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VIRTUAL GO GREEN: CONFERENCE AND PUBLICATION

"Rethinking Built Environment: Towards a Sustainable Future"

Organiser:
Research, Industrial Linkages, Community & Alumni Network (PJIM&A)

Co-organiser:
Department of Built Environment Studies & Technology (JABT), Faculty of Architecture, Planning & Surveying (FSPU)

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Cool Colour Impact Towards Occupant's Thermal Comfort and Sensation

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Abstract
Colour being the characteristic of any indoor environment was commonly used for its beautification and triggering human behaviour, emotion and changing perceived dimension. However, the thermal impact of colour has rarely been used to its fullest benefits in the interior. This study aims to identify cool colours that influence occupants' thermal comfort and sensation. Content analysis and colour preference surveys have been carried out. Analysis of past studies found that cool colour consists of blue, blue-green, green, purple and purple-blue hue where cool colour has been identified to make people feel cooler in a warm environment. 3 sample colours with different ratios of brightness and saturation had been selected for blue-green, green, purple and purple-blue hues from the Munsell colour chart to be used in the colour preference survey. 390 participants from different ages, gender and race had volunteered in the survey. The most preferred colour for each hue was Summer space (green), Neptune Jewel (blue-green), Bangor blue (purple-blue) and Proudly purple (purple). Recent studies showed that cool colours manipulate people to feel cooler. However, the colour sample use was too general. Therefore, the result from this study helps in providing specific cool colour that soothes the eye of occupants and thermally comforting for sustainable interior design purposes to achieve human health and well-being in the built environment.

Keywords: *Cool colour, Thermal comfort, Thermal sensation, Content analysis, Color preference survey*

1.0 Introduction

The level of thermal comfort in the residential buildings significantly influences the emotion and physicality of its occupants. A good condition of thermal comfort can improve productivity (Rosenlund, 2000) increase performance (Heschong, 2002) as well as occupant's health (Senin & Mydin, 2013). Factors that can directly affect thermal comfort can be categorised into two groups which are: 1) Environmental factors consisting of air velocity (V), relative humidity (RH), air temperature (Ta), and mean radiant temperature (Tr) and, 2) Personal factors consisting metabolic rate and clothing level.

Hettiarachchi & Emmanuel (2017) recorded that colour being one of the important characteristics in indoor spaces has always been utilized only for its beautification. Colour has been able to manipulate the perceived dimension of space, triggering the occupant's thoughts, feeling, emotions and behaviour. However, colour thermal impact has been less considered as there is a lack of scientific investigation and evidence regarding the thermal impact of colour (Candas and Dufour, 2005). The theory of colour described that colour can indicate warmth and coolness (Mahnke, 1996). Based on the duality of the group between warm and cool colours, the properties, characteristics and effects of colour have been classified mainly into the two groups. For example, red, orange and yellow are described as warm and stimulating while colours such as blue, green and purple are cool and pacifying (Fanger et al, 1977, Mahnkey, 1996, Stone 2001, 2002). Psychologically, warm colours evoke emotion, ranging from feeling warmth, joy and aggression and cool colour are often characterised as relaxing and soothing. Physiologically, colour produces electrical impulses and magnetic currents that influence the autonomic nervous system that controls the sympathetic and parasympathetic systems. Warm colours influence the sympathetic system, increasing heart rate and

blood pressure while cool colour influence the parasympathetic system causing a decrease in heart rate and blood pressure that contact coolness and relaxation (Mayer & Bikha, 2014).

Therefore, this paper attempts to review the literature relating the thermal impact of cool colour and cool colour samples that can be used as the element in the colour preference survey. The result from the two methods of content analysis and colour preference survey will provide knowledge on cool colours that were most preferred regardless of age, gender and race as well as their thermal impact for sustainable built environment purposes.

