Basic Studies and
New Technologies of
Architecture and
Planning

Naqshejahan 6-4 (2017) 013–025

Naqshejahan

www.http://bsnt.modares.ac.ir/

Investigating the Effect of Changing the Transmitted Light's Color on Thermal and Visual Comfort[a]

Mohammad Haghshenas [a], MohammadReza Bemanian [b*], Zahra Ghiabaklou [c]

[a] *Ph.D. Candidate, Department of Architecture, Faculty of Art and Architecture, Tarbiat Modares University*

[b] *Professor, Department of Architecture, Faculty of Art and Architecture, Tarbiat Modares University*
[c] *Associate Professor, Department of Energy and Architecture, University College of Fine Arts, University of Tehran*

Abstract

Thermal comfort is one of the key factors for achieving energy saving in the buildings. In the survey of thermal comfort, psychological aspects are as important as the physical parameters such as temperature and relative humidity. If thermal comfort could be achieved by using non–physical parameters, a significant energy and cost would be saved. The aim of this study is to investigate the effect of changing the color of inward daylight (into cool/warm), on sensation of thermal and visual comfort. This study was conducted to answer these questions: to what extent can the lights, which are traditionally called cool and warm, cause the real sensation of cold and heat? What is their influence on thermal and visual comfort? And what is the effect of changing the color of transmitted light on the occupant's sensation of illumination? Research method is descriptive–analytical; in this study, thermal and visual effects of changing the color of inward light from the windows is surveyed, by using questionnaires, in three naturally ventilated high–schools; and the results were compared with the outputs of PMV simulation analysis. The results show that changing the inward light to a cool color (blue) and a warm color (red) resulted in a difference of $0.33^{\circ C}$ in the sensation of thermal comfort. Moreover, the AMV in all cases had a neutral temperature below the PMV's neutral temperature which was simulated by the software. In lower illuminance levels (lower than 300 lux) blue light aroused more visual satisfaction; but in higher illuminance levels (more than 300 lux), simple windows produced the best visual satisfaction. Red light produced the least visual satisfaction amongst these three. While, blue and red glazing generated better distribution of light in the room, than the witness group.

Keywords: Thermal Comfort, Visual Comfort, Cool and Warm Color, Stained Glass, Fanger Model.

[a] This paper is derived from Mohammad Haghshenas's Ph.D. thesis under the supervision of Prof. Mohammadreza Bemanian which advising by Dr. Zahra Ghiabaklou submitted to Tarbiat Modares University, Tehran, Iran.

* Corresponding author. Tel.: +98-912-108-1534; fax: +0-000-000-0000 .
E-mail address: bemanian@modares.ac.ir

doi:

1. Introduction

Thermal sensation is caused by receiving the information from different sensors in the body, and analyzing them in the brain. The information received by the brain is not limited to physical parameters such as temperature and relative humidity, so the feeling of thermal comfort is not limited to these parameters either. The ASHRAE standard defined thermal comfort as “the condition of mind that expresses satisfaction with the thermal environment” [1]. Trying to achieve thermal comfort just by changing the physical parameters is costly and difficult. So if thermal comfort could be achieved by using non–physical parameters, a significant energy and cost would be saved. Al–Sanea and Zedan (2008) have shown that about 10% reduction in yearly cooling transmission load can be achieved per $1^{\circ C}$ increase in thermostat setting within the thermal comfort zone [2]. Despite a corresponding increase of about 14% in yearly heating transmission load, a net saving in yearly energy cost of about 4% could still be achieved per $1^{\circ C}$ increase in the thermostat setting. Stramler, Kleiss and Howell (1983) have shown a significant effect of purported temperature increase on perceived comfort, even when the actual temperature is not changed. This shows that non–physical factors can play an important role in the perception of thermal comfort [3].

One of the parameters that may affect thermal comfort is the color of entering light from the windows. The question is this: can choosing the color of window glass from the red family (which are known as warm colors) actually cause the occupants of the room to feel warm? (And can the cool colors such as blue cause the opposite? And can we achieve thermal comfort and save energy, by controlling the color of inward light? Hypothesis of this research was that using window glass with warm colors, can cause the occupants to feel thermally comfortable in lower temperatures, and window glass with cool colors can cause thermal comfort in higher temperatures. The survey research method using questionnaires was used to test this hypothesis, and the results were compared with the results of quantitative software calculations.

