

RELATION BETWEEN LIGHT ENVIRONMENT EVALUATION AND PERSONAL ATTRIBUTES

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Abstract

The light environment in a climate chamber was evaluated at two levels of lighting. Differences in evaluations offered by 200 student subjects were analyzed. Results revealed the following. 1) Sleep time during the day before the experiments, regularity of meal times, habits of window opening, and desire for a natural life are all related to evaluation of light. 2) Sex, use of corrective lenses, site of residence, and habits of saving light are unrelated to light evaluation. 3) Lighting comfort and preference depend on whether subjects live in wooden homes or in concrete homes. Concrete-home-residents are more comfortable than wooden-home-residents in dark conditions, although light environment evaluations of concrete-home-residents and wooden-home-residents do not differ in a lighted condition. 4) Wooden-home-residents respond similarly to concrete-home residents if they do not desire continuity to outdoors. Concrete-home-residents respond similarly to wooden-home-residents if they change lighting according to the weather.

Keywords: Lighting comfort, Lighting preference, Personal attributes, Daily exposure to light

1 Introduction

Personal attributes such as age and ophthalmological disease are sometimes considered in light environment evaluation studies. Naoi et al. (2003) analysed the effects of subjects' daily exposure to light and attitudes about lighting on light environment evaluation. Because of the limited number of special experimental devices, or because of the need to assess many patterns of the experiments in a limited time, it has been difficult to use numerous subjects in light evaluation studies. Consequently, few subjects were used and there was little need to consider personal differences was observed. To analyse the effects of daily exposure to light, however, statistical analysis is needed. It necessitates the use of significantly numerous subjects. This study used data of 200 subjects to analyse different evaluations of light environments by subjects' attributes.

2 Methods

2.1 Experimental room

Figure 1 portrays the experimental room. Four fluorescent lamps were installed on the ceiling shown as shaded areas. Lighting power was conditioned at two levels: 25% and 100%. Room temperature and humidity were kept at 25°C and 50%. The four walls were covered by curtains. Six subjects participated in the experiment simultaneously. The mean horizontal illuminance among six seats was 342 lx in the Dark and 2238 lx in Light conditions.

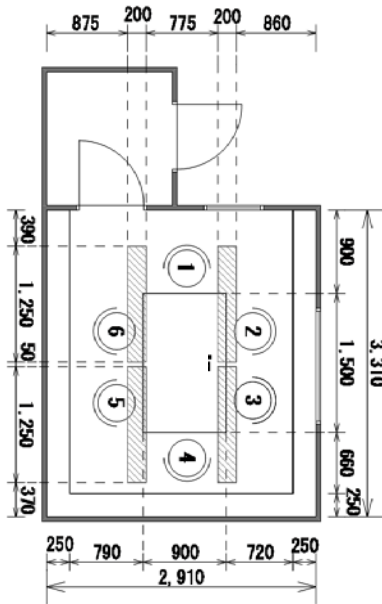


Figure 1. Experimental room

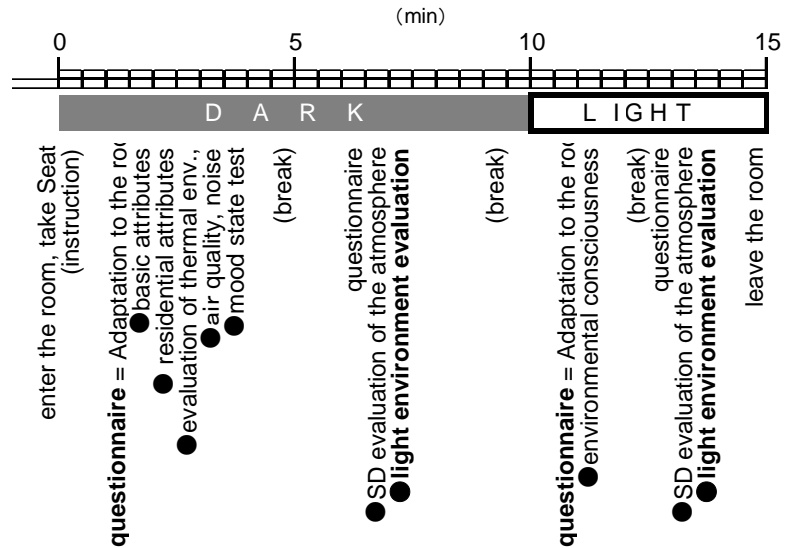


Figure 2. Experimental procedure (D-to-L exp.)

