Color as a Psychological Agent to Perceived Indoor Environmental Quality

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Abstract. Achieving suitable and comfortable indoor environmental quality comfort via innovative, sustainable, energy efficient approaches is a contemporary research aim world-wide. The indoor space and its perception are influenced by three basic components: the surrounding factors (temperature, noise, odor, noise and lighting), the structural factors (architecture, color, materials, pattern, and structure) and the social factors (occupants). The relationship between IEQ and wellbeing is complicated. A range of indoor factors such as thermal, visual, acoustic, and chemical can impact the wellbeing, performance and health of the occupants. Colors are an interesting and well-studied psychological phenomenon. Colors, combinations, saturation and shades are the focus of advertising creators, interior designers and exteriors, architects, psychologists and many others. Specific colors and patterns have a direct influence on health, emotions, behavior, and performance of building users. Color is one of the basic properties of objects and environments. Colors have a great impact on our perception and evaluation. For example, it is proven that long-term stay in a deeply painted room is very nervous on the nervous system or that red and yellow tend to be seen as warning signals. A color's hue is determined by its wavelength [nm]. Long wavelengths are associated with warm colors, with red (~ 625–800 nm) being most extreme followed by orange (~ 590–625 nm). Short wavelengths are associated with cold colors, with violet (~ 430–500 nm) being most extreme followed by blue (~ 430–500 nm). In this study, the impact of indoor color’s use and indoor environmental quality is examined. The focus of this contribution is to establish a link between the color as IEQ parameter and health and well-being of occupants.

1. Introduction
The indoor environment is an essential determinant of sustainable building quality because people spend 90% of their time indoors. A number of studies aimed at evaluating the quality of the indoor environment were created in recent years. [1, 2]. Achieving suitable and comfortable indoor environmental quality comfort via innovative, sustainable, energy efficient approaches is a contemporary research aim world-wide. The perception of the quality of the indoor environment is determined by the chemical, physical and biological properties of the space, both exterior and interior. The indoor space and its perception are influenced by three essential components: the surrounding aspects (temperature, noise, odor, noise and lighting), structural aspects (architecture, color, materials, pattern, and structure) and social aspect (occupants) [3, 4]. The relationship between IEQ and wellbeing is complicated and multidisciplinary. A range of indoor factors such as thermal, visual, acoustic, and chemical can impact the wellbeing, performance and health of the occupants.
The physical component includes, among other things, optical and visual qualities, including the color of the indoor environment. The luminous environment is an important factor that has physiological and psychological effects [5]. Colors are an interesting and well-studied psychological phenomenon. Colors, combinations, saturation and shades are the focus of advertising creators, interior designers and exteriors, architects, psychologists and many others. Specific colors and patterns have a direct influence on health, emotions, behavior, and performance of building users. Color is one of the basic properties of objects and environments. Colors have a great impact on our perception and evaluation. For example, it is proven that long-term stay in a deeply painted room is very nervous on the nervous system or that red and yellow tend to be seen as warning signals. The color is determined by its wavelength [nm]. Long wavelengths are associated with warm colors, with red (~ 625–800 nm) being most extreme followed by orange (~ 590–625 nm). Short wavelengths are associated with cold colors, with violet (~ 430–500 nm) being most extreme followed by blue (~ 430–500 nm) [4].

2. Psychology of colors
Color psychology is the study of hues as a determinant of human behavior. Each color has a certain psychological value. Color and tone affect the comfort and productivity of the users of the indoor environment. Color perception varies depending on age, gender, origin, climatic conditions, etc. Psychological perception of color interior environment can vary widely over time and is not constant. Color perception can be perceived differently by everyone. In addition, people have a different style that also plays a significant role. Colors also play an important role in consumer marketing and behavior [6].

Every architect and designer need to take into account the color aspects of creating creative color interiors for both residential and commercial spaces. It is necessary to take into account the personal preferences of future users, cultural, geographic and economic influences and trends forecasts [7].