2. Research background

The warm–cool principle which started with the Munich school of painting, states that blue color appears cool and its adjacent group, yellow, orange and red look warm [4]. Although it is a well–known theory in the world of art, not much studies have been conducted to measure the exact effect of warm and cool lights, in creating warm and cool environments. In the mid–twentieth century, Kruithof’s research showed that people tend to higher light intensities in warm colors of light, and lower light intensities in cool colors of light [5]. In later research, the tendency of people to artificial lights with higher “color temperature” (which will result in cool light), at higher ambient temperatures, was examined [6, 7, 8, 9].

Fanger, Breum and Jerking (1977), studied the effect of changing the ambient color on thermal comfort. Their studies were conducted for eight male and eight female high school students in a controlled laboratory environment. The laboratory had only artificial light and its environment was totally controlled in the comfort zone. The subjects were exposed to blue and red colors, and their sensation of comfort was questioned. The results showed a slight effect of changing the color of ambient light in the thermal sensation; so that the neutral temperature of the people who were subjected to the red light, was $0.4^{\circ C}$ lower than those who were subjected to the blue light [10]. Although this study was amongst the most reliable studies analyzing the possible effects of changing the color of light on thermal comfort, but its results may be questioned based on the work of Nicol and his colleagues, who showed that the results of thermal comfort studies performed in the lab environment are not generable; these surveys should be conducted in the real environments while the people wear their normal clothing and go about their usual work [11].

Greenea and Bella in 1980, studied the effect of changing the colors of the walls on thermal sensation

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

of 72 male and 72 female undergraduate college students, in a completely controlled situation. Four carrels with 18, 22, 29, and 35°C temperatures were chosen which their walls were painted either white, red, or blue. They were asked to predict the ambient temperature, and also their thermal sensation, and their arousal were questioned by the use of forms. This study concluded no special influence of changing the wall colors on perceived temperature [12]. Despite their effort on specifying the effect of color on thermal comfort, their research method is not much defendable; because most people do not have an accurate perception of the quantity of air temperature, although they express their feeling quite well. So, only the people's thermal sensation (and not their prediction of air temperature) should be asked in the questionnaires and the results can be analyzed by the use of statistical methods.

Laurentin, Bermtto and Fontoynont in 2000 studied the influence of natural and artificial light sources on thermal and visual comfort. They found that subjects preferred a lower illuminance under electric light than under daylight, and correlated color temperature has a tendency to affect visual and thermal perception [13].

Nakamura and Oki in 2002 studied the effect of color temperature of general lighting on psychological preferences of the occupants, in different seasons [14]. Kakitsuba and his colleagues studied the effect of gender difference and seasonal change on preferred color temperature. They found that high color temperatures were preferred in spring and summer and lower color temperatures were preferred in winter for both genders [15, 16, and 17]. According to the fact that higher color temperatures are prone to blue and lower color temperatures are prone to red, the results of these studies can be an introduction to study the effects of changing the inward light's color on thermal sensation of the occupants.

Cajochen and colleagues in 2005, studied the influence of monochromatic light at 460 and 550 nm, on melatonin balance, alerting response, thermoregulation and heart rate of ten men aged 21 to 29 years located in a controlled situation. They found that in lower wavelengths, melatonin and subjective sleepiness are higher and the heart rate and core body temperature of the subjects are lower [18].

Finally, Winzen and his colleagues in 2014 studied the influence of artificial yellow light (as an example of warm colors) and blue light (as an example of cool colors) on thermal sensation of 199 subjects in a light laboratory [19]. Albers and his colleagues also studied the same experiment in an aircraft cabin. They both found that Colored light may convey the impression that the environmental temperature is warmer or cooler than it actually is; room temperature was perceived as being different depending on the color of the lighting: In yellow light, room temperature was felt to be warmer than in blue light. While, air quality was perceived as being higher and subjects felt more alert in blue light [20]. The research background is summarized in table 1. In the current study, the influence of changing the color of natural light is being experienced, and the colors red and blue are studied; so it can be a complement for the previous researches.