2.2 Experimental procedures

Figure 2 presents the experimental procedures. Subjects entered the room and sat at the table and answered questionnaires in the first lighting condition. Then the lighting level was changed and subjects answered the questionnaires in the second lighting condition. The Dark-to-Light experiment was conducted in 2009. The Light-to-Dark experiment was conducted in 2010. Each Dark-to-Light experiment continued for about 15 minutes. Each Light-to-Dark experiment continued about 19 minutes. Questionnaire items are presented in Table 1¹. The light environment evaluation was done in each lighting condition. Questionnaire items aside from the light environment evaluation were answered as subjects adapted to the light conditions.

3 Subjects' attributes

In all, 80 subjects participated in the experiments in 2009 and 120 subjects participated in 2010. Subjects' attribute items comprise personal attributes such as sex, the use of corrective lenses, vision, health condition, constitution, and living habits of eating or sleeping, residential attributes such as structure, site, height, family number and lighting use, and environmental consciousness such as desire for natural living, desire to have natural light, desire to have continuity with the outdoors, resistance to hot and cold temperatures, and requirements of brighter outdoors at night. Subjects' attributes did not differ significantly between the 2009 and 2010 experiments except for resistance to cold. When data of both years were combined, 68.7% of subjects were male, 56.6% wore corrective

¹ Environmental consciousness was reported as one of four categories: 'fairly yes', 'yes', 'slightly yes', and 'no'. These answers were analysed by categories of 'fairly yes' and 'yes' and categories of 'slightly yes' and 'no'.

Table 1. Questionnaire items

Basic attributes	Sex, Age, Grade, Use of glasses or contact lenses, Vision, Sleeping hours [last night, ordinary], Sleeping hours [last night, ordinary], Exercise (5),
Residential attributes	Structure (3), Gathering (5), Site (5), Interval (3), Layout (4), Family number, Residential floor, Lighting apparatuses (4), Lighting style (3), Direction of windows, Daytime light use (2), Brightness of living room (7), Frequency of window opening (3), Air conditioner use (5), Glance from outside (4), Spaciousness (5)
Environmental consciousness	Long for living in nature such as living in mountain lodge(4), Desire to live in natural light if possible (4), Be interested in lighting apparatuses (4) Turn off needless lights (4), Desire to continuity to outdoor (4), Be interested in environmental problems (4), Require of brighter outdoor at night (4), Require of more stores 24 hour open (4), Be patient to heat (4), Be patient to cold (4)

Table 2. Light environment evaluation

Item	Questionnaire	Choices
Brightness	How do you think about brightness of this room?	1. very bright, 2. bright, 3. slightly bright, 4. neutral, 5. slightly dark, 6. dark 7. very dark
Glare	How do you think about glare of this room?	1. very disturbing, 2. disturbing, 3. slightly disturbing, 4. almost non disturbing, 5. not disturbing at all
Lighting comfort	Do you think lighting of this room comfortable?	1. very comfortable, 2. comfortable, 3. slightly comfortable, 4. neutral, 5. slightly uncomfortable, 6. uncomfortable
Lighting preference	Do you like lighting of this room?	1. very preferable, 2. preferable, 3. slightly preferable, 4. neutral, 5. slightly unpreferable, 6. unpreferable, 7. very

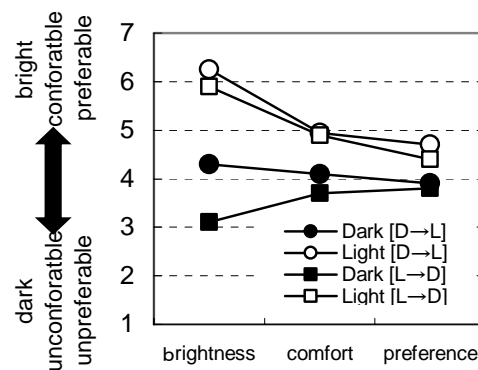


Figure 3. Means of light environment

lenses, 60.4% lived in concrete homes (35.3% in wooden homes²), 71.7% changed daytime lighting by weather (28.3% used lighting during the daytime). 59.3% longed to live in natural areas such as living in a mountain lodge. In addition, 63.5% desired continuity with the outdoors.

