Paper

Effect of Personal Adjustment of Brightness on the Satisfaction Level of Office Lighting

Nuiko MIYASAWA, Yoshiki NAKAMURA and Naoki WAKASA

Tokyo Institute of Technology

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ABSTRACT

To clarify the importance of personal adjustments on office lighting, 17 general office workers and 38 experts in the lighting industry are interviewed. Experiments are conducted to quantify the effect of the subjects' capability to change the illuminance on their satisfaction level, and to distinguish the effect of "control" from the effect of illuminance change itself.

It is shown through the interviews that although the awareness on the importance of adjustment is not prevalent, both general office workers and lighting designers regard lighting adjustment as a key factor. Through the experiments, it is observed that evaluations on the lighting environment vary greatly depending on whether or not the subjects are capable of adjusting the lighting level, while effects of both "control" and illuminance change are small.

KEYWORDS: control, illuminance change, office lighting, satisfaction level, interview, evaluation

1. Introduction

Personal adjustment of air conditioning and lighting, not only fulfills diversified individual desires and enhances comfort, but also presumably increase work efficiency and intellectual productivity. Hence, personal adjustment is becoming an important factor, when considering comfort of building spaces. Moreover, if designed properly, this would contribute to energy conservation, as well.* It may be safely said that the promotion of personal adjustment will have a great impact on future design of interior environment.

In the field of lighting, an example of personal adjustment is the adjustment of brightness by the individual. However, personal adjustment of brightness has not been hitherto considered in lighting designs. Therefore, it is not clear what types of value people attach to brightness adjustment. This study aims to quantitatively analyze the effect of personal brightness adjustment.

2. Previous Studies

Not many studies on brightness adjustment are prevalent to this date. Veitch (1996)¹⁾ examined the effect of choosing one out of three types of task ambient ratios obtained by different lighting equipment output with the same illuminance level at the desktop, by applying the concept of "control".

"Control" is defined as "a determinant of the cognitive appraisal of threat" (quotation 1) by Corah, et al (1970)²⁾. Generally, the term "control" may be translated as "governance" or "rule" in Japanese. However, in this

discussion, "control" is considered as a determinant that influences the evaluation of a particular environment (here, stress). On the other hand, Averill (1973)³⁾ conducted a detailed study on the relationship between "control" and the state of coping with stress, assuming that "control" influences the evaluation of stress (aversive environment). He identified an individual's "direct action on environment" (quotation 2) as "behavioral control", and assuming that "control" exists in the state in which one recognizes how certain events occur, he defined this as "cognitive control". Furthermore, assuming there exists "control" in a situation where one deliberately chooses an unfavorable condition out of several alternatives and tries to regard that as positive, he called this "decisional control". Averill pointed out the necessity of grasping "control" from these three aspects. As a subset of the state of having "cognitive control", Barnes (1981)⁴⁾ identified the state where one can cope with stress by knowing that the cause of the occurrence of certain events is up to the individual and thus "one's choices determine outcomes" (quotation 3), as having "perceived control".

Based on these studies, Miyasawa, et al. (2000)⁵⁾ confirmed the existence of the effect of "control" through an experiment where subjects were actually required to adjust the brightness of office lighting. However, this study did not clarify the role of adjustment in office lighting and did not provide a quantitative analysis on the effect of "control".

3. Objective of the Study

This study aims first to clarify the role of brightness adjustment in office lighting through interviews with office workers. An office is chosen because people spend long hours in offices. Second, this study tries to quantitatively clarify the effect of brightness adjustment by requesting subjects to actually adjust the brightness of office lighting.

* Some examples of task and ambient lighting are shown in the special issue entitled as "Visual environment and illumination in intelligent buildings" of Journal of IEIJ in 1987.

In this study, "brightness adjustment" refers to brightness adjustment made by the individual for the sake of himself and is defined as "to change brightness in order to create a comfortable environment." "Control" is defined as "the determinant that creates a difference in evaluation between the situation after the adjustment and the stable situation." Brightness adjustment will be described by applying the following concept of "control".

(1) Behavioral Control

The determinant that creates a difference between the evaluation of the environment that is improved by the individual and the evaluation of the same environment that is provided without any direct action by the individual.

Eg.) The determinant that creates a difference between the evaluation of the environment that is brightened by the individual with a switch because it is dark and of the same environment that is provided without any direct action by the individual.