2.0 Methodology

A content analysis was conducted to extract the suitable content from scientific journal publications related to keywords of thermal comfort and sensation, warm and cool colour, colour thermal impact and colour chart. The papers were collected from various fields of architecture, interior design, built environment, applied thermal engineering, psychology of art and human physiology. Relevant articles have been extracted using qualitative systematic content analysis which all-encompassing review of the available literature on the aforementioned keywords. While colour preference survey was conducted to identify the most preferred colour for each cool colour hue that has already been selected from the content analysis above. This will help the researcher to scale down the number of colours to be used during the colour preference survey. It will be a close-ended survey consisting of 2 different sections (Section A: Demographic Background) & (Section B: Colour Preferences).

3.0 Cool Colour Impact on Thermal Comfort and Sensation

For the researcher to be able to identify specific and accurate cool colour hue that impacts occupant thermal comfort and sensation, content analysis of past studies on colour thermal impact had been conducted. The keywords needed for the researcher during the content analysis were the type of colour in the cool colour range (Green – Purple), the colour chart used by the past researchers, and the findings of past studies on cool colour thermal impact.

Colours have been classified and grouped in various ways depending on their influence on certain hypotheses as well as grouped based on the effect of the colour (AIC, 2006, 2008 cited in (Mikellides, 2017). Warm and cool colours are one of the most common groupings that are widely used around the world. According to the hue-heat hypothesis, the terms cool colours were colour with the wavelength visibly towards the blue end spectrum. Supported with the Colour theory where the colour wheel in this theory was divided into duality of warm and cool colour (Ballast, 2002). Hues such as red, orange and yellow were grouped under the division of warmth colour as these hues were seen as warmth and exciting while hues such as blue, turquoise, purple and green were seen as coolness, calming and relaxing thus it was grouped as cool colours (Mikellides, 2017).

Past research on colour and thermal comfort from the 20th century and 21st century, both determine that colour have been divided into warm and cool colour due to the hue-heat hypothesis as well as the colour theory. However, research from the 20th century found that cool and warm colours did not affect human thermal comfort. For example, Fanger et al (1972) stated that the colour effect on human preferred thermal comfort was so small resulting in no practical significance. In addition, Thomas, Green & Bell (1980) stated that wall colours either warm or cool do not affect the thermal comfort of occupants, therefore, wall colour would not help in energy conservation in buildings.

Meanwhile, recent studies on colour impact towards thermal comfort support the hue-heat hypothesis. Huebner et al (2016) found that occupants put more clothes in warm colour than cool colour. While Amilani, Hetteriachi & Emmanuel (2017) stated that participants perceived red as warm colour even when the room temperature was in cool condition. In 2018, Wang et al. found that warm colour intends to make people feel warmer and cool colour intends to make people feel cooler. This finding was supported by the subjective voting of participants on thermal comfort and thermal sensation as well as their heart rate index. The latest study by Wijeretna, Hetteriachi & Amilani (2019) found that subjects demand higher fan speed in a red colour environment than a blue colour environment. Thus, recent studies showed that cool colours and warm colours do affect human thermal comfort. However,

these studies only focus on red and blue colours. Wijeretna, Hetteriachi & Amilani (2019) suggested following up on the finding on the cool colour impact on thermal comfort. Therefore, the researcher needs to identify other cool colours except for blue colour to follow up the finding by Wijeretna, Hetteriachi & Amilani (2019).

4.0 Munsell Colour Chart

To identify cool colours, content analysis was conducted by analysing the colour chart that was used by past studies. From the content analysis, it was found that past researchers used the Munsell Colour chart to do a selection of colours such as Jones & Faye (1968), Park (2007) & Jalil et al (2018). The Munsell Colour system is widely used across literature on colour because of its practicality, systematic system and accepted internationally (Indow, 1988). In addition, each colour notation in the Munsell Colour system can also be found in the ICI Dulux Paint (Jalil et al, 2016). The system's method was accurate in specifying colour according to the three attributes of colour Hue, Brightness (Value) and Saturation (Chroma).