4 Light environment evaluation

Light environment evaluation items were brightness, brightness for writing, uniformity of brightness, glare, light colour preference, lighting waver, lighting comfort, lighting preference, and performance. Subjects were instructed to evaluate the light environment of the experimental room. This paper analyses mainly brightness, glare, lighting comfort, and lighting preference. Expressions of questionnaires and answers given to these four items are presented in Table 2.

² Answers related to the structure of the home are wooden home, concrete home, and other. Subjects who responded in the latter category were eliminated because they were only nine. The ratio of concrete homes were 35.5% in Japan, but 63.0% in this study. Subjects were not familiar with the building structure and they might have misunderstood wooden homes as concrete homes. Therefore, concrete homes in this study might actually include wooden homes. It can be said that homes described as wooden homes in this study are traditional wooden homes.

Table 3. Correlation coefficients among evaluation items

		glare	comfort	preference
brightness	Dark (D→L)	0.38 (1%)	0.37 (1%)	0.32 (1%)
	Light (D→L)	0.37 (1%)	0.34 (1%)	0.28 (1%)
	Dark (L→D)	—	0.59 (0.01%)	0.49 (0.01%)
	Light (L→D)	0.27 (1%)	0.25 (1%)	0.29 (1%)
glare	Dark (D→L)	/	—	—
	Light (D→L)		−0.39 (1%)	−0.30(1%)
	Dark (L→D)		—	—
	Light (L→D)		−0.27 (1%)	−0.20 (5%)
comfort	Dark (D→L)	/	/	0.71 (0.01%)
	Light (D→L)			0.82 (0.01%)
	Dark (L→D)			0.80 (0.01%)
	Light (L→D)			0.71 (0.01%)

4.1 Comparison of mean evaluation values between lighting conditions and presented orders

Figure 3 presents the mean evaluation values of brightness, lighting comfort, and lighting preference for each lighting level and the order of presentation. Light conditions are evaluated as markedly brighter, more comfortable, and more preferred than Dark conditions both in the Light-to-Dark experiment and Dark-to-Light experiment. The Light condition presented first is evaluated as markedly brighter, more comfortable, and more preferred than when the Dark condition is presented first.

4.2 Interrelation among light evaluation items

Table 3 shows correlation coefficients for light evaluation of brightness, glare, comfort and preference for each lighting condition and the presented order. Comfort and preference highly correlate, with significance of 0.01%. Brightness correlates to comfort and preference irrespective of lighting conditions and the order of presentation. Comfort correlates better to brightness than preference does. Glare relates to brightness in the Light condition, irrespective of the order of presentation. Glare correlates negatively to comfort and preference in the Light condition irrespective of the order of presentation.

5 Subjects' attributes and light environment evaluation

5.1 Attributes related to light environment evaluation

Figure 4 shows the light environment evaluation by the habit of air conditioner use, sleeping time of the day before, habits of window opening, and the structure of the home. The light environment evaluation differs significantly according to these attributes³. The more frequently that subjects use air conditioners, the brighter they evaluate the environment in the Light condition presented first ($p=5\%$). Subjects with fewer than six hours' sleep evaluate more glare than those with more than six hours' sleep in a Light condition presented secondly ($p=1\%$). The more frequently subjects open windows, the more comfortable and preferred their environment is regarded in the Light condition ($p=10\%$). Only figures for the Light condition presented secondly are shown in Figure 4. Concrete-home-residents evaluate their surroundings as more comfortable and preferred than wooden-home-residents in Dark conditions when presented first ($p=5\%$).

³ Mann–Whitney U-test was used for comparison. The Wilcoxon test was used for paired comparison.