Red is the most intense color. The red color is vigorous and reportedly increases blood pressure. The red color is suitable for living room, dining room, kitchen and entrance hall. Its use should be considered and ideally used only as a complementary color in smaller areas. White is synonymous with order and purity. White color combines perfectly with other colors. The white color has the highest light reflectance and is suitable for smaller and dark spaces. Very often used in bathrooms. The red color does not fit into the bedroom. The yellow color expresses heat, sun and energy. Yellow is optimistic and open. Yellow color leads to higher performances and encourages appetite. Yellow is suitable for dining rooms, kitchens, offices and bathrooms. Yellow color reflects light well and is also suitable for darker and darker rooms. In too much, it can encourage anger and frustration. Orange is the color of gold, crop and richness. This color looks optimistic, solemn and gives a good mood. The orange color promotes appetite and is waterproof to the dining rooms, kitchens and also to the living room. The orange color shines even in dark rooms. Brown is the color of the earth symbolizing well-being and safety. Brown promotes concentration. The brown color is suitable for workrooms, hallways and living rooms. Green is the color of security, safety and peace. Green helps to focus. Green is suitable for almost all rooms. The light shade of the green color extends the space visually. Blue is the coolest color. Blue color induces humility, calm, but also cold. Blue slows heartbeat. It's the color of heaven and water. The blue color is suitable for a bedroom or bathroom. It is recommended to use lighter shades on larger areas. Blue color should be combined with warmer colors. Purple is emotive and exotic. Purple color promotes peace and harmony. It is suitable for a bedroom. Purple and white do not fit into the kitchen. Black color generally induces a negative feeling and sadness. It is also very elegant, mystical and luxurious. The black color reflects light at least and is particularly suitable as a complementary color. The gray color is neutral and has a dull, formal and dignified appearance. The gray color combines well with other colors. It is especially suitable for use in the study, living room and bedroom.
3. Results and discussions
The assessments of user’s perception of colors were carried out at the Institute of Technology and Business situated (České Budějovice, Czechia). Ten different university classrooms are observed. Two of the observed university classrooms are computer classrooms. Two classrooms serve as lecture halls for more than 200 listeners. One of them is equipped with a forced ventilation system. One classroom serves as a laboratory. The walls and ceilings are fitted with a classic internal plaster with white paint. Flooring is synthetic smooth flooring - linoleum. The windows are new, plastic with a shading system of internal blinds. The classroom equipment is classical and includes tables, chairs, whiteboard, computer and projector. Overall, 299 students were interviewed (82% men, 18% women). The small proportion of women is due to the common composition of students in technical fields (Civil Engineering). Before the lesson, the panelists indicated their immediate evaluation on two continuous scales regarding color comfort (CC) and overall satisfaction (OS). The scale of perceived colors applied in the interior has 5 levels: +2 too high, +1 high, 0 just right, -1 low, -2 too low. The scale of overall satisfaction includes 5 levels: +2 too high, +1 high, 0 just right, -1 low, -2 too low.

Figure 1 shows a correlation diagram (scatter plot) of perceived color comfort and perceived overall satisfaction with the internal environment. The data is represented as a set of points positioning on the horizontal axis indicates the value of perceived color comfort and location perceived overall satisfaction on the vertical axis. Data is interpolated by nonlinear dependence.

\[
y = -0.0226x^4 + 0.0046x^3 + 0.0687x^2 + 0.2036x + 0.3098 \\
R^2 = 0.0505
\]

**Figure 1.** Correlation diagram of color comfort and overall satisfaction

The choice of the statistical tool depends on the data distribution. First of all, it is necessary to decide whether the analyzed data samples (Color Comfort and Overall Satisfaction) come from normal data distribution (Gaussian distribution) or not. The normal distribution of the data sample could be verified by the Kolmogorov-Smirnov test for one choice. The principle of the Kolmogorov-Smirnov test of normality is to validate or reject the null hypothesis $H_0$ with the level of relevance 5%. The null hypothesis is that the random sample of an interval for $n$ elements originates from the basic file with a
normal distribution where the distribution function is \( F(x) \). If \( \text{Sig.} \) (p-value) is higher than the level of relevance 5%, the null hypothesis \( H_0 \) cannot be ruled out and is expected to be valid [8].

