Immersive Virtual Environment (IVE) as a potential tool for interior colour study in office environments

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Abstract

Interior design elements, particularly colours, have shown significant influence on employers' performance in office environments. The task performance was often measured against different coloured offices in physical built environments. An identified challenge for these studies is to alter colour settings for experiments. Immersive virtual environment (IVE), as an advanced technology, may potentially address to this challenge. Although few studies applied IVE in colour related research, some studies have successfully applied IVE in light and space research for performance assessment. These studies underpin this research to examine the feasibility of applying IVE in colour studies. A virtual model of office environment was built and rendered in Autodesk building design suite (Revit and 3Ds MAX) and presented in Virtual Desktop. Within the virtual offices, only the wall colour was changed while the other parameters remained the same. This enabled the task performance to be measured in the IVE-made offices with different colours (including white, red, green and blue). Proofreading tasks were used for measuring the task performance in each coloured office. The data of error numbers and time expense were collected and then analysed by the analysis of variance (ANOVA). Two significant findings were identified. Firstly, compared to the other three colours, task performance in the white offices was the best. Secondly, performing tasks in red office has better performance than green and blue offices. These two significant findings were supported by several colour related studies although there were some research presenting different results. This study demonstrated the potential of applying IVE for interior colour research in office environments. This study can support a further assessment for the feasibility of IVE by evaluating human emotion and physiological conditions for our funded project.

Keywords-

Immersive virtual environment (IVE), physical built environment, task performance, proofreading tasks

1 Introduction

People spend most of their time in interior environments [1]. This raised research interests on investigating how the elements (e.g. lights and space) in interior environments affect human in physiological and psychological domains [2, 3]. Given the multiple interior elements, colour is a fundamental one in interior environments [4]. Many studies, particularly for office environments, explored the ways interior colours (i.e. white, red, blue and green) affect task performance [5, 6, 7]. Some studies pointed out, compared to blue and green offices, employers performed better in white and red offices [8, 9], while other studies showed dissimilar results [10].

All the aforementioned research were conducted in physical built environments. They manipulated office colours by either painted walls or coloured lightings. A significant challenge within these studies is to alter interior colour settings [11], which may be mitigated by using advanced technologies (e.g. 3D imaging technology and virtual reality). Of particular relevance is immersive virtual environment (IVE) that can realistically simulate scenarios (e.g. colour, light and space) for interior environment research [12, 13, 14].

Although IVE was not widely adopted in colour research, some studies have demonstrated the feasibility of IVE used in light and space simulations for the interior environment [12, 14]. These may potentially support this study to examine the feasibility of applying IVE in colour research. This study shared part of data and analysis results from a funded project that focusing on IVE and interior colour.

2 Research Methodology

This study examined the task performance against four coloured offices including white, red, blue and

green. These four colours are determined in accordance with aforementioned studies. The four coloured offices have been built in IVE for experiments. Information related to experiments including participants, colour samples, instruments and experiment procedures is described in the following sections.

2.1 Participants

There were 56 participants (undergraduate students) recruited from the Hong Kong Polytechnic University, including seven female students (12.5%) and 49 male students (87.5%). All of them were local students with English as second language and were in range of 20 to 28 years old.

Among 56 participants, 13 participants were excluded because of poor eyesight (11 participants), failure on colour blindness (1 participant) and uncomfortable feeling (1 participant) during the experiment. Therefore, 43 data samples were collected and analysed.

2.2 Colour samples

The four colours were identified by Munsell Colour Notation (MCN) system. The brightness and saturation of the four colours were secured in similar degrees. The determined colours in the MCN system were 6.05R 4.59/11.15 (red), 9.75YR 8.74/0.45 (white), 3.45G 4.44/7.89 (green) and 2.43PB 5.12/10.51 (blue) (See Figure 1).

2.3 Instruments

Colour blindness: The Ishihara Colour Blindness Test was used to evaluate colour vision of participants. This blindness test consists of 13 circular plates with pointillist painting.