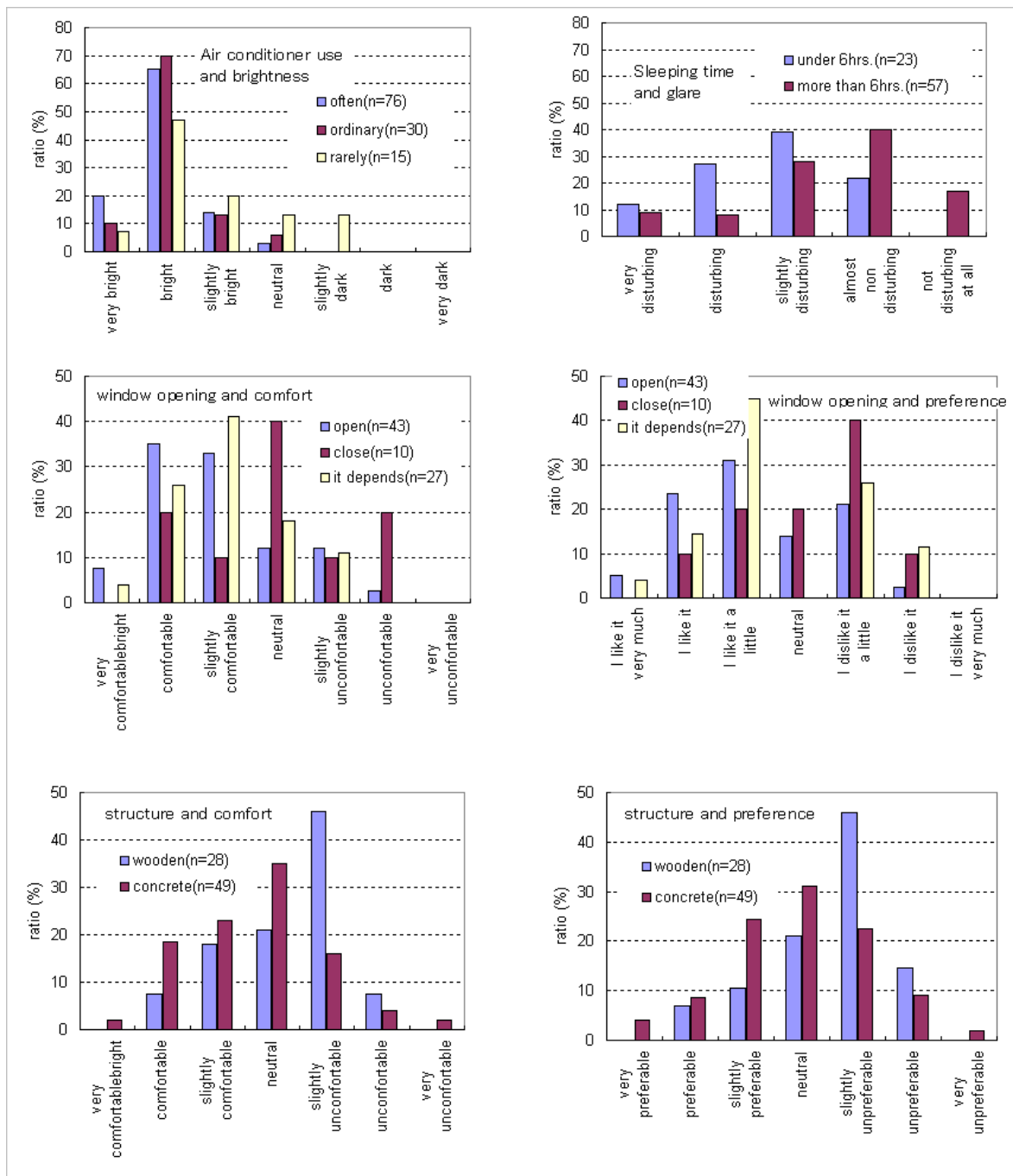


Figure 4. Light environment evaluation by personal attributes

Subjects are classified into categories A and B for each item shown in Table 4. For example, subjects with a desire to embrace natural living are classified into category A and others into category B regarding the items of desire for natural living. Subjects living in wooden homes are classified into category A. Similar tendencies in evaluation of Dark conditions presented first are found for desire to natural living, desire for continuity with outdoors and light use in daytime⁴, as shown in Table 5.