(2) Decisional Control

The determinant that creates a difference between the evaluation of the environment that is deliberately made unfavorable by the individual and the evaluation of the same environment that is provided without any direct action by the individual.

(Eg.) The determinant that creates a difference between the evaluation of the environment that is deliberately darkened by switching off the light to save energy and the evaluation of the same environment that is provided without any direct action by the individual.

(3) Perceived Control

The determinant that creates a difference between the evaluation of the environment in which the individual has the cognition that he can adjust the environment when necessary and the evaluation of the same environment without such cognition.

Eg.) The determinant which creates a difference between the evaluation of the environment that is currently dark but the individual is aware that he can brighten it by turning on the lights whenever necessary and the evaluation of the same environment when the individual is not aware

"No control" refers to the state where none of the above determinants exists. Among the above "controls", the objective of this study is to quantitatively examine the effect of "behavioral control" and "perceived control". Meanwhile, "decisional control" will not be discussed in this study, since frequency of appearance of "decisional control" is relatively lower than that of "behavioral control" and is prone to be affected by the individual's sense of values.

4. Interview-type Experiment to Clarify the Role of Personal Adjustment in Office Lighting

4.1 Outline of the Experiment

An interview-type experiment is conducted to extract all viewpoints that are necessary for each subject in evaluating

Table 1 Experiment Plan.

Stage	Questions	Purpose	Materials presented
<1>	Office lighting requirements	Probe office lighting requirements that subjects are ordinarily aware of	
<2>	Office lighting classification method	Probe office lighting classification perspectives that subjects are ordinarily aware of	
<3>	Office lighting classification method	↓ Raise awareness by showing photos	Show office photos
<4>	Explanation on office photos	↓ Further raise awareness by showing photos in details	Show office photos one by one
<5>	Office lighting classification method	↓ Further raise awareness by providing textbook information	Make subjects read literature on office lighting

Table 2 Composition of Subjects.

		Designers	Engineers	General office workers
20's	Male	2	3	2
	Female	3	2	10
30's	Male	12	7	2
	Female	3	3	0
40's	Male	1	2	1
	Female	0	0	0
50's	Male	0	0	2
	Female	0	0	0
Total		21	17	17

office lighting, to understand how each of these viewpoints are regarded by each subject, and to clarify where brightness adjustment is positioned among these viewpoints.

The experiment is comprised of five stages and conducted with each subject in an interview-style (Table1). A total of 55 subjects are grouped into three types according to their attributes, namely lighting designer, lighting engineer and general office worker without technical knowledge of lighting, presuming that depending on the attribute, the evaluation of office lighting environment will vary. Attributes of each group will be named "designer", "engineer", and "general office worker", and the number of subjects is 21, 17 and 17, respectively. All subjects regularly work in offices. Table 2 shows the composition of the subjects.

4.2 Procedure of the Experiment

According to a preliminary experiment, the subjects often used the expression "sufficiently bright" to describe the office lighting environment. This expression can be regarded as the combination of "brightness", which is the viewpoint and "sufficient", which is the evaluation of the said viewpoint. Hence, for the purpose of this experiment, the evaluation portion is detached and only the viewpoint portion is used.

Generally, the true meaning of a viewpoint used by the subject is made clearer by posing an opposing concept. If the subject mentions "bright" for example, he is asked if he can name an antonym for "bright" that can be used to evaluate

Fig.1 Relation among viewpoints, scales and preference.

office lighting. If the subject answers "yes", then this viewpoint is represented as a scale that has two extremes.

Some evaluation viewpoints were scales, the degree of which can be evaluated in several ranks, such as from "bright to dark", while others were scales that had only two or several ranks, such as "window size" or "window existence". And some viewpoints did not have two extremes but had several groups such as "square-framed lighting or pendant lighting".

Among the above viewpoints, some are scales in which the subjects would prefer either end of the extreme, for example degree of glare. Some are scales in which the subjects would find an appropriate level somewhere in the middle of the two extremes, for example bright-dark. Some are scales in which the position of the appropriate level would differ according to the subject, for example existence or size of the window. Furthermore some viewpoints are not directly related to preference, such as semi-indirect lighting. Therefore the

experimenters tried to clarify the relationship between the scale evaluation or the viewpoint grouping and the subjects' preferences (Fig. 1).