The Munsell colour system divide colours into ten hue families where 5 colours were the major hue families (5R-Red) (5Y-Yellow) (5G-Green) (5B-Blue) (5P-Purple) and5 minor hue families (5YR-YellowRed) (5GY-GreenYellow) (5BG-BlueGreen) (5PB-PurpleBlue) (5RP-RedPurple). Brightness refers to the lightness of a colour. The point of brightness ranges from zero (0) for black and ten (10) for white. Saturation refers to the degree of departure of colour from the neutral colour of the same lightness. Saturation often indicates the strength of colour because low saturation colours are called weak while high saturation colours are called strong.

Colour is specified by the notation of hue, brightness/saturation (H B/S) in the Munsell Colour Chart (Park, 2007). Four hue families will be selected consisting of 5BG-BlueGreen, 5G-Green, 5PB-PurpleBlue and 5P-Purple as this research focus is only on cool colour to follow up the findings of Wijeratna & Hettiarachi (2019). Three samples for each hue family were selected from the coordinates (brightness & saturation) with one step difference in saturation and two-step differences for brightness. As a result, a total of 12 colour samples were selected and implemented in the colour preference survey. 12 colour samples selected were referred with ICI Dulux Paint to identify the name of the colour from Dulux paint sample for each colour notation from the Munsell Colour system. The ratio of perceptual differences for brightness and saturation in this study is 2:1 because the perceptually equal step of brightness and saturation defined by previous studies was mostly between one to four steps (Matori, 2014). Figure 1 below shows the selected colour notation and the name of the colour based on ICI Dulux paint.

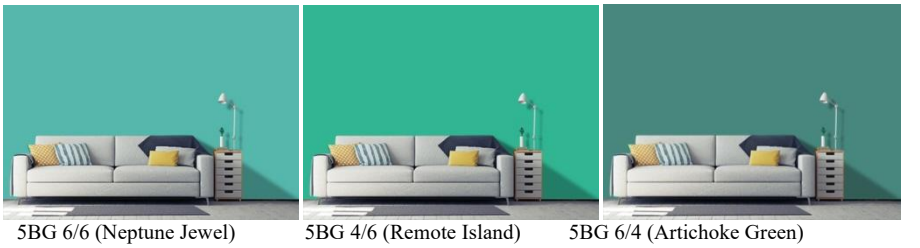
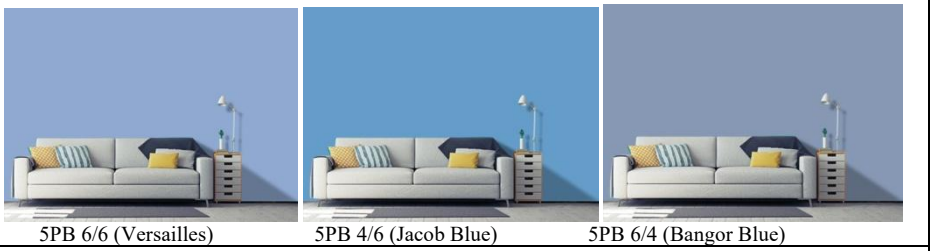
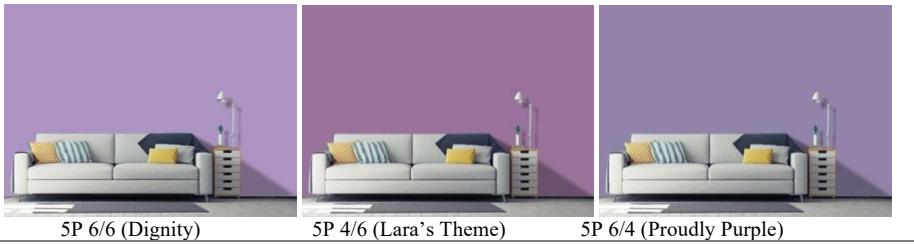
Hue	Colour notation and ICI Dulux Paint
Green	 5G 6/6 (Irish Spring) 5G 4/6 (Forest Fall) 5G 6/4 (Summer Space)
Blue-Green	 5BG 6/6 (Neptune Jewel) 5BG 4/6 (Remote Island) 5BG 6/4 (Artichoke Green)
Purple-blue	 5PB 6/6 (Versailles) 5PB 4/6 (Jacob Blue) 5PB 6/4 (Bangor Blue)
Purple	 5P 6/6 (Dignity) 5P 4/6 (Lara's Theme) 5P 6/4 (Proudly Purple)