Table 1: brief summary of the research background

Researcher(s)	**Year**	**Results of the study**
Kruithof	1941	Tendency to higher light intensities in warm colors of light
Willoughby	1974	Tendency to artificial lights with higher color temperature in higher temperatures
Atson & Bellchambers	1969	
Wake	1977	
Yoon	1995	
Fanger, Breum & Jerking	1977	The neutral temperature of the people who were subjected to the red light, was 0.4°C lower than those who were subjected to the blue light
Greenea and Bella	1980	No special influence of changing the wall colors on perceived temperature
Laurentin, Bermtto and Fontoynont	2000	Preference of lower illuminance under electric light Tendency of correlated color temperature on visual and thermal perception
Nakamura & Oki	2002	Tendency to high color temperatures in spring and summer and lower color temperatures in winter
Kakitsuba et al.	2000–2003	
Cajochen et al.	2005	In lower wavelengths, melatonin and subjective sleepiness are higher and the heart rate and core body temperature of the subjects are lower

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

Winzen et al.	2014	In yellow light, room temperature was felt to be warmer than in blue light
Albers et al.	2014	

3. Methodology

There are two general approaches for determining thermal comfort: a) climate chamber studies, and b) field studies: The best advantage of climate chamber studies is the ability to produce desired environmental conditions (air temperature, radiant temperature, air velocity, and humidity) while controlling unwanted variables; but the results may not represent an exact situations in the real world [21]. Field studies are proposed to solve this problem, so they are conducted while subjects go about normally with their work [22]. In field surveys, there is no attempt to control the environmental factors; these factors (especially air temperature) along with personal factors such as clothing value and metabolic rate are just being measured and recorded, trying to discover what combination of environmental variables best describes responses of the subjects [23]. Each of these methods have their own limitations and application. The results of climate chamber studies can often predict thermal sensation for the people in buildings with fully controlled environment, but are not suitable for buildings with mechanical ventilation [24]. In these buildings, the actual mean vote (AMV) can be measured by field studies.

In this paper, field study method is used, in which thermal sensation of some school boys are asked by the use of questionnaires, while the color of natural light entering the classroom was changed by applying transparent colored sheets (red and blue) in front of all the window glazing. In each experiment only one color was used, in order to use the benefits of color constancy. The students answered the questionnaires, at the end of the class, after sitting about an hour in the classroom. Blue color was experimented in 5 classrooms, red color was experimented in 6 classrooms, and simple windows (without colored sheets) were experimented in 7 classrooms. All the cases were chosen from experiment was shiny and clear, and the class was illuminated by natural light passing through the windows.

3.1. Designing the questionnaires

The questionnaire was composed of nine questions, as well as the subject's age, height, and weight. Three questions asked the students' thermal comfort and preferences: one of them asked the students' thermal sensation using ASHRAE septet classification (hot, warm, slightly warm, neutral, slightly cool, cool, and cold). The second asked if they were satisfied with class temperature and the other asked if they prefer the class to be warmer, colder, or no change. Two questions asked the students' visual sensations and preferences: one of them asked if they were satisfied with class illuminance level and the other asked if they prefer the class to be brighter, darker, or no change.

Two questions asked if the student felt discomfort caused by radiation asymmetry or draught, and the next one asked the students health status. The aim of these three questions was to detect the subjects whose thermal sensation was different from the others (because they were subject of local discomfort or their sensations were affected by their disease), and to eliminate their questionnaire from the final results. The last question asked the students to mark the type and number of clothing they wear.

3.2. Measurements of the environmental factors

Temperature, humidity, and light intensity of indoor and outdoor environment were measured by two data–loggers in 5–minutes intervals. Because the experiment was held in a limited time of the class, and there were not extreme variations during the experiment, a Hobo Oneset temp/RH/light datalogger, U12

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

model was appropriate for measurements. Interior device was located in 1.1m height (height of a sitting man's head) to prevent vertical gradient of air temperature; and was 1m away from all the windows and walls in order to prevent the effects of draught, cross ventilation, and radiation asymmetry; and away from direct solar radiation. Exterior device was also located away from direct radiation with 1.5m distant from the walls.

3.3. Predicting comfort conditions by the software

After accomplishment of the field studies and before stating to analyse the results, a prediction of thermal comfort was done using ASHRAE Thermal Comfort Tool (Version 1.0.0.1). This software was chosen because of its accuracy and applicability, as it has been used in many other studies [25, 26, 27, and 28]. In order to predict thermal comfort by the use of this software, basic data such as air temperature, mean radiant temperature, humidity ratio, Air velocity, metabolic rate, skin area, clothing factor, etc. were needed.

