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Experimental Study on Living Room Lighting Environment for Residential Activities

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Abstract

This study performed a subjective evaluation of the Semantic Differential (SD) method for living room activities to evaluate the living room lighting environment and investigated the relationship between these through luminance distribution in the space. As a result, three factors-"lightness", "emotion" and "calmness"-have been grouped together. According to the analysis of experimental variables, difference has been observed depending on color temperature, the dimming of the ceiling & cove lights and the use of down lights and a bracket. 'Conversation with Family', 'Having Fun with Family', 'Entertaining Guests' and 'Reading a Book or Newspaper' requires "lightness". In terms of "emotion"-centered activities, 'Watching TV' is the highest, but all three factors are related. In terms of "calmness"-centered activities, 'Relaxing' is the highest.

Key Words : Living Room, Lighting Environment, Activities, Lightness, Emotion, Calmness

1. Introduction

In terms of house lighting, lighting and maintaining the indoor environment have been the main focuses of the past. Recently, however, refreshing or romantic lighting has come to the fore, and in a house, the living room is a very important space because a variety of doings are done in this space with variable lighting required. Based on the results of the analysis (2012)1)of previous studies, a laboratory environment was configured.

In order to determine living room mood through change in the position and brightness of light sources, this study used the SD method and a 7-stage subjective evaluation of six living room activities. Iluminance distribution was measured and its correlation with each factor was analyzed.

After analyzing those lighting factors that impact the living room environment, the results can be used in experiments to find the optimal lighting environment for each activity.

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2. Experimental Method

2.1 Configuration of Laboratory

The overall environment of the evaluation target is shown in Table 1. To create a living room mood, a TV, couch, floor lamp and flower planter were utilized. Using achromatic color, visual stimulus was minimized and artificial lighting was avoided. The light sources used in the laboratory were FPL 36W and 55W (3,000K, 4,000K and 5,000K), and luminaires are shown in Table 2. The width of the ceiling cove light was 2.5×2.5m with 20 units of FPL 55W. The ceiling light was installed in the middle of the ceiling with 4 units of FPL 55W. Three down lights were installed in the ceiling above the TV set. Bracket lights were also placed on the wall behind the couch.

Table 1. Laboratory Environment

Dimension (m)	L×W×H = 6.4×5.8×2.2		
Indoor Finishing Materials	Ceiling: Wallpaper (white) Wall: Wallpaper (ivory) Window Wall : Wallpaper (gray) Floor: Wood vinyl tile		
Indoor Color	Location	Refraction Rate (L*)	Chromaticity (a*,b*)
	Ceiling	95.5	(0.7, 0.6)
	Wall	85.5	(3.5, 7)
	WindowWall	76	(1.5, -0.8)
	Floor	49.5	(9.6, 16.8)
	Rug	55.1	(2, 6.3)
	Couch	27	(2, 1.7)
Supplies	Couch, table, rug, TV, TV cabinet, round table, floor lamp, 2 flowerpots, 1 picture frame		
Simulation			

Table 2. Luminaires Used in the Laboratory

Luminaire		Light Sources (3000, 4000, 5000K)	No. of Lights Used
Ceiling Light		FPL 55W	4
Cove Light		FPL 55W	20
Down light		FPL 36W	3
Bracket		FPL 36W	2

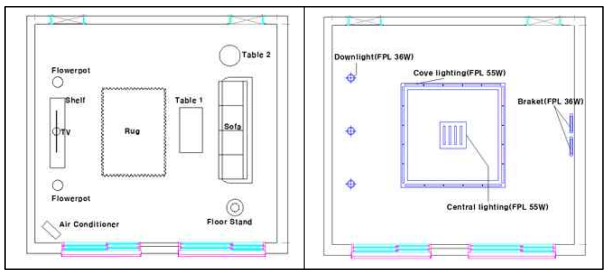

Fig. 1. Laboratory Floor Plan & Ceiling Plan

Fig. 2. Laboratory

2.2 Experimental Conditions

In this experiment, a total of 56 lights (3,000K: 20, 4,000K: 18, 5,000K: 18) were used. The ceiling light and cove light were set to 0, 50 or 100% while the down light and bracket were set to ON or OFF. In terms of the color temperature, three conditions (3,000K, 4,000K and 5,000K) were given (Table 3). The experiment was performed under 57 conditions in total.