⁴ There were two answers of daytime light use: 'use light all time', and 'change lighting according to weather'.

Table 4. Category-A and Category-B

		category	
		category-A	category-B
item	structure	wood	concrete
	natural living	long for	not long for
	continuity	desire	not desire
	daytime light use	by weather	allday

Table 5. Comparison between two categories
(Dark in Dark-to-Light experiments)

		light environment evaluation			
		brightness	glare	comfort	preference
item	structure	—	—	B>A (5%)	B>A (5%)
	natural living	—	—	B>A (15%)	B>A (20%)
	continuity	B>A (10%)	—	B>A (1%)	B>A (1%)
	daytime light use	—	—	B>A (10%)	B>A (5%)

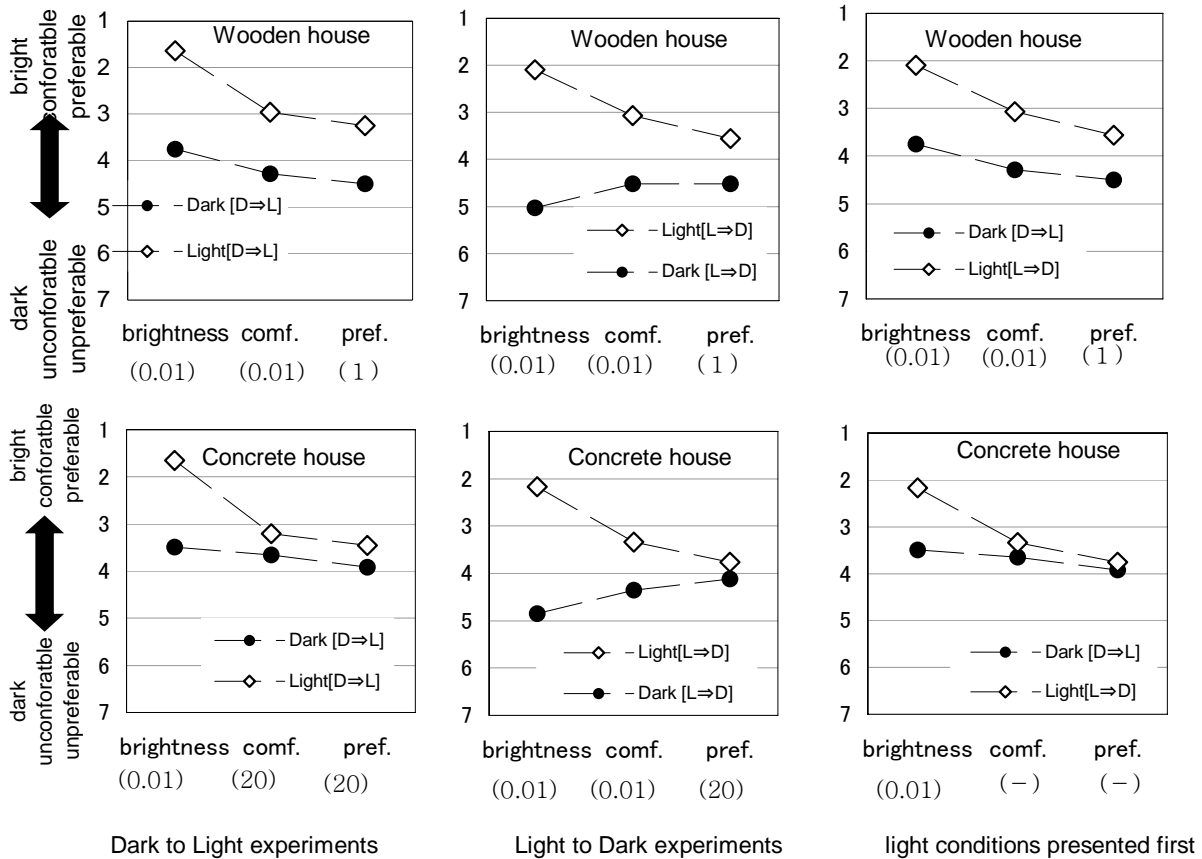


Figure 5. 'Structure' and light environment evaluation

Subjects in category A evaluate their environment as less comfortable and less preferred when they desire natural living ($p=15\%$ for Comfort, 20% for Preference), desire continuity with outdoors ($p=1\%$ for C, 1% for P), and light use during daytime ($p=10\%$ for C, 5% for P) in Dark conditions presented first. Subjects who desire continuity with the outdoors evaluate their surroundings as darker with a Dark condition presented first ($p=10\%$).

5.2 Light environment evaluation difference by structure of the home

The preceding section, 5.1, described how the structure of the home—concrete home or wooden home—relates to subjects' light environment evaluation. It does not relate directly to the subjects'

Table 6. Comparison between Light and Dark

Difference between L and D in Dark to Light experiments

	category-A			category-B		
	brightness	comfort	preference	brightness	comfort	preference
structure	L>D (0.01)	L>D (0.01)	L>D (1)	L>D (0.01)	L>D (20)	L>D (20)
continuity	L>D (0.01)	L>D (0.01)	L>D (0.01)	L>D (1)	–	–
daytime light	L>D (0.01)	L>D (0.01)	L>D (0.01)	L>D (0.01)	–	–

Difference between L and D in Light to Dark experiments

	category-A			category-B		
	brightness	comfort	preference	brightness	comfort	preference
structure	L>D (0.01)	L>D (0.01)	L>D (1)	L>D (0.01)	L>D (0.01)	L>D (20)
continuity	L>D (0.01)	L>D (0.01)	L>D (1)	L>D (0.01)	L>D (1)	–
daytime light	L>D (0.01)	L>D (0.01)	L>D (1)	L>D (0.01)	L>D (1)	L>D (10)