Clothing factor was calculated based on the students' answers in the questionnaires, and based on the values below: men underwear (0.04 clo); long sleeves undershirt (0.16 clo); thick trousers (0.24 clo); long sleeves sweater (0.36 clo); socks (0.02 clo); shoes (0.02 clo); and two–piece wooden chair (0.15 clo). Finally, total value of 0.99 clo was estimated for average clothing factor of the students in winter conditions.

Value of skin area can be estimated based on the people's height and weight. Although students height and weight were asked in the questionnaires, but the accuracy of the students responses to these two questions could not be verified. Thus, the results of previous studies [29] was used as average values for height and weight of all the students, as it is shown in table 2. Body skin area (BSA) was also calculated based on the equation 1 [30]:

$$BSA = 0.007184 \times (height)^{0.725} \times (weight)^{0.425} \quad (1)$$

Table 2: average of age, weight, and height of the students and the results of their skin area calculation

School / class	Average age	Average weight (kg)	Average height (cm)	Body surface area (m^2)
1st intermediate school	12	35.71	141.73	1.19
2nd intermediate school	13	41.97	148.4	1.32
3rd intermediate school	14	46.09	153.82	1.41
1st high school	15	51.91	160.66	1.53

Physical parameters such as air temperature, humidity ratio and illuminance level were measured using Hobo Oneset temp/RH/light U12 datalogger. With the proviso that mean radiant temperature was assumed to be equal to the measured indoor air temperature, air temperature measured by the device was used for MRT too. The students were sitting in the classroom, so metabolic rate was estimated 1 met. Amounts of perspiration coefficient from skin surface, skin temperature, internal body temperature and air velocity were assumed as software's presupposes: 170 g/m^2 per hour, 35$^{\circ C}$, 36.6$^{\circ C}$ and 0.1 m/s respectively.

4. Results and discussion

4.1. Thermal comfort analysis

Before starting to analyze, some questionnaires were omitted from the results, including: questionnaires of the students who had any kind of illness such as cold (which their illness affects their thermal sensation), or those who were complaining about draught or direct radiation of the sun (had local

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

thermal discomfort), or were sitting next to the room's heating equipment. Totally, 148 correct questionnaires for the blue light, 135 correct questionnaires for the red light, and 141 correct questionnaires for simple windows (witness) were chosen and analyzed; In which, students thermal sensation were weighted based on the ASHRAE model, such as table 3.

Table 3: ASHRAE septet classification used for weighting student's answers

Hot	Warm	Slightly warm	Neutral	Slightly cool	Cool	Cold
– 3	– 2	– 1	0	+1	+2	+3

The results of this analysis are shown in figures 1, 2, and 3. Vertical axis in these figures, is actual weighted mean vote of the students (AMV), and horizontal axis is average mean operative temperature of the classroom in time of the experiment (from entering the class until filling the questionnaires). In Fig. 3, actual mean votes of the students are compared to the predicted mean votes (PMVs) calculated by ASHRAE Thermal Comfort Tool software.

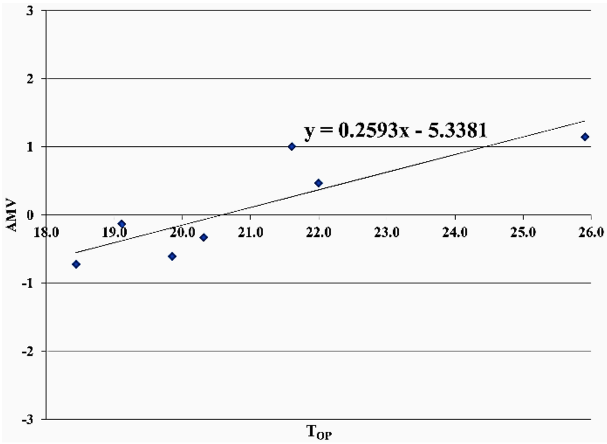

Figure 1: analysis of the actual mean votes of the groups exposed to blue light, in each temperature