Table 3. Experimental Conditions

Ceiling Light (Dimming)			Cove Light (Dimming)			Down light		Bracket		Color Temperature(K)		
0%	50%	100%	0%	50%	100%	0%	100%	0%	100%	3000	4000	5000

2.3 Evaluation Categories and Subjects

For evaluation purposes, the 7-Stage SD method and subjective evaluation were used. In the SD method-based evaluation, those items which were found to be inappropriate for the factor structure, contribution rate and load were excluded. As a result, a total of 18 pairs of adjectives (Table 4) were used. The subjective evaluation categories are stated in Table 5.

The experiment was conducted with college students from the Department of Design and Design of Architecture. In order to avoid any difference related to gender perception, all subjects were female (Table 6).

Table 4. SD Method-based Evaluation Categories

Lively - Calm	Broad - Narrow
Light - Heavy	Dynamic - Static
Natural - Awkward	Clear - Dim
Bright - Dark	Relaxing - Tense
Stable - Unstable	Familiar - Non-Familiar
Pleasant - Unpleasant	Fatiguing for the Eye - Not Fatiguing for the Eye
Unglaring - Glaring	Favorite - Non-favorite
Open - Closed	Soft - Hard
Comfortable - Uncomfortable	
Homogeneous-Heterogeneous	

Table 5. Subjective Evaluation Categories

1. Watching TV
2. Reading a book or newspaper
3. Taking a rest
4. Having a conversation with family
5. Having a fun with family
6. Receiving guests

Table 6. Subjects

Department	17 Students: Dept. of Design 5 Students: Dept. of Architectural Eng.
Age	22 in Average
Gender	Female (22 Students)
Visual Acuity (Corrected)	Left: 0.9, Right: 0.9

3. Experimental Results and Analysis

3.1 Reliability and Factor Analysis

Subjects reliability was high for all experiments

Table 7. Factor Analysis

Factor	Category	Factor Loading			Communality	Factor Naming
		Ⅰ	Ⅱ	Ⅲ		
Ⅰ	Bright - Dark	.902	.173	-.050	.847	Lightness
	Open - Closed	.884	.125	.055	.799	
	Light - Heavy	.877	.065	-.017	.773	
	Lively - Calm	.871	.021	-.088	.767	
	Clear - Dim	.867	.057	.086	.763	
	Dynamic - Static	.863	.072	-.079	.757	
	Broad - Narrow	.826	.150	.157	.729	
	Pleasant - Unpleasant	.675	.379	.100	.610	
Ⅱ	Relaxing - Tense	.037	.828	.039	.688	Emotion
	Soft - Hard	.043	.827	-.110	.679	
	Comfortable - Uncomfortable	.018	.825	.225	.731	
	Familiar - Non-Familiar	.229	.824	.028	.733	
	Favorite - Non-favorite	.121	.821	.131	.705	
	Stable - Unstable	.014	.756	.287	.654	
	Natural - Awkward	.296	.703	.102	.592	
Ⅲ	Homogeneous - Heterogeneous	.359	.336	.630	.638	Calmness
	Unglaring - Glaring	-.617	.280	.499	.709	
	Fatiguing for the Eye - Not Fatiguing for the Eye	.359	.555	.421	.689	
	Eigen Value	7.732	4.890	.918		
	Explanatory Variables (%)	36.2	28.8	6.3		
	Accumulated Variables (%)	36.2	65.0	71.3		

(Cronbach's alpha=.89). After analyzing the key components with personal SD scores and an average of SD scores as data, the varimax rotation was performed. After that, the factor structure was decided. Factor I was related to 'activity' with the state-related evaluation categories such as 'bright', 'open' and 'lively' (36.2% of explanatory variables). It was named "lightness" because its brightness had the biggest impact. In Factor II, explanatory variables were 28.8%. It was related to psychological categories including 'relaxing', 'soft' and 'comfortable'. Because the colors of light source or light distribution were influential, it was named "emotion". Factor III includes 'homogeneous', 'not glaring' and 'not fatiguing for the eye' with 6.3% of explanatory variables. It was named "calmness".