Difference between Light presented first and Dark presented first

	category-A			category-B		
	brightness	comfort	preference	brightness	comfort	preference
structure	L>D (0.01)	L>D (0.01)	L>D (0.01)	L>D (1)	–	–
continuity	L>D (0.01)	L>D (1)	L>D (1)	L>D (1)	–	–
daytime light	L>D (0.01)	L>D (1)	L>D (1)	L>D (1)	L>D (20)	–

living habits, physical conditions, or environmental consciousness. The reasons for the difference remain unclear. This section presents analyses of the relation between the structure and light environment evaluation.

Figure 5 shows the light environment evaluation by lighting conditions and presented orders for wooden-home and concrete-home-residents.

For wooden-home-residents, Light conditions presented first are more comfortable and more preferred than with Dark conditions presented first. For concrete-home-residents, no significant difference was found in comfort and preference between the Light condition presented first and Dark condition presented first.

If evaluations are compared between Dark and Light conditions in Dark-to-Light experiments, for wooden-home-residents, the Light condition presented second is more comfortable and more preferred than when the Dark condition is presented first. For concrete-home-residents, little difference was found in comfort and preference between the Light condition presented secondly and Dark condition presented first.

If evaluations are compared between Dark and Light conditions in Light-to-Dark experiments, then for wooden-home-residents, the Light condition presented first is more comfortable and more preferable than Dark condition presented secondly. For concrete-home-residents, the Light condition presented first is more comfortable than the Dark condition presented secondly. Little difference was found in preference between Light and Dark conditions presented first.

It can be said that comfort and preference differ between lighting conditions for wooden-home-residents, but little difference exists for concrete-home-residents because Dark conditions are more comfortable and more preferred by concrete-home-residents than by wooden-home-residents.