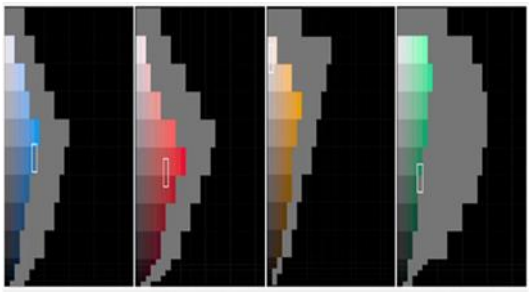

Figure 1. The position of chosen colour in Munsell Colour System

Pre-questionnaire: It is used to collect participants' personal information such as genders, age, education degrees and colour preferences etc.

Head Mounted Display (HMD): HMD used in this study is Oculus rift. It enables IVE-made offices to be presented to participants.

Immersive virtual environment: The ways to present IVE-made coloured office were shown in Figure 2. The office models, referring to an actual office, were built in Revit 2017 and rendered in 3D MAX. The office models were then imported into Virtual Desktop that can present the four coloured offices for experiments. In terms of hardware, HMD provides display of virtual model (e.g. 3D graphics database and appropriate sensory information) back to participants. Tracking sensor detects the position and orientation of participants in virtual space. It should be noticed that only wall colour of virtual office was modified while the other parameters (i.e. dimensions, textures and illumination) remained the same. The four models of virtual office were shown in Figure 3 respectively.

Performance assessment: Many studies assess task performance by using proofreading tasks. Address-checking tests adopted in this study were commonly used proofreading tasks for performance assessment. The test contains 15 address-checking questions that were shown to participants on the interface of Virtual Desktop. Each question include two similar addresses

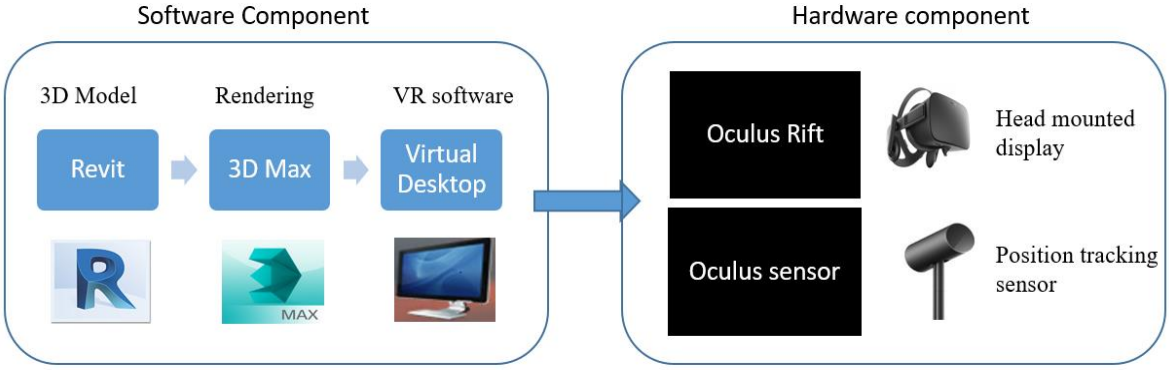

Figure 2: Modeling steps and apparatus.

with a few or no differences in zip codes and/or street names. The participants were then required to respond no differences or identify the differences between the two addresses.

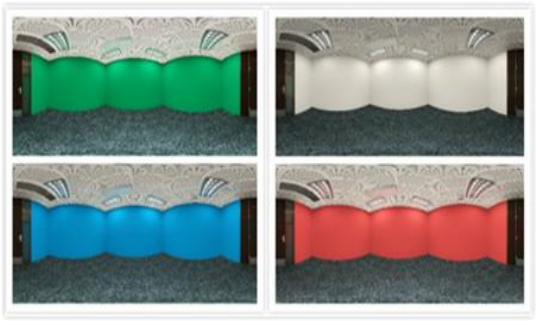

Figure 3. Panorama of virtual model of office room.

2.4 Experimental procedure

Firstly, participants were guided to waiting area for commencing colour blindness tests. The participants who successfully passed the colour blindness test were allowed to undertake the experiments. Prior to the experiments, the participants firstly needed to complete pre-questionnaires. Since the participants had few experiences in such task, they were then given five sample address-checking practices to get familiar with the task process.