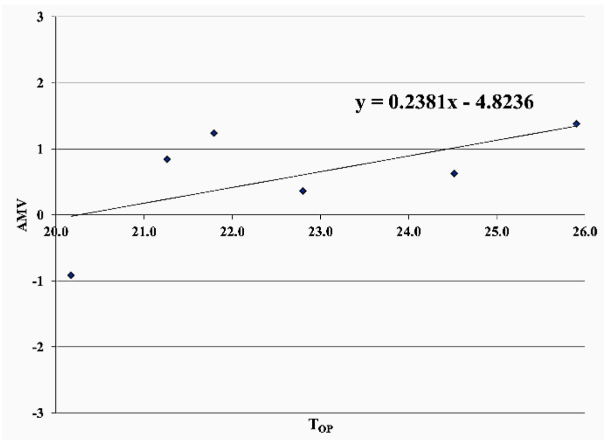

Figure 2: analysis of the actual mean votes of the groups exposed to red light, in each temperature

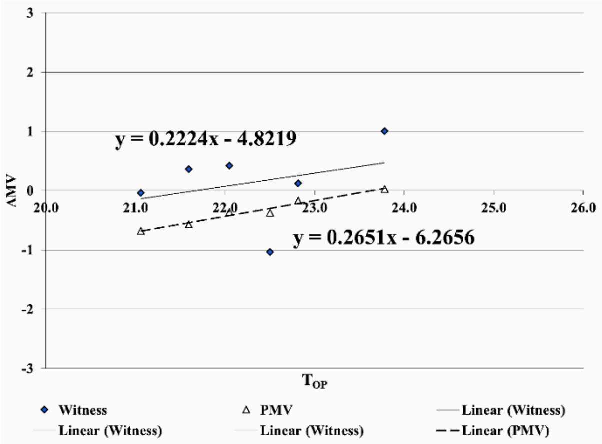

Figure 3: analysis of the actual mean votes of the groups exposed to simple light, in each temperature, comparing with the results of software PMV calculation

The comparison of results of three experiment with software analysis are demonstrated in table 4. These results indicate that warm or cool colors can make people feel slightly warm or cold. According to table 4, changing the color of inward light to blue and red, have 0.33°C effect on students' neutral temperature. These results supports Fanger's studies in this field.

Table 4: comparison of the results of field studies with software analysis

	Witness group	Exposed to blue light	Exposed to red light	Software analysis
Neutral temperature	21.7	20.6	20.3	23.6
Regression equation of the students thermal sensation	y = 0.2224x–4.8219	y = 0.2593x–5.3381	y = 0.2381x–4.8236	y = 0.2651x–6.2656

Comparison of the neutral temperature in all three field studies with results of predicted mean votes calculated by the software show that neutral temperature in all field studies were lower than predictions, which indicates students' adaptation to the environment. According to the fact that none of the governmental schools chosen as case studies uses HVAC systems, and students adapt themselves to the environment by actions such as opening and closing the windows, so they have a wider range of thermal comfort zone than PMV predictions. On the other hand, the AMV graph's inclination in both situations of exposed to blue and red light, are lower than the witness situation. This indicates that students' adaptation to the environment increases when colored glazing were used.

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

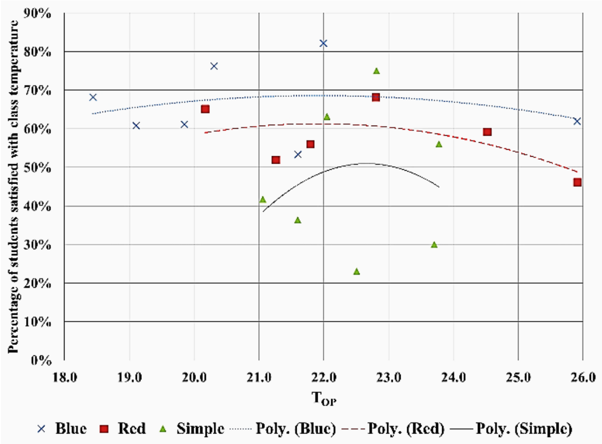

Figure 4: comparison of the students' satisfaction with class temperature in each group

The answers of students to the question if they were satisfied with class temperature or not (yes/no question) is demonstrated in figure 4. This figure shows that students exposed to colored light generally had better thermal sensation than the witness group (those who were exposed to simple windows); among these, blue light had better results than the others. Moreover, the peak point of blue trendline, is a little bit lower than the peak point of red trendline, showing that the maximum percentage of satisfaction for the students exposed to blue light occurs in a lower temperature; and this reinforces our previous results about the effect of light color on thermal comfort.