3.2 Analysis of Physical Measurements

In terms of the measurement of luminance, the evaluation targets were measured on the ceiling, three walls and floor at a subjects eyesight height by experimental conditions using the luminance meter LMK. Figure 3 shows a spot in which physical measurement was conducted. The results of the analysis performed by factor using average luminance are stated below:

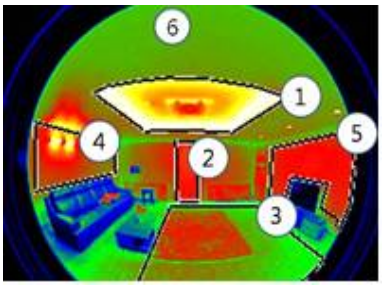

Fig. 3. ① Luminaire on the ceiling, ② Window Wall, ③ Floor, ④ Wall behind the couch, ⑤ Wall behind the TV, ⑥ All other area except for the luminaire on the ceiling

According to a comparative analysis of ① the

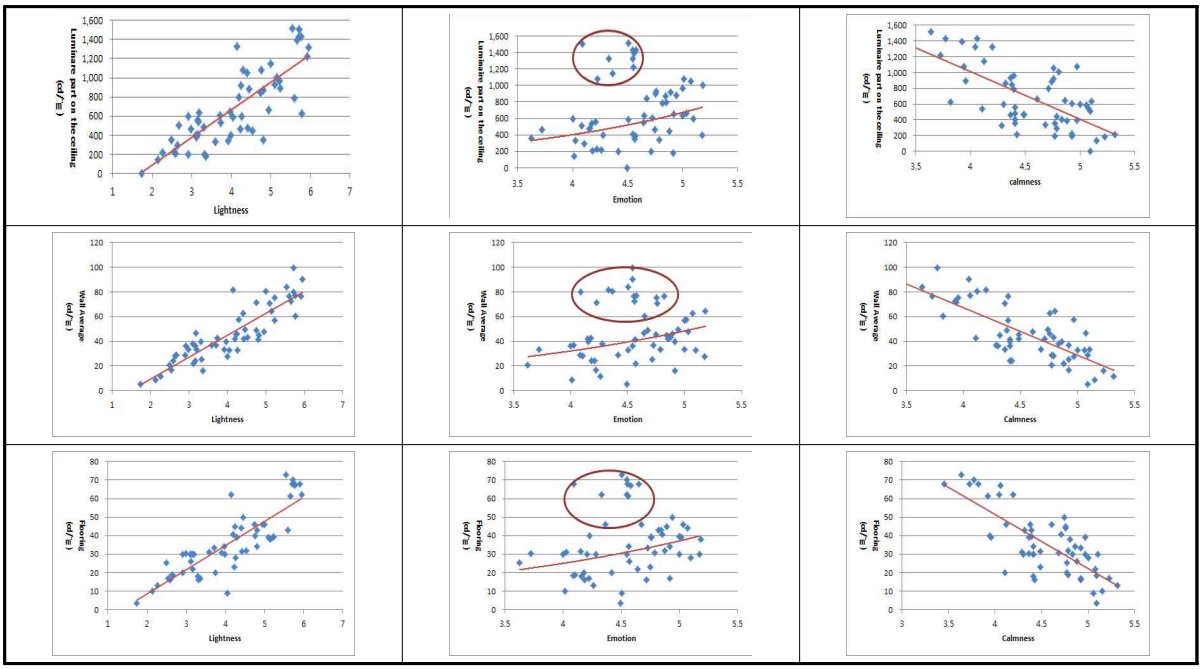

Fig. 4. Relations between Luminance of Room Surface and Factors

average of the luminaire section on the ceiling, ②+④+⑤ wall average and ③ floor average by factor, the results were more positive when luminance was higher on the ceiling, walls and floor. In “calmness”, in contrast, the results were more positive as luminance was lower. In “emotion”, no clear proportional relations were observed compared to the case of “lightness”, but the results were more positive when luminance is higher. However, poor results were observed at too high or too low luminance. To get better results in “emotion”, it is desirable to determine the appropriate luminance.

3.3 Analysis of Living Room Activities

(1) Optimum conditions by living room activity

Table 8. Best Conditions for each activity

Activities	Mean	Lightness	Emotion	Calmness	Test Conditions				
					Ceiling Light	Cove Light	D/L	Bracket	Color Temperature
Watching TV	5.45	4.95	5.03	4.61	100	50	100	0	3000
	5.45	4.53	4.88	4.79	100	0	100	100	3000
	5.45	4.74	4.68	4.38	100	50	100	0	4000
Reading a Book	5.59	5.66	4.56	3.92	100	100	0	0	5000
Relaxing	6.41	1.74	4.49	5.09	0	0	100	0	3000
Having a Conversation with Family	5.73	5.72	4.55	3.77	100	100	100	100	3000
	5.73	5.60	4.82	4.39	0	100	100	100	4000

According to the analysis of the 7-stage subjective evaluation of living room activities, optimum conditions by activity are found (Table 8).