Afterwards, each participant was asked to expose the IVE offices with random colours. In the IVE office, participants were firstly asked to adapt to the environment for two minutes. After that, participants were required to complete proofreading test (15 address-checking tests). Then participants were asked to have a four minutes' rest for washing out their impression of previous colour. Following that, they were required to repeat the same process in other three offices with different colours.

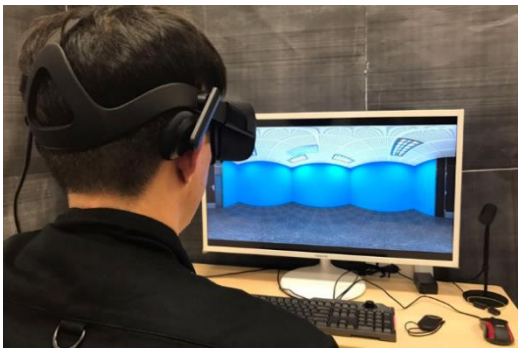

Figure 4. Participants adapting to office environment within IVE

3 Analysis of Result

Our study examined the influence of colour on task performance in accordance with number of error per minute. Lower number of error per minute indicated better task performance. The analysis of variance (ANOVA) showed significant differences of task performance among four colours ($F = [3,171] = 2.684$ $P=0.048$). In terms of multiple comparisons analysed by least-significant difference (LSD) between two colours, there were significant differences of task performance between white colour and blue colour ($P=0.044$), as well as white and green colour ($P=0.007$). In addition, it is apparent from Figure 5 that participants perform best (mean=0.4915 number of error per minute) in the white office, compared to the other three colour offices. In addition, participants achieved better task performance in the red office than blue and green offices.

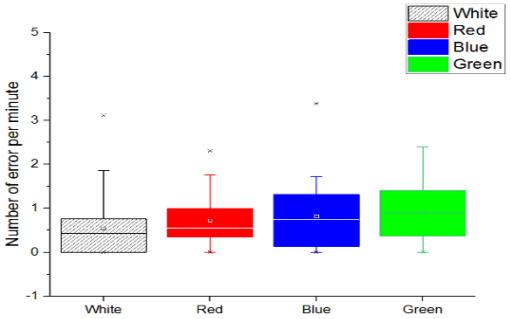

Figure 5: The data represent group means for error of number per min from baseline and their 95% confidence intervals.

4 Discussion

The analysis results showed white and red offices can significantly influence the task performance. Within the four colours, this study presented the best task performance in the white colour office (Figure 5). This result may be different from some studies that they mentioned participants in the white office made the largest number of errors in proofreading tasks [9, 15]. While there were some studies with similar result supporting our findings. Compared with green and red, employers felt least distracted in the white office [16]. This aligned with a study that workplace with neutral colours (e.g. white and gray) could enhance concentrations on their tasks [17]. These demonstrated the office environment with white colour can significantly improve task performance.

In accordance with the analysis results, the participants in the red office, compared with blue and green colours, have better task performance (Figure 5). This is supported by several studies that demonstrated similar results that red colour in interior environments

can improve task performance [9, 18, 20]. Meanwhile, other research showed the interior environments with cool colours (i.e. blue and green) have poorer task performance [10, 19].

Although some studies have different results, our findings provided potential opportunities to utilize IVE in colour related research. The potential may be further strengthened by adopting wider range of sample data because the most of participants in this study are Hong Kong undergraduate students.

5 Conclusion

This study investigated the ways the four colours (including white, blue, green and red) affect participants' task performance in office environments. The number of errors per minute was used to estimate task performance in the IVE-made offices. It showed significant differences for task performance between the four colour office environments. Differentiated from the indicator (i.e. number of errors) in related studies, the number of errors per minute can also be an effective indicator for evaluating task performance. In addition, two significant findings were identified. Within the four coloured IVE-made offices, it has the best task performance in the white colour office. Moreover, participants perform better in the red office than in the blue and green offices. These two findings were underpinned by several colour related research. Our findings demonstrated the potential of applying IVE to explore interior colours study in office environments. Furthermore, this study supported our project to assess the feasibility of IVE by investigating human emotions and physiological conditions in different coloured offices.

6 Reference

[1] United States Environmental Protection Agency. *Air Quality Criteria for Particulate Matter*, Volumes I, II, and III: EPA/600/ P-95/001; Office of Research and Development: Washington, DC, 1996.