4.2. Visual comfort analysis

There were also two questions in the questionnaires, which asked the students' visual comfort. The first question asked if the students were satisfied with the class illuminance; they could answer it with "yes" or "no". The second question asked the students' preferences of the illuminance level; they could either choose "want to be brighter", "want to be darker", or "no change". The students' answers to the first question are demonstrated in figures 5 and 6. The X-axis in these figures is the room illuminance level, and the Y-axis is the percentage of students satisfied with it.

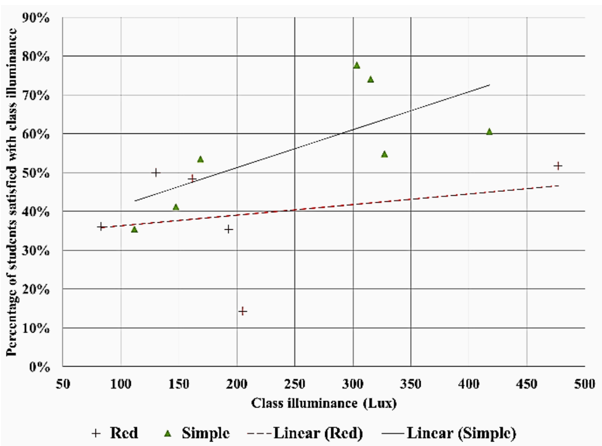

Figure 5: percentage of students exposed to red light, satisfied with the class illuminance level, comparing with witness group

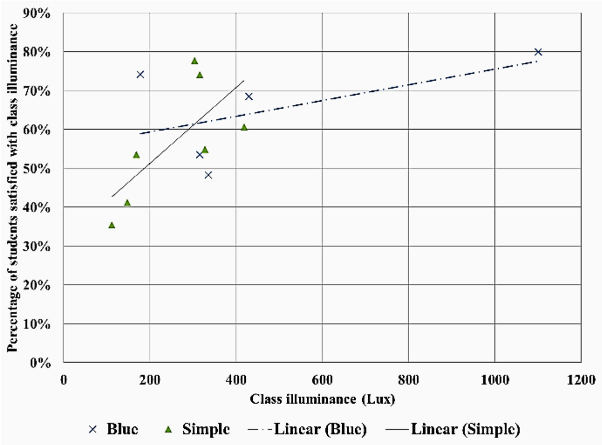

Figure 6: percentage of students exposed to blue light, satisfied with the class illuminance level comparing with witness group

Figures 5 and 6 demonstrate that student's agreement to the class illuminance level never exceeded 80 percent. In lower illuminance levels (less than 300 lux), blue light aroused more visual satisfaction than the others; but in higher illuminance levels (more than 300 lux) simple windows (witness group) produced the best visual satisfaction. Red light produced the least visual satisfaction amongst these three (blue/red/witness). The trend-line's inclination for both groups exposed to blue and red light is lower than the witness group. This shows that blue and red glazing generated better distribution of light in the room.

Table 5: Preferences of the students exposed to blue light, in each illuminance level

Class illuminance level (lux)		**177**	**197**	**315**	**335**	**429**	**605**	**1099**
Number of the students	Want to be brighter	12	23	11	20	13	14	8
	No change	16	9	13	5	15	17	15
	Want to be darker	3	1	4	4	2	4	7

Table 6: Preferences of the students exposed to red light, in each illuminance level

Class illuminance level (lux)		**83**	**130**	**162**	**193**	**205**	**477**
Number of the students	Want to be brighter	28	20	17	23	15	13
	No change	7	8	8	4	2	12
	Want to be darker	1	2	5	4	10	4

Table 7: Preferences of the witness group (students exposed to colorless light), in each illuminance level

Class illuminance level (lux)		**112**	**147**	**169**	**304**	**315**	**327**	**418**
Number of the students	Want to be brighter	20	21	16	9	6	18	10
	No change	8	9	10	10	17	11	17
	Want to be darker	4	4	2	0	4	1	7

Preferences of the students about the class illuminance level, based on their answers to the second question are demonstrated in tables 8, 9, and 10. These tables show that glare was not the most important factor for the students; because in every situation and in each illuminance level, most of the students who disagreed with class illuminance, wanted it to be brighter.