The subjects were, furthermore, requested to evaluate importance of these scales or viewpoints in the following four ranks: "extremely important and almost indispensable", "very important", "important", and "better to have".

Finally, in order to clarify the level of consistency among the subjects in their evaluations, they are requested to place each of the 19 office photos to the corresponding location on the scales or on the viewpoint groups*.

A series of procedures, i.e., extracting viewpoints, sorting them into the scales and the categorical viewpoints, evaluating importance level and photo placing, are repeated

* Scales or viewpoints shown in the table are only those on which subjects can place these 19 photos.

Fig. 2 Relation between viewpoints and categories.

in each of the five stages shown in Table 1. However, for stages 1 and 2, in order to extract viewpoints without being exposed to external information, the photos were not shown to subjects until stage 3.

4.3 Results of the Experiment and Discussions

4.3.1 Difference of Important Viewpoints among Attributes

79 viewpoints relating to office lighting are extracted from the experiment, based on 5 stages shown in Table 1.

Among the viewpoints some seems to represent multiple viewpoints (shown in gray enclosure in Fig 2). 14 of these are observed and each of them is named "category" (shown in black enclosure in Table 3). In order to visualize the relationship between categories and viewpoints as well as viewpoints themselves, they are connected with lines as shown in Fig. 2. For example, it is found that "brightness" can be broken down into "brightness of the surrounding, brightness at hand, brightness of the ceiling surface, and brightness of the wall," based on subjects' responses. By researching all subjects' responses and drawing these lines, "networks," where all categories are connected to each other by viewpoints and where all viewpoints are connected to various categories, are obtained. These are called "network charts." In this discussion, "adjustment" and "sensor" are

Table 3 List of 79 viewpoints (categories are shown in black enclosures).

1	Brightness	21	Appearance of luminaire used	41	Energy saving	61	color
2	Brightness of the surrounding	22	Structural lighting	42	Lighting control	62	Color of room finish
3	Brightness of the ceiling	23	Indirect lighting	43	Daylight usage	63	Color of interior
4	Brightness of the wall	24	Lighting system	44	Lighting planning through all day	64	Directivity of light
5	Brightness in the evening	25	Ceiling lighting	45	Sensor	65	modeling
6	Brightness at one's hand	26	Relation between ceiling height	46	Zoning	66	Vertical illuminance
7	Brightness of the entire surrounding	27	Exposure of fluorescent lamp	47	Direct lighting	67	glare
8	Uniformity	28	Pendant luminaire	48	Natural lighting	68	Glare control/ G classification
9	Relation with the desk and luminaire	29	Number of luminaire	49	Blinds	69	Glare of luminaire
10	Can cope with relocation	30	Wall washer/bracket	50	Window/ daylight	70	Dazzle of luminaire
11	Layout of desk and lighting	31	Simple ceiling surface	51	View	71	Louver
12	Distribution of lighting	32	Partition	52	Dramatic change in brightness	72	Reflection on VDT monitor
13	Lighting of day time and night time	33	Top light	53	Openness	73	Glare light source
14	Visibility from the outside	34	Adjustment	54	Less noise (unpleasantness of brightness)	74	Reflection
15	Items related to luminaire	35	Adjustment by purpose	55	Atmosphere	75	Background luminance
16	Task ambient	36	Adjustment of the entire room	56	Relaxing	76	Satisfies necessary illuminance level
17	Task light	37	Light source	57	Tinting	77	Lighting combination
18	Effective use of task light	38	Color temperature	58	Vigor/ cheerfulness	78	Lighting method
19	Efficiency of indirect lighting	39	Degree of color rendering properties	59	design	79	Personal lighting
20	Local versus general lighting	40	Flicker	60	Corner separation (lighting planning depends on working zone)

Fig. 3 Importance level of categories by attributes (on a scale of 0-100).

considered as different categories, because the subjects' responses suggest that "adjustment" refers to adjustment made by individuals and thus is used to express the action of changing the existing situation, while the subjects limit the function of "sensor" to maintaining a certain level of brightness.

The importance level of each category is determined by importance level of all viewpoints that are connected to the category. The difference in importance level of all categories among attributes is examined (Fig. 3). The calculation method is as follows.