[2] Jacobs, K. W., & Frank E. Humstmyer, J. *Effects of Four Psychological Primary Colours on GSR, Heart Rate and Respiration Rate.* Journal of Perceptual and Motor Skills, 38: 763-766, 1974.

[3] Küller, R., Ballal, S., Laike, T., Mikellides, B., & Tonello, G. (2006). *The Impact of Light and Colour on Psychological Mood: A Cross-Cultural Study Of Indoor Work* Environments. Ergonomics, 49(14): 1496-1507.

[4] Marilyn A. Read, Deborah Upington. *Young Children's Colour Preferences in the Interior* Environment, Early Childhood Education Journal, 36(6): pages 491–496, 2009.

[5] Goodfellow, R. A., and Smith, P. C. *Effects of environmental colour on two psychomotor tasks*, Perceptual and Motor Skills, 37: 296-298, 1973.

[6] Green, W. K., Hasson, S. M., Mohammed, S. K., Phillips, C. L., Richards, P. E., Smith, M. E., & White, A. *Effect of viewing selected colours on the performance of gross and fine motor tasks*, Perceptual and Motor Skills, 54, 778, 1982.

[7] Camgoz, N., Yener, C., Guvenc, D. *Effects of hue, saturation, and brightness: Part 2*, Colour Research and Application, 29, 20-28, 2003.

[8] Bette, L. *Colour Your World*, Journal of Business Mexico, 6 (2), 20 – 22, 1996

[9] N. Kwallek, C. M. Lewis, J. V. D. Lin-Hsiao, H. Woodson. *Etfects of Nine Monochromatic Office Interior Colours on Clerical Tasks and Worker Mood*, Colour research and application, 21(6): 448-458, 1996.

[10] Andrew J. Elliot, Markus A. Maier, Arlen C. Moller and Ron Friedman, Jo¨rg Meinhardt. *Colour and Psychological Functioning: The Effect of Red on Performance Attainment*, Journal of Experimental Psychology: General Copyright by the American Psychological Association, 136(1): 154–168, 2007.

[11] S.-Y. Yoon and K. Wise. *Industrial Applications of Affective Engineering*, pages 219–232, Springer, Basel, Switzerland, 2014

[12] A. Heydarian, J.P. Carneiro, D. Gerber, B. Becerik-Gerber, T. Hayes, W. Wood. *Immersive virtual environments versus physical built environments: a benchmarking study for building design and user-built environment explorations*, Automation in Construction 54: 116–126, 2015.

[13] M. Kozhevnikov, J. Royan, O. Blazhenkova, A. Gorbunov The Role of Immersivity in Three-dimensional Mental Rotation, in *Proceedings of 3rd International Conference on Design Computing and Cognition*, pages 143-157, Atlanta, GA, United States, 2008.

[14] M.F. Shiratuddin, W. Thabet, D. Bowman. Evaluating the effectiveness of virtual environment displays for reviewing construction 3D models, In *Proceedings of the 4th Conference on Construction Applications of Virtual Reality*, pages 13-15 Lisbon, Portugal, 2004.

[15] N. Kwallek and C.M.Lewi. *Effects of environmental colour on males and females: A red or white or green office*, Applied Ergonomics, 21(4): 275-278, 1990.

[16] N. Kwallek, K. Soon, H. Woodson, J. L. Alexander. *Effect of Colour Schemes and Environmental Sensitivity on Job Satisfaction and Perceived Performance*, Perceptual and

Motor Skills, 101(2): 473-486.

[17] E Sundstrom, MG Sundstrom. *Work places: The psychology of the physical environment in offices and factories*, pages 179-189 New York: Cambridge Uni. Press.

[18] N. Kwallek and C.M.Lewi. *Effects of environmental colour on males and females: A red or white or green office*, Applied Ergonomics, 21(4): 275-278, 1990.

[19] Poursafar, Z., Devi, N. R., & Rodrigues, L. R. *Evaluation of colour and lighting Preferences in architects' offices for enhancing productivity*, International Journal of Current Research and Review, 8(3), 1, 2016.

[20] Hill, R. A., & Barton, R. A. *Red enhances human performance in contests*, Nature, 435: 293, 2005.