5. Conclusion

The effects of changing color of transmitted light into red and blue, on thermal and visual comfort of the subjects, were studied in this paper. The following results were obtained:

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

- There was a bit difference in subject's neutral temperature when they were exposed to warm and cool colors; the subjects' neutral temperature was 0.33°C lower when they were exposed to blue light. This results supports Fanger's studies in this field.
- Students exposed to red and blue light generally had better thermal sensation than the witness group; among these, blue light had better results than the others.
- Neutral temperature in all three groups were lower than software's predictions; that is probably because the case buildings did not use mechanical ventilation, and this improves the occupants' adaptations.
- Student's agreement to the class illuminance level never exceeded 80 percent.
- In every situation and in each illuminance level, most of the students who disagreed with class illuminance, wanted it to be brighter.
- Blue light aroused more visual satisfaction in lower illuminance levels (lower than 300 lux) but in higher illuminance levels (more than 300 lux), simple windows (witness group) produced the best visual satisfaction. Red light produced the least visual satisfaction amongst these three (blue/red/witness).
- Blue and red glazing generated better distribution of light in the room, than the witness group.

In the end, this study does not acclaim to be the final result in measuring thermal and visual effects of warm and cool colors, and suggests more experimental studies about the field.

Acknowledgments

Supports and cooperation of administrative and scientific staff of Shahid Behrooz Pandi and Azadegan intermediate schools and Shahid Motahari high school is appreciated; specially Mr. Hamzeluee, Mr. Tusi, and Mr. Alikhani, without their cooperation this study could not be accomplished.

References

[1] ASHRAE, A. H.; Fundamentals; *American Society of Heating, Refrigerating and Air–Conditioning Engineers; Atlanta*. 2005, 8.1.

[2] Al–Sanea, Sami A., and Zedan, M.F.; Optimized monthly–fixed thermostat–setting scheme for maximum energy–savings and thermal comfort in air–conditioned spaces; Applied Energy; 2008, 85 (5), 326–346.

[3] Stramler, C. S., Kleiss, J. A., and Howell, W. C.; Thermal sensation shifts induced by physical and psychological means. *Journal of Applied Psychology*, 1983, *68*(1), 187.

[4] Albers, J.; Interaction of color; Yale University Press, 2006: 59–60.

[5] Kruithof A.A.; Tubular luminescence lamps for general illumination; Philips Technical Review; 1941, Vol.6, No.3, 65–73.

[6] Atson S.M. and Bellchambers H.E.; Illumination, color rendering and visual clarity; Lighting Research and Technology; 1969, Vol.1, No.4: 259–261.

[7] Willoughby A.H.; New Lamps: Their Suitability for Interior Lighting; Lighting Research and Technology; 1974, Vol.6, No.1, 1–8.

[8] Wake T.; The effects of illuminance, color temperature and color rendering index of light sources upon conformable visual environments—in the case of office; Journal of Light & Visual Environment; 1977, Vol.1, No.2, 31–39.

[9] Yoon, In; The effect of spectral power distribution of sources on brightness perception part 2. Comparison of brightness in wide vision between 4 kinds of lighting sources; Proceedings of annual conference of Architectural Institute of Japan (A.I.J.); 1995, 461–462.

[10] Fanger P.O., Breum N.O., and Jerking E.; Can colour and noise influence man's thermal comfort?; Ergonomics; 1977, Vol.20, No.1, 8–11.

[11] Nicol, F., Humphreys, M., and Roaf, S.; 2012; *Adaptive thermal comfort: Principles and practice*. Routledge.

[12] Greenea, T.C., and Bella P.A.; 1980; Additional considerations concerning the effects of 'warm' and 'cool' wall colours on

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

energy conservation; Ergonomics; Vol.23, No.10, 949–54.

[13] Laurentin, C., Bermtto, V., and Fontoynont, M.; Effect of thermal conditions and light source type on visual comfort appraisal; International Journal of Lighting Research and Technology; 2000, Vol. 32, No. 4, 223–33.

[14] Nakamura, H. and Oki M.; Influence of air temperature on preference for color temperature of general lighting in the room; Journal of the Human–Environment System; 2002, Vol. 4, No. 1, 41–47.

[15] Kakitsuba N., Moyoshi M., Nakamura H., Inagaki T., and Horikoshi, T.; Evaluation on preferred color temperatures combined with room air temperatures from psychological and physiological responses. Part 2. Seasonal change in preferred color temperatures at 200lx; Journal of Architecture, Planning and Environmental Engineering (Transactions of A.I.J.); 2000, Vol. 532, 87–92.

