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**EFFECTS OF LIGHTING ON VISUAL IMPRESSIONS OF A
MEETING ROOM IN VIRTUAL REALITY**

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EFFECTS OF LIGHTING ON VISUAL IMPRESSIONS OF A MEETING ROOM IN VIRTUAL REALITY

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Abstract

The present study took a meeting room as an example to investigate how direct lighting and indirect lighting can affect visual impressions of a VR space. This study adopted 10 lighting designs for the room, and each design was assessed via 7 semantic scales. Experimental data show good repeatability for all but the relaxing/nervous scale, with correlation coefficients for each scale between visual responses given for the first time and those for the second time. The results indicate that direct lighting has a greater impact than indirect lighting on some visual impressions of the room.

Keywords: Interior Lighting, Virtual Reality, Visual Response

1 Introduction

Currently, the combination of direct and indirect lighting is commonly applied in the interior design, not only the lighting efficiency but also the visual experience. With increasing popularity of virtual reality (VR) technology, there is a strong demand for how this technology can be applied to interior design area as a communication tool between designer and customer.

Lighting as an environmental and architectural element can influence the viewer's perception, emotion and even behaviour. Little is known, however, of the impact of lighting on a VR space, in particular the difference between direct lighting and indirect lighting in their contribution to visual impressions of a VR space. As an initial attempt in this new area, the present study took meeting room as an example to investigate how lighting can affect visual impressions of a VR space.

2 Methods

To achieve this aim, a psychophysical experiment was conducted using a Miniso Simple 3D VR Glasses headset. A Huawei P20 smartphone, with a 5.8-inch screen and a resolution of 2240x1080 pixels, was used to present the VR images.

The 3DS MAX software was used to create a meeting room, 5.70m (width) by 3.70m (depth) by 2.85m (height) in size, where a meeting table, with 3.55m (width) by 1.40m (depth) by 0.75m (height) in size, was placed at the middle of the room, as shown in Figure 1

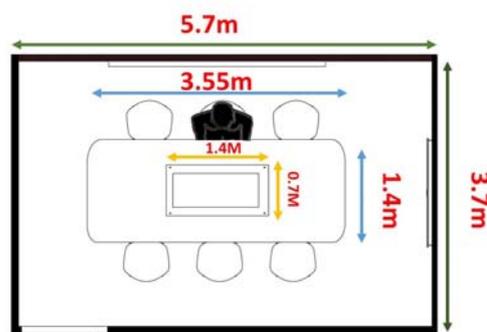
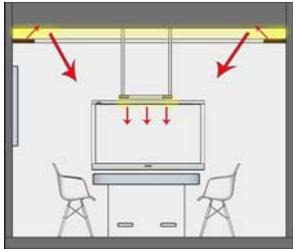
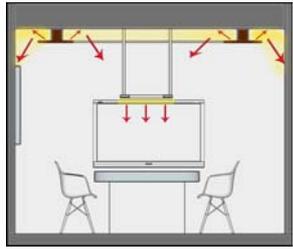
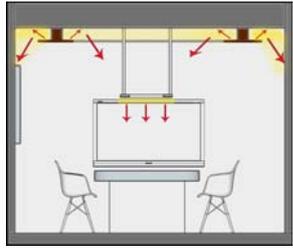
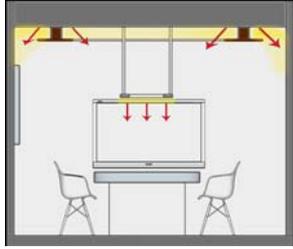
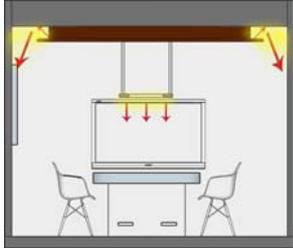


Figure 1 – The layout of the VR space used in the study

This study adopted 10 lighting designs for the room, as summarised in Table 1.

Table 1 – The 10 lighting designs used in the study

Design name	Luminance measured on the wall	Luminance measured on the table	scenes
AH	6.97cd/m ²	33.83cd/m ²	
AL	2.03cd/m ²	8.75cd/m ²	
BH	8.47cd/m ²	34.01cd/m ²	
BL	3.22cd/m ²	8.80cd/m ²	
CH1	14.48cd/m ²	34.74cd/m ²	
CL1	8.29cd/m ²	9.49cd/m ²	
CH2	6.44cd/m ²	33.07cd/m ²	
CL2	1.71cd/m ²	8.25cd/m ²	
DH	7.49cd/m ²	32.79cd/m ²	
DL	2.27cd/m ²	7.90cd/m ²	

AH design – high intensity of direct lighting was created by a 1.40m by 0.70m pendant hollow LED panel; indirect lighting was provided by light cast upward to the central area of ceiling from LED strips hidden on a false ceiling installed around the ceiling lines. The measured luminance values from the VR image were 6.97cd/m² for the main wall and 33.83cd/m² for the table.