- (1) The importance level for each viewpoint is ranked from 4 to 1 points ("extremely important and almost indispensable" =4, "very important"=3, "important"=2, and "better to have"=1)
- (2) The sum of the above points for all subjects by attributes is calculated
- (3) Then, the sum of the above points is divided by the number of subjects in each attribute

Through this, the importance level of each category is displayed in numbers (points) to show how much importance is placed on each category per subject by attributes on average. In the case none of the subject mentions any viewpoint connected to a certain category, the importance level of that category is assigned 0 points. The greater the number of lines connected to a viewpoint and the more that viewpoint is evaluated as being important, the higher the importance level of a category becomes. The final importance level of each category is defined by standardizing the above points by dividing each point by the sum of all points of the 14 categories. When there is a viewpoint connected to multiple categories, the importance level of the viewpoint is included in the multiple categories.

Notes:

- Categories shown in black enclosures are those with importance levels of 10 or more.
- Categories shown in white enclosures are those with importance levels of 4 or more and less than 10.
- Viewpoints which connect categories shown without enclosures
- Numerical figures in charts indicate the proportion of subjects who mentioned that the categories are related to each other.
- Thin lines: related
- Bold lines: strongly related

Fig.4 Network charts by attributes.

As an overall trend, categories regarded as important are "brightness", "glare", "natural lighting", "items related to luminaire", "atmosphere", "design" and "adjustment" when ranked from the top. For each attribute, the top three categories are common. However, the category ranked fourth is "ambience" for designer, "items related to luminaire" for engineer and "light source" for general office worker. Moreover, "adjustment" is ranked 7th among the 14 categories and is found to be relatively less important.

With consideration to the importance levels, the difference between network charts drawn by attributes is observed (Fig. 4). Although the network charts for both designer and general office worker possess the connection between "items related to luminaire" and "adjustment" by task light, which is not observed in the network chart for engineer, not many categories in these two charts are connected to each other. In the network chart for engineer, connections of categories are formed around "items related to luminaire", whose importance level is higher than that for other attributes. Meanwhile, the importance level of "adjustment" for engineer is lower than 4 points. The author's opinion on why "items related to luminaire" and "energy-saving" are not connected to "adjustment" for engineers is indicated below. It can be thought that most engineers do not think that adjustment of the lighting is necessarily linked to energy-saving. Moreover, it can be presumed that, because many of their responses for "equipment" are related to illuminating equipment, engineers regard "adjusting equipment (adjustment)" as an equipment that does not belong to the lighting equipment itself, which is a different perspective from the other two attributes. Therefore, it can be assumed that "adjusting" is connected neither to "equipment" nor "energy saving".

"Adjusting" is not regarded as very important for all subjects, but it plays an important role for designer and general office worker when they try to understand office lighting.

4.3.2 Consistency of Each Viewpoint among Subjects

The consistency of evaluation scales for each subject is observed through the evaluation of the 19 photos. For the scale of "brightness", which is a category regarded as the most important of the 14 categories, 33 out of 55 subjects stated that the evaluation for this category can be ranked and the appropriate level exists somewhere in between the two extremes. The results of the evaluations of the 19 photos using this scale are shown in Table 4. The evaluations for

each photo vary widely. The variances of evaluations for 10 out of the 19 photos are 1 or greater and are displayed in white letters in black enclosures. Most of the photos scatter in a four rank range in a five rank scale, which shows that the subjects placed those photos from 1st to 4th or 2nd to 5th rank. The evaluation of brightness varies according to the subject and the range of variation is wide.

Based on the above information and since the difference in evaluation by the individual is great even when the scale can be commonly extracted, such as brightness, it can be said that adjusting the lighting environment along with individual preference is essential.

It is clarified that although the importance level of "adjustment" is only ranked the 7th among the 14 categories, particularly for designers and general office workers, "adjustment" plays an important role in interpreting and understanding office lighting. Furthermore, since there is a necessity to cope with the difference in evaluation by the individual, it is clarified that "adjustment" is highly important.

Next, another experiment is conducted to quantitatively examine how much effect brightness adjustment on office lighting gives to subjective evaluation.