[16] Kakitsuba N., Nakamura H., Inagaki T., and Horikoshi, T.; Evaluation on preferred color temperatures combined with room air temperatures from psychological and physiological responses. Part 1 seasonal change in preferred color temperatures at 1,500 lx; Journal of Architecture, Planning and Environmental Engineering (Transactions of A.I.J.); 2000, Vol. 528, 67–73.

[17] Ishi M., and Kakitsuba N.; Preferred Color Temperatures at 200 lx during Exposure to Cool or Warm Environments for Middle–Aged Female Subjects; Journal of the Human–Environment System; 2003, Vol.6, No.2, 93–100.

[18] Cajochen C, Munch M, Kobialka S, Krauchi K, Steiner R, Oelhafen P, Orgul S, and Wirz–Justice A.; High Sensitivity of Human Melatonin, Alertness, Thermoregulation, and Heart Rate to Short Wavelength Light; The Journal of Clinical Endocrinology & Metabolism; 2005, 90(3), 1311–1316.

[19] Winzen J., Albers F., and Marggraf–Micheel C.; The influence of coloured light in the aircraft cabin on passenger thermal comfort; Lighting Research and Technology; 2014, Vol. 46, 465–475.

[20] Albers F, Maier J, and Marggraf–Micheel C; In search of evidence for the hue–heat hypothesis in the aircraft cabin; Lighting Research and Technology; 2014, Vol.0, 1–12.

[21] Djongyang, N., Tchinda, R., and Njomo, D.; Thermal comfort: A review paper; *Renewable and Sustainable Energy Reviews*; 2010, *14*(9), 2626–2640.

[22] Mishra, A. K., and Ramgopal, M.; Field studies on human thermal comfort—an overview; *Building and Environment*; 2013, *64*, 94–106.

[23] Taleghani, M., Tenpierik, M., Kurvers, S., and van den Dobbelsteen, A.; A review into thermal comfort in buildings; *Renewable and Sustainable Energy Reviews*; 2013, *26*, 201–215.

[24] Rupp, R. F., and Ghisi, E.; What is the most adequate method to assess thermal comfort in hybrid commercial buildings located in hot-humid summer climate?; *Renewable and Sustainable Energy Reviews*; 2014, *29*, 449-462.

[25] Yau, Y. H., and Chew, B. T.; Thermal comfort study of hospital workers in Malaysia. *Indoor air*; 2009, *19*(6), 500–510.

[26] Simone, A., Olesen, B. W., Stoops, J. L., and Watkins, A. W.; Thermal comfort in commercial kitchens (RP–1469): Procedure and physical measurements (Part 1); *HVAC&R Research*; 2013, *19*(8), 1001–1015.

[27] Toftum, J. R., Kolarik, J., Belkowska, D., and Olesen, B. W.; Influence on Occupant Responses of Behavioral Modification of Clothing Insulation in Nonsteady Thermal Environments (RP–1269). *HVAC&R Research*; 2010, *16*(1), 59–74.

[28] Schiavon, S., Hoyt, T., and Piccioli, A.; Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55; *Building Simulation;* 2014, Vol. 7, No. 4, 321–334.

[29] Naghizade, Abbas and Nemati, Ali; A Survey of Height and Weight of Ardebilan boys aged 7–19 years and comparison of them with NCHS reference population and other Studies in Iran; Science and Technology magazine; 2008, 8(1, 2), 118–128.

[30] DuBois D., and DuBois, E.F.; A formula to estimate the approximate surface area if height and weight be known; Archives of internal medicine; 1916, Vol. XVII; No. 6–2, 863–871.

Authors Information

Author name	Title	Membership	Contact	Author affiliation
Mohammad Haghshenas	S.E.		m.haghshenas@modares.ac.ir / 09177122931	Ph.D. Candidate, Faculty of Art, Tarbiat Modares University, Tehran, Iran; P.O.Box: 14115–335.

[DOR: 20.1001.1.23224991.1395.6.4.2.6]

MohammadReza Bemanian	Prof.		bemanian@modares.ac.ir / 09121081534	Professor, Faculty of Art, Tarbiat Modares University, Tehran, Iran; P.O.Box: 14115–335.
Zahra Ghiabaklou	A. Prof.		ghiabaklou@ut.ac.ir / 09121469579	Associate Professor, College of Fine Arts, University of Tehran, Tehran, Iran; P.O.Box: 14155–6458.

[DOR: 20.1001.1.23224991.1395.6.4.2.6]