AL design – same as AH except the pendant LED panel provided low, instead of high, intensity of direct lighting. The measured luminance values were 2.03cd/m² for the main wall and 8.75cd/m² for the table.

BH design - same as AH except there was additional indirect lighting created by light cast upward to the ceiling at the ceiling line areas from another set of LED strips installed near the ceiling lines. The luminance values were 8.47cd/m² for the main wall and 34.01cd/m² for the table.

BL design – same as BH except the pendant LED panel provided low intensity of direct lighting. The luminance values were 3.22cd/m² for the main wall and 8.80cd/m² for the table.

CH1 design – same as BH except the indirect lighting was created by light cast downward, instead of upward, from the LED strips. The luminance values were 14.48cd/m² for the main wall and 34.74cd/m² for the table.

CL1 design – same as CH1 except the pendant LED panel provided low intensity of direct lighting. The luminance values were 8.29cd/m² for the main wall and 9.49cd/m² for the table.

CH2 design – same as CH1 except the indirect lighting created by the LED strips was less bright for CH2 than for CH1. The luminance values were 6.44cd/m² for the main wall and 33.07cd/m² for the table.

CL2 design – same as CH2 except the pendant LED panel provided low intensity of direct lighting. The luminance values were 1.71cd/m² for the main wall and 8.25cd/m² for the table.

DH design – same as AH except the indirect lighting was created by LED strips that cast light upward to the ceiling at the ceiling line areas, instead of the central area. The luminance values were 7.49cd/m² for the main wall and 32.79cd/m² for the table.

DL design – same as DH except the pendant LED panel provided low intensity of direct lighting. The luminance values were 2.27cd/m² for the main wall and 7.90cd/m² for the table

These 10 designs were selected for this study to cover the most commonly used lighting solutions for a meeting room nowadays, as show in Figure 2. During the experiment, each of the designs were evaluated in VR using 7 semantic scales, like/dislike, relaxing/nervous, exciting/dull, intense/soft, spacious/tiny, safe/unsafe and bright/dark. For each observer, the 10 designs were presented in random order and were all presented twice. The observer responses were recorded and analysed using the categorical judgement scaling method.

A panel of 30 observers, including 15 males and 15 females, all university students with normal colour vision, participated in the study.

3 Results

Experimental data show good repeatability for all but the relaxing/nervous scale, with correlation coefficients for each scale between visual responses given for the first time and those for the second time, all greater than 0.85. Bright/dark shows the highest correlation coefficient (R=0.98), whereas relaxing/nervous shows the lowest (R=0.06). It is thus reasonable to remove visual data of relaxing/ nervous from further analysis due to its poor repeatability.

To compare the impacts of direct lighting and indirect lighting on the observer responses, the visual data were tested using ANOVA. The test results show that visual responses for the 6 scales are all significantly affected by direct lighting, with p values all below 0.001, whereas indirect lighting shows significant impact only on bright/dark (p<0.001), exciting/dull (p=0.002) and like/dislike (p=0.031), as shown in Table 3. The results suggest that direct lighting had a greater influence than indirect lighting on some visual impressions of the room.

The visual responses were also compared with luminance values measured on the main wall and on the meeting table. As a result, high correlation was found between luminance on the table and responses for each scale, with a mean correlation coefficient of 0.83. High correlation was also found between luminance on the wall and the responses, with a mean correlation coefficient of 0.76.

Table 3 – ANOVA results for testing whether direct lighting and indirect lighting had a significant impact on the 7 scales studied

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
indirect	like	15.506	4	3.876	2.680	.031	.018
	relaxing	2.407	4	.602	.420	.794	.003
	exciting	21.437	4	5.359	4.345	.002	.029
	soft	1.672	4	.418	.296	.880	.002
	spacious	7.976	4	1.994	1.331	.257	.009
	safe	11.249	4	2.812	1.790	.129	.012
	bright	61.192	4	15.298	13.401	.000	.085
direct	like	59.867	1	59.867	41.388	.000	.067
	relaxing	.446	1	.446	.311	.577	.001
	exciting	162.104	1	162.104	131.421	.000	.185
	soft	43.590	1	43.590	30.905	.000	.051
	spacious	100.574	1	100.574	67.130	.000	.104
	safe	76.736	1	76.736	48.837	.000	.078
	bright	507.980	1	507.980	444.981	.000	.435

4 Conclusion

A psychophysical experiment was conducted in a VR space, taking the meeting room as an example, to investigate the relationship between lighting design and visual impression of the room. The experimental results indicate that direct lighting has a greater impact than indirect lighting on some visual impressions of the room, and that the luminance measured on the meeting table has high correlation with the visual impressions.