Table 1 shows the results of the Kolmogorov-Smirnov test of normality for color comfort and overall satisfaction, by means of a statistics editor IBM SPSS Statistics ver. 25. In this study, the values \( \text{Sig.} \) are in both cases less than the level of relevance. The null hypothesis \( H_0 \) cannot be accepted. Therefore, the alternative hypothesis \( H_A \) is assumed to be valid - The data sample does not originate from the basic file with the normal distribution. Non-parametric testing of hypotheses should be used for analyses of dependences.

|                      | Kolmogorov-Smirnov\(^a\) | Shapiro-Wilk |
|----------------------|--------------------------|--------------|
|                      | Statistic | df | Sig. | Statistic | df | Sig. |
| Color Comfort        | 0.317 | 299 | 0.000 | 0.820 | 299 | 0.000 |
| Overall Satisfaction | 0.338 | 299 | 0.000 | 0.791 | 299 | 0.000 |

\(^a\) Lilliefors Significance Correction

The correlation analysis is used to determine the closeness of dependence (the strength of relation) of two continuous random variables. The closeness of two random variables can range from complete absence of correlation (all values of \( Y \) occur with the same probability with any value of \( X \)) to absolute correlation (for each value \( Y \), there is an only one value of \( X \)) [8]. The correlation coefficient describes, in terms of quantity, the closeness of relation between two correlated quantities. Correlation between two random variables, \( X \) and \( Y \), with unknown distribution of probability and the degree of closeness of the relation are described using the Spearman correlation coefficient. The Spearman correlation coefficient is based on the rank of the element by their size and is related to both variables.

Table 2 shows the Spearman correlation coefficients for the color comfort and the overall satisfaction. Spearman’s correlation coefficient is equal to 0.209. This indicates a minor nonlinear dependence.

|                      | Overall Satisfaction |
|----------------------|----------------------|
| Color Comfort        | Correlation Coefficient | 0.209** |
|                      | Sig. (2-tailed)      | 0.000 |
|                      | N                    | 299 |

** Correlation is significant at the 0.001 level (2-tailed)

Despite the strength of interdependence is small, the Spearman test of independence is necessary [8]. It is inconceivable to verify the validity of the null hypothesis \( H_0 \) that the color comfort and overall satisfaction are random independent quantities. An alternative hypothesis \( H_A \) is that the color comfort and the overall satisfaction are random dependent quantities. The observed level of significance of the Spearman independence test for the relationship between color comfort and overall satisfaction \( (\text{Sig.} = 0.00) \) is less than the significance level 5% (respectively 1%). The null hypothesis is rejected in favor of an alternative hypothesis. The color comfort and overall satisfaction are random correlated quantities.

The determination coefficient is used to clarify clearly the dependence between two coefficients. The determination coefficient defines the percentage through which the parameter contributes to the final effect [8]. The color’s contribution to the overall satisfaction with indoor environmental quality is
4.368%. 95.632% of the indoor environmental quality is influenced by other factors than the color represented by the colors of the interior.

4. Conclusions

In this study, the impact of colors of the interior on the indoor environmental quality (IEQ) was examined. Results from approximately 300 panelists (students) showing that the perceived color comfort statistically significantly influences the perceived overall indoor quality. The correlation coefficient analysis is positive. Satisfaction with color comfort is positive, in contrast with a minority, reflected in the overall satisfaction with the indoor environment. The color’s contribution to the overall satisfaction with the indoor environmental quality is less than 5%. The indoor environment quality in the places used for education affects learning processes, concentration, and productivity of students. Various color attributes such as hue, color tone, saturation, value (brightness) and color harmony have an effect on behavioral responses and performance in the educational buildings. It can be assumed that indoor color is an effective tool to increase student’s comfort and performance. This knowledge is useful to develop appropriate strategies to create and maintain a sustainable indoor environment for education and training (schools and universities).

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