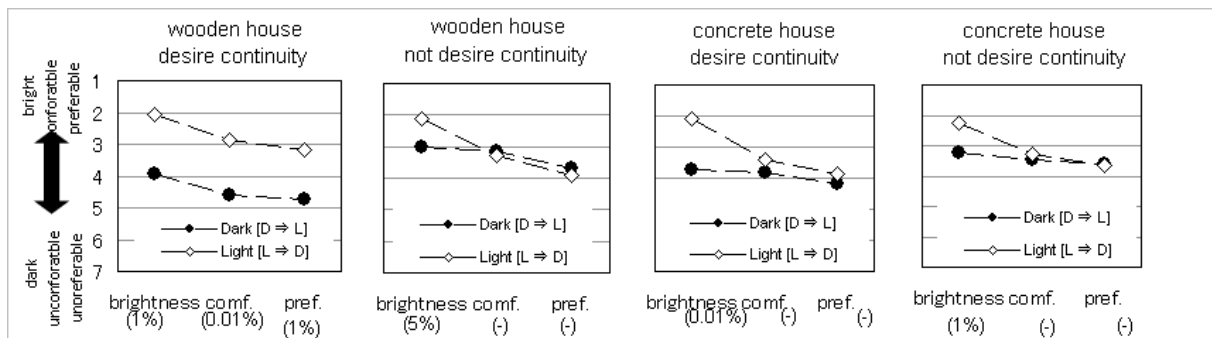


Figure 6. Light environment evaluation by 'structure' and 'continuity'
(comparison between conditions presented first)

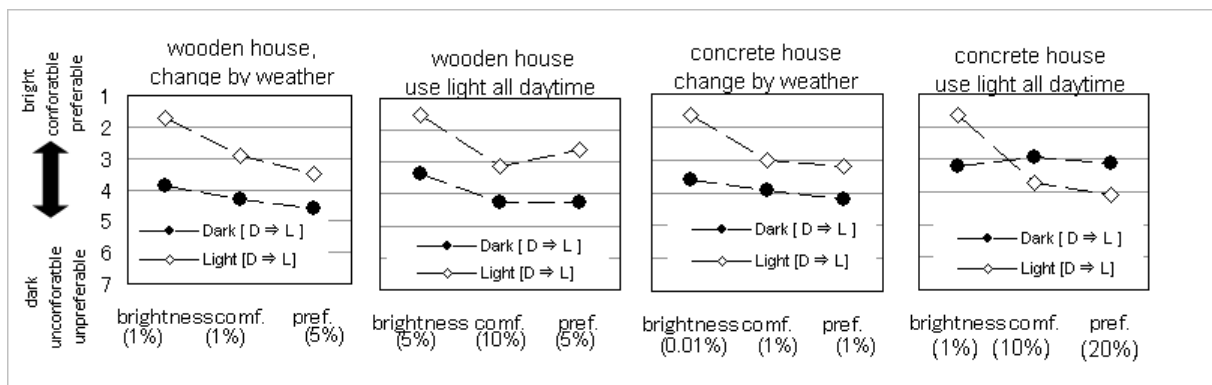


Figure 7. Light environment evaluation by 'structure' and daytime light use
(comparison between Dark and Light in Dark-to-Light experiments)

5.3 Effects of 'continuity' and 'daytime light use' on the difference of evaluation by 'structure'

If subjects are classified by attributes of 'structure', 'continuity', and 'daytime light use' into each category A (wooden, desire, depends on weather) and B (concrete, not desire, all day), then the Light condition is more comfortable and more preferred than the Dark condition for category A. Little difference exists between Light and Dark conditions for category B, as shown in Table 6.

It is verified that attributes of 'structure', 'continuity', and 'daytime light use' are statistically independent. Then effects of 'continuity' and 'daytime light use' on 'structure' in light environment evaluation are analysed to clarify whether 'structure' relates independently to light evaluation or not. Comfort and preference are compared between Dark and Light conditions for four categories of 'structure' combined by 'continuity' and 'daytime light use'. Figures 6, 7, and 8 present cases of remarkable differences among four categories.