5. Experiment for Quantitative Analysis on the Effect of Brightness Adjustment

5.1 Outline of the Experiment

The experiment is conducted in an experimental room set up to appear like an office where daylight is blocked with the procedures shown in Table 5. The procedures are as follows. Under the condition "with personal adjustment", subjects are presented with various lighting patterns (Table 6). After adaptation, subjects are informed that personal adjustments can be made later. Next, subjects are requested to execute a task (calculation) for 60 seconds. Then, they are asked to subjectively rank the evaluation viewpoints shown in Table 7 on a scale of 1-7. Further, the subjects are informed that if necessary, they can personally adjust the lighting. The subjects then adjust only the general lighting or only the task light by using a pre-installed brightness adjusting instrument. After the personal adjustment, subjects are again required to execute the task for 60 seconds and conduct the subjective ranking. Similarly, under the condition "no personal adjustment-a" and "no adjustment-b" in Table 5, the subjects are presented with various lighting patterns (Table 6). After adaptation, subjects are informed that personal adjustment can not be made. Then the subjects execute the task and subjective evaluation (Table 7). In both conditions, "no personal adjustment-a" and "no adjustment-b", subjects are not permitted to make personal adjustments.

The total number of subjects is 11 (male 6, female 5, ages 21-30) and the total duration of each set of procedures is approximately 2.5 hours. The order of lighting patterns to be presented and lighting equipment to be adjusted is determined by using the table of random numbers. In order to achieve a uniform illuminance level for each subject after

Table 4 Mean, variance and range of evaluation for bright to dark.

Photo number	No.1	No.2	No.3	No.4	No.5	No.6	No.7	No.8	No.9	No.10
Mean	3.74	2.77	3.56	3.19	2.45	3.59	3.28	3.56	2.78	3.27
Variance	1.00	1.11	1.03	0.67	1.92	0.89	1.05	1.29	0.89	0.96
Range	4	4	4	3	4	4	4	4	4	4
Photo number	No.11	No.12	No.13	No.14	No.15	No.16	No.17	No.18	No.19	
Mean	2.87	3.71	2.33	2.72	2.26	1.81	1.44	1.61	1.61	
Variance	1.18	1.41	1.4	0.79	1.26	0.61	0.71	0.91	0.98	
Range	4	4	4	4	4	3	4	4	4	

Table 5 Experiment plan.

Adjustable or not	Flow of experiment	
With personal adjustment	Adaptation→Execution of task→Evaluation 1→ <div style="border: 1px solid black; padding: 2px; display: inline-block;">Subject makes Adjustment</div> →Adaptation→Execution of task→Evaluation 2	
No personal adjustment-a	Adaptation→Execution of task→Evaluation 3→ <div style="border: 1px solid black; padding: 2px; display: inline-block;">Experimenter makes Adjustment</div> →Adaptation→Execution of task→Evaluation 4	
No personal adjustment-b	Adaptation -Execution of task→Evaluation 5	task: calculation

Evaluation Type 1	Perceived control + stable condition prior to adjustment
Evaluation Type 2	Behavioral control + illuminance change + stable condition after adjustment
Evaluation Type 3	Stable condition prior to adjustment
Evaluation Type 4	illuminance change + stable condition after adjustment
Evaluation Type 5	stable condition after adjustment

Table 6 Lighting patterns.

Lighting patterns		
A	Initial setting of desk top illuminance is 300 lx by general lighting	MIN300 lx MAX700 lx
	general lighting adjustment only (in 3 steps) 300-500 lx, 300-700 lx, 500-700 lx	Raise illuminance with general lighting by 200 lx
B	Initial setting of desk top illuminance is 300 lx by general lighting and 0 lx by task light	MIN300 lx MAX700 lx
	Task light adjustment only (in 3 steps) 0-200 lx, 0-400 lx, 200-400 lx	Raise illuminance with task light by 200 lx
C	Initial setting of desk top illuminance is 700 lx by general lighting and 400 lx by task light	MIN700 lx MAX1100 lx
	Task light adjustment only (in 3 steps) 400-200 lx, 200-0 lx, 400-0 lx	Reduce illuminance with task light by 200 lx

the adjustment, brightness is adjusted intermittently. Prior to the experiment, subjects experience several lighting adjustments in order to be somewhat accustomed to "lighting adjustment". Table 8 shows the apparatus to be used for the experiment.

An assumption made in this study is that the law of addition exists between the evaluation of a particular lighting condition and the evaluations followed by the effect of "controls". Table 5 indicates the types of evaluations obtained (1 to 5). The state of control and evaluation value derivation is as follows.