Figure 1. 12 selected sample from Munsell Colour chart based on colour notation and name in ICI Dulux Paint

5.0 Colour Preference Survey

The questionnaire was constructed by referring to related literature reviews, thesis, papers, websites and journals. A stratified sampling technique has been applied for this survey as it allows the researcher to obtain a sample population that best represents the entire population (Murphy, 2020). According to Barratt (2009) and Shantikumar (2018), stratified sampling was used when researchers expect the measurement of interest to vary between each subgroup.

Thus, the researcher has first divided the subgroups into gender, age and race. The subgroups will be divided into (Malay male age 18-24, Malay male age 25-34, Malay male age 35-44, Malay male age 45-54, Malay male age 55 & above), (Malay Female age 18-24, Malay female age 25-44, Malay female age 35-44, Malay female age 45-54, Malay female age 55 & above), (Chinese male age 18-24, Chinese male age 25-34, Chinese male age 35-44, Chinese male age 45-54, Chinese male age 55 & above), (Chinese Female age 18-24, Chinese female age 25-44, Chinese female age 35-44, Chinese female age 45-54, Chinese female age 55 & above), (Indian male age 18-24, Indian male age 25-34, Indian male age 35-44, Indian male age 45-54, Indian male age 55 & above), (Indian Female age 18-

24, Indian female age 25-44, Indian female age 35-44, Indian female age 45-54, Indian female age 55 & above).

To calculate the sample size, the first researcher calculated the sample size for an infinite population using the formula (S= z2 * p * (1-p)/m2). Next, the researcher adjusted the sample size to the required population. For example population of 500,000 as 500,000 is the number of population in Kota Kinabalu based on The Department of Statistics Malaysia (2021).The formula will be sample size = (s) / 1 + [(s-1)/population]. Therefore, the sample size for this survey will be 390 so that the questionnaire will be more secure, and the number of the sample size will be divided according to the characteristics of participants as this survey will be using stratified sampling techniques.

The content validity of the questionnaire was assessed by a panel of experts, which included a university lecturer, Dr Nurlelawati Binti Ab. Jalil, from International Islamic University Malaysia, department of Architecture and environmental design, was experienced in colour studies. A pilot study was also conducted on 30 respondents and all of the respondents found that the questions were easy and give full cooperation during the survey.

390 respondents from different backgrounds of gender, age and race had participated in the survey. The following table below shows all 390 respondents' gender, age and race that had been interviewed to identify the most preferred colour among the cool colour hues of green, blue-green, purple-blue and purple.

Table 1. Total male and female respondents

	Gender	Frequency	Percent	Valid Percent	Cumulative percent
Valid	Male	199	51	51	51
	Female	191	49	49	100
	Total	390	100	100	

Table 2. Division by age of respondents

	Age	Frequency	Percent	Valid Percent	Cumulative percent
Valid	18-24	121	31	31	31
	25-34	128	32.8	32.8	63.8
	35-44	65	16.7	16.7	80.5
	45-54	49	12.6	12.6	93.1
	55-Above	27	6.9	6.9	100
	Total	390	100	100	

Table 3. Division by race of respondents

	Race	Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bumiputera	213	54.6	54.6	54.6
	Chinese	107	27.4	27.4	82.1
	India	70	17.9	17.9	100
	Total	390	100	100	

The following table shows the mean score and most preferred colour for each hue in the colour preference survey. According to the result, Summer Space (green hue), Neptune Jewel (blue-green hue), Bangor Blue (purple-blue hue) and Proudly Purple (purple hue) were the most preferred by the respondents in the study, as shown in the highest mean score in Table 1.