5.3.1 Combination of 'structure' and 'continuity'

Figure 6 shows that four categories of 'structure' combined by 'continuity' show remarkable differences in comparison between Dark and Light conditions presented first. The Light condition is more comfortable and preferred than the Dark condition for categories of 'wood' combined with 'continuity', although no significant difference was found between Dark and Light conditions in comfort and

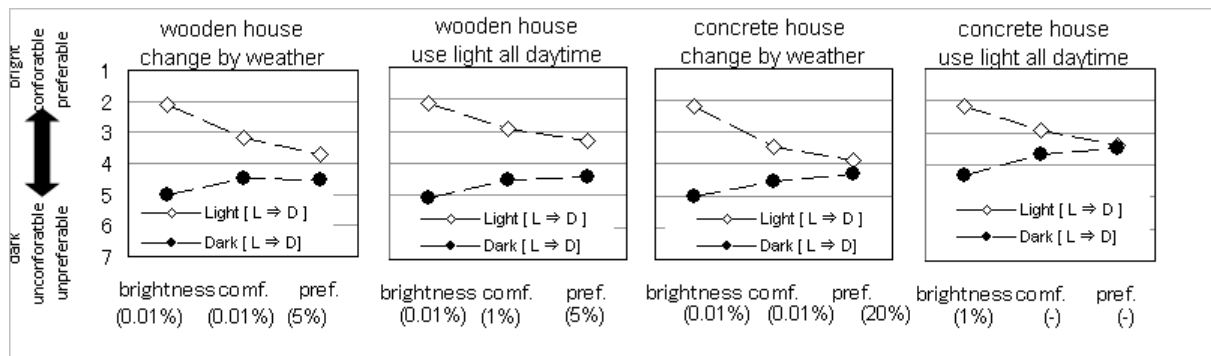


Figure 8. Light environment evaluation by 'structure' and daytime light use (comparison between Dark and Light in Light-to-Dark experiments)

preference for the other three categories. It can be said that wooden-home-residents respond similarly to concrete-home-residents if they do not desire continuity with outdoor areas. Living in a wooden home is not the sole cause of sensitivity to lighting comfort and preference. Only subjects who desire continuity to outdoor areas as a result of living in wooden homes are sensitive to light. Larger windows and lighter indoor areas of wooden homes are presumed as factors.

5.3.2 Combination of 'structure' and 'daytime light use'

Figure 7 shows that four categories of 'structure' combined by 'daytime light use' show remarkable differences in comparison between Dark and Light conditions in Dark-to-Light experiments. The Dark condition is more comfortable and preferred than the Light condition for the category of 'concrete' combined with 'use light all daytime', although the light condition is more comfortable and preferred than the Dark condition for the other three categories.

In Light-to-Dark experiments, Figure 8 shows that no difference was found between Dark and Light conditions for category of 'concrete' combined with 'use light all daytime', although the Light condition is more comfortable and preferred than the Dark condition for the other three categories. The concrete-home-residents respond similarly to wooden-home-residents if they change lighting by weather. Subjects living in concrete homes who use lighting all the time evaluate both Dark and Light conditions as comfortable and preferred. It is presumed that they live in concrete homes with less effects of sunlight and exposed artificial light constantly and lose their standards for comfort and preference in lighting.

6 Personal Attributes and impression evaluation of the room

Brightness, comfort and preference of the experimental room are evaluated using semantic differential scales in the experiments. These include reports of overall impressions of the room beyond the light environment evaluation. Differences of impressions of brightness, comfort, and preference between Dark and Light conditions were compared by 'structure'. No differences were found in brightness, comfort, or preference evaluations between wooden-home-residents and concrete-home-residents. Results show that 'structure' has effects only on the light environment evaluation. It has no effects on impression evaluation of comfort and preference.

7 Conclusions

Comfort and preference evaluation of light differ according to subjects' home structure, desire to have continuity to outdoor areas, and daytime lighting use. Wooden-home-residents who do not desire continuity respond similarly to concrete-home-residents. Concrete-home-residents who change artificial lighting by weather respond similarly to wooden-home-residents. Results clarified that subjects' home structure does not solely affect the evaluation, and that environmental consciousness and lighting habits in daily life relate to the evaluation of comfort and preference of the light environment. However, brightness evaluation of the light environment does not differ according to these subjects' attributes.

Results of this study clarify that it is necessary to consider subjects' environmental consciousness and lighting habits during comfort and preference evaluations of light, although little effects of these attributes were found in brightness evaluation. Consideration of these attributes will engender more comfortable and preferred lighting design.

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