Type1: The evaluation value of Type 1 is the sum of the evaluation value derived from the effect of perceived control and the evaluation value of the stable condition prior to any personal adjustment, because the subject is informed that he is able to make personal adjustment but has not yet made such adjustment.

Type 2: The evaluation value of Type 2 is the sum of the evaluation value derived from the effect of behavioral control, the evaluation value derived from the effect of illuminance change, and the evaluation value of the stable condition after personal adjustment, because the evaluation is conducted after personal adjustment is made by the subject.

Type 3: The evaluation value of Type 3 is the evaluation value of the stable condition prior to the adjustment. Here, the state is "no control" as the subject is informed that he can not make personal adjustment. The stable condition here is the same as that of Type 1.

Type 4: The evaluation value of Type 4 is the sum of the evaluation value of the stable condition after the adjustment and the evaluation value derived from the effect of the

illuminance change. Here, the state is "no control" as the experimenter makes the adjustment and the subject is told to be aware only of the change in brightness. The interior lighting environment is the same as that of Type 2.

Type 5: The evaluation value of Type 5 is the evaluation value of the stable condition. Here, the state is "no control" as the subject is informed that he cannot make personal adjustment. The stable condition is the same as that of Type 2.

Thus, the effect of perceived control can be quantified by subtracting the evaluation value of Type 3 from the evaluation value of Type 1; the effect of behavioral control can be quantified by subtracting the evaluation value of Type 2 from the evaluation value of Type 4; and the effect of illuminance change can be quantified by subtracting the

Table 7 Evaluation scales.

No.1	Desktop brightness	No.8	Level of not needing adjustment to ceiling lighting
No.2	Ceiling brightness	No.9	Level of not needing adjustment to lighting at hand
No.3	Brightness of the wall facing the subject's seat	No.10	Ease of carrying out task
No.4	Preference of the desktop	No.11	Level of not being strenuous on the eyes
No.5	Level of not needing adjustment to the desktop	No.12	Level of eagerness
No.6	Preference of the entire room	No.13	Ease of concentrating
No.7	Level of not needing adjustment to the entire room	No.14	Satisfaction level

Table 8 Apparatus used for the experiment.

	Apparatus	Installation area/remarks
General lighting	fluorescent lamps FLR-40S W/M Rapid start cool white with ballast by National	Installed eight 40W fluorescent lamps on ceiling. Adjusted all together by a single master dimmer.
Dimmer for general lighting	Master Licon NQ20581-322 by National	Installed at one's hand by extension cord (originally designed for wall installation)
Task light	Incandescent lamp 100V 100W by Toshiba	1 lamp Floor setting; height of light source is 500mm above desk top surface. Blue filter was attached to compensate for color temperature.
Dimmer for task light	Dimmer Lucon for incandescent lamp by Toyo-star	Installed at one's hand.

Table 9 Effect of control and change in illuminance.

Raising illuminance (of desk top) by general lighting (Lighting pattern A)				Mean	P value
Evaluation type	Actual procedures	Evaluation details			
Raw data	Stable condition	General lighting 300 lx	General lighting stable condition 300 lx	2.49	
	Stable condition	General lighting 500 lx	General lighting stable condition 500 lx	3.28	
	Stable condition	General lighting 700 lx	General lighting stable condition 700 lx	3.80	
	Before personal adjustment	Subject is informed that the illuminance of 30 lx with general lighting can be raised by adjusting general lighting	300 lx stable condition + perceived control 300 to 500 lx or 300 to 700 lx	2.67	
	Before personal adjustment	Subject is informed that the illuminance of 500 lx with general lighting can be raised by adjusting general lighting	500 lx stable condition + perceived control 500 to 700 lx	3.57	0.00 * *
	After personal adjustment	Subject raises the illuminance by adjusting general lighting by 200 lx from the illuminance of 300 lx attained by general lighting	500 lx stable condition + change 300 to 500 lx + behavioral control 300 to 500 lx	3.40	
	After personal adjustment	Subject raises the illuminance by adjusting general lighting by 400 lx from the illuminance of 300 lx attained by general lighting	700 lx stable condition + change 300 to 700 lx + behavioral control 300 to 700 lx	4.27	
	After personal adjustment	Subject raises the illuminance by adjusting general lighting by 200 lx from the illuminance of 500 lx attained by general lighting	700 lx stable condition + change 500 to 700 lx + behavioral control 500 to 700 lx	4.00	
	After adjustment by experimenter	Experimenter raises the illuminance by adjusting general lighting by 200 lx from the illuminance of 300 lx attained by general lighting	500 lx stable condition + change 300 to 500 lx	3.31	
	After adjustment by experimenter	Experimenter raises the illuminance by adjusting general lighting by 400 lx from the illuminance of 300 lx attained by general lighting	700 lx stable condition + change 300 to 700 lx	4.01	
	After adjustment by experimenter	Experimenter raises the illuminance by adjusting general lighting by 200 lx from the illuminance of 500 lx attained by general lighting	700 lx stable condition + change 500 to 700 lx	3.90	
	Calculated data		Perceived control 300 to 500 lx or 300 to 700 lx	0.18	0.04 *
			Perceived control 500 to 700 lx	0.28	0.00 * *
			Behavioral control 300 to 500 lx	0.09	0.37
			Behavioral control 300 to 700 lx	0.26	0.05 *
			Behavioral control 500 to 700 lx	0.10	0.29
			Change 300 to 500 lx	0.02	0.13
			Change 300 to 700 lx	0.22	0.18
			Change 500 to 700 lx	0.10	0.34