Table 4. The most preferred colour for each hue in the colour preference survey

Hue	Munsell Color Notation	ICI Dulux paint	Number of subjects	Mean	Standard Deviation	Reference
Green	5G 6/4	Summer Space	390	7.13	1.430	Most Preferred
	5G 6/6	Irish Spring	390	3.90	0.780	
	5G 4/6	Forest Fall	390	1.83	0.379	Least Preferred
Blue-Green	5BG 6/6	Neptune Jewel	390	7.03	1.410	Most Preferred
	5BG 6/4	Artichoke Green	390	5.20	1.040	
	5BG 4/6	Remote Island	390	0.11	0.120	Least Preferred
Purple-Blue	5PB 6/4	Bangor Blue	390	6.90	1.380	Most Preferred
	5G 6/6	Versailles	390	3.50	0.700	
	5G 4/6	Jacob Blue	390	2.60	0.520	Least Preferred
Purple	5P 6/4	Proudly Purple	390	6.90	1.380	Most Preferred
	5P 4/6	Lara's Theme	390	3.50	0.700	
	5P 6/6	Dignity	390	2.60	0.520	Least Preferred

A chi-square test of independence was performed to examine the relationship between gender, race and colour preferred. There was no significant relationship between gender and colour preference, X^2 (2, N=390) = 5.5, p= 5.99. (Green hue), X^2 (2, N=390) = 4.8, p= 5.99. (Blue-Green hue), X^2 (2, N=390) = 4.4, p= 5.99. (Purple-Blue hue), X^2 (2, N=390) = 2.4, p= 5.99. (Purple hue) Both genders preferred the same colour for each hue in the survey. There was also no significant relationship between the two variables of race and colour preference, X^2 (4, N=390) = 5.8, p= 9.48. (Green Hue), X^2 (4, N=390) = 4.6, p= 9.48. (Blue-Green hue), X^2 (4, N=390) = 2.8, p= 9.48. (Purple-Blue hue), X^2 (4, N=390) = 2.8, p= 9.48. (Purple hue). Participants preferred the same colour without any relation between their races. Figure 2 shows the most preferred colour for each hue in the survey.

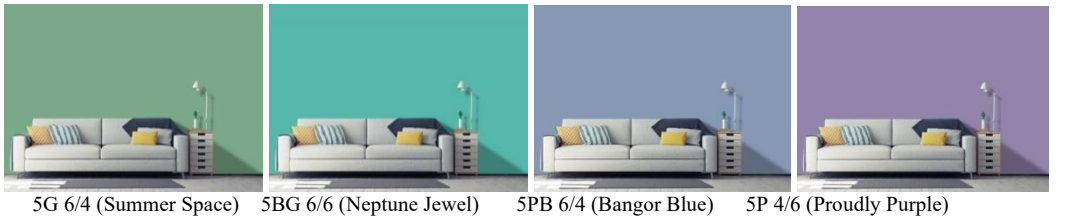


Figure 2. The most preferred colour for each hue family

6.0 Conclusion

Colour being the characteristic of any indoor environment was commonly used for its beautification and triggering human behaviour, emotion and changing perceived dimension. However, the thermal impact of colour has rarely been used to its fullest benefits in the interior. Reviewed articles showed that colour influence the thermal comfort of occupants. Warm colour makes people feel warmer while cool colour the opposite effect where these results identified through different methodologies ranging from subjective voting of thermal comfort and sensation, heart rate index, colour perception survey and fan speed preference.

A colour preference survey was conducted to identify the most preferred colour for each hue family in a cool colour grouping. Summer space, Neptune jewel, Bangor Blue and Proudly Purple were the most preferred colours. There was no significant relationship between gender, race and colour preference. The result from this research provides valuable information for interior designers and architects to produce a quality design that soothes the eye of occupants as well as achieving thermal comfort and sensation.

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