In ‘Watching TV’, both the ceiling light and down light are turned ON under three conditions, and color temperature is 3,000K and 4,000K respectively. Among the six activities, the best condition (5,000K) is observed in ‘Reading a Book’ only. Among the rest of the activities, 3,000K and 4,000K are preferred. In the case of 3,000K, better results are observed when the ceiling light was used.

(2) Correlations of the living room activities by factor

According to the analysis on subjective scores by factor (Fig. 5), difference by activity is observed by

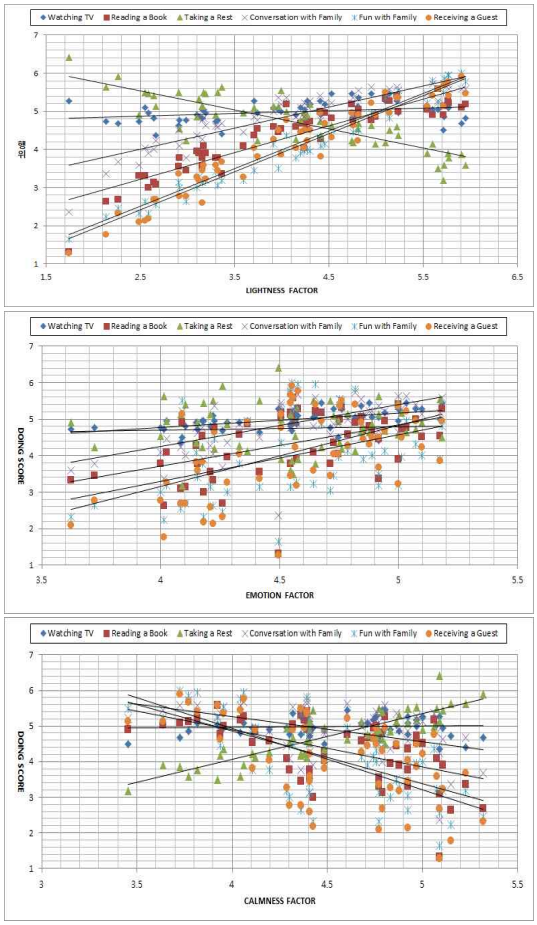

Fig. 5 Living Room Activities-Factor Correlations

factor. In the case of “lightness”, higher results are observed as “lightness” is higher for ‘Reading a Book or Newspaper’, ‘Having a Conservation with the Family’, ‘Having Fun with the Family’ and ‘Entertaining Guests’. In ‘Watching TV’, no difference is observed in terms of brightness. These results show that other factors are related in a complex manner. In the case of ‘Relaxing’, better results are observed a slightness is lower. In the case of “emotion”, good results are observed in all activities under the conditions with mostly high scores. Specifically, ‘Watching TV’ is mainly related to “emotion”. In the case of “calmness”, better results are observed when “calmness” scores are higher. No significant correlations are observed in ‘Watching TV’. In ‘Having a Conservation with the Family’, ‘Having Fun with the Family’ and ‘Entertaining Guests’, better results are detected as calmness scores decreased.

4. Conclusions

This study has used the SD method and a subjective evaluation of living room activities and discovered correlations by measuring luminance under different conditions in order to evaluate the lighting environment of living rooms.

1. According to the SD method-based factor analysis, three factors have been named as categories and are named “Lightness”, “Emotion” and “Calmness”.
2. According to the average luminance of the ceiling, wall and floor, better results were observed as luminance was higher for “lightness”. In terms of “calmness”, on the contrary, the opposite results are detected. In the case of “emotion”, it is desirable to maintain luminance at a moderate level.
3. According to the analysis of the conditions by the living room activities, the living room activities in which “lightness” was important are ‘Having a Conversation with the Family’, ‘Having Fun with the Family’, ‘Entertaining Guests’ and ‘Reading a Book or a Newspaper’. In the case of “emotion”, the most important living room activity is ‘Watching TV’. However, because the three factors are all related, it would be necessary to provide a diverse lighting environment. In the case of “calmness”, the important living room activity is ‘Relaxing’. In ‘Reading a Book or Newspaper’ only, 5,000K is preferred. In other activities, either 3,000K or 4,000K is preferred.

Based on the results above, it was confirmed that the difference in experimental conditions by factor is correlated with luminance and important activities by factor have been analyzed. Based on all these results, a further study will be carried out to determine an optimum lighting environment system.

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