buildings is vital to visual comfort. The design of interiors could take advantage of the fact that some colours offer more sensation of light than others under the same lighting conditions. This doesn’t mean that some colours should be banned or considered obligatory; it means that an intelligent use of colour may help to highlight some parts of a space and improve visual comfort for users. The use of colour goes beyond a choice based on reflection index, tastes or fashions.

ACKNOWLEDGEMENTS

The authors would like to thank the *Escola Superior de Cinema i Audiovisuals de Catalunya* (ESCAC) for providing the spaces where the field work was performed. We also want to thank ESCAC staff, the ESCAC Art Direction students and the *Architecture, Energy and Environment Master* students for their help during preparation of the study and for carrying out the assessments.

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