Raising illuminance (of desk top) by task light (Lighting pattern B)				Mean	P value
Evaluation type	Actual procedures	Evaluation details			
Stable condition	General lighting 300 lx	stable condition 300 lx		2.38	
Stable condition	General lighting 300 lx + task light 200 lx	stable condition 500 lx		3.81	
Stable condition	General lighting 300 lx + task light 400 lx	stable condition 700 lx		4.03	
Before personal adjustment	Subject is informed that the illuminance of 300 lx with general lighting can be raised by task light	300 lx stable condition + perceived control 0 to 200 lx or 0 to 400 lx		2.48	
Before personal adjustment	Subject is informed that the illuminance of 300 lx with general lighting + 200 lx with task light can be raised by adjusting task light	500 lx stable condition + perceived control 200 to 400 lx		3.39	
After personal adjustment	Subject raises the illuminance by adjusting task light by 200 lx from the illuminance of 300 lx attained by general lighting	500 lx stable condition + change 0 to 200 lx + behavioral control 0 to 200 lx		2.48	0.00 * *
After personal adjustment	Subject raises the illuminance by adjusting task light by 400 lx from the illuminance of 300 lx attained by general lighting	700 lx stable condition + change 0 to 400 lx + behavioral control 0 to 400 lx		3.39	0.00 * *
After personal adjustment	Subject raises the illuminance by adjusting task light by 200 lx from the illuminance of 300 lx attained by general lighting + 200 lx attained by task light	700 lx stable condition + change 200 to 400 lx + behavioral control 200 to 400 lx		3.75	0.04 *
After adjustment by experimenter	Experimenter raises the illuminance by adjusting task light by 200 lx from the illuminance of 300 lx attained by general lighting	500 lx stable condition + change 0 to 200 lx		3.88	
After adjustment by experimenter	Experimenter raises the illuminance by adjusting task light by 400 lx from the illuminance of 300 lx attained by general lighting	700 lx stable condition + change 0 to 400 lx		4.23	
After adjustment by experimenter	Experimenter raises the illuminance by adjusting task light by 200 lx from the illuminance of 300 lx attained by general lighting + 200 lx attained by task light	700 lx stable condition + change 200 to 400 lx		4.21	
Calculated data		Perceived control 0 to 200 lx or 0 to 400 lx		0.10	0.28
		Perceived control 200 to 400 lx		-0.41	0.00 *
		Behavioral control 0 to 200 lx		-0.13	0.32
		Behavioral control 0 to 400 lx		-0.15	0.31
		Behavioral control 200 to 400 lx		-0.35	0.07
		Change 0 to 200 lx		0.07	0.39
		Change 0 to 400 lx		0.20	0.20
		Change 200 to 400 lx		0.24	0.34

Decreasing illuminance (of desk top) by task light (Lighting pattern C)				Mean	P value
Evaluation type	Actual procedures	Evaluation details			
Stable condition	General lighting 700 lx	stable condition 700 lx		3.68	
Stable condition	General lighting 700 lx + task light 200 lx	stable condition 900 lx		4.35	
Stable condition	General lighting 700 lx + task light 400 lx	stable condition 1100 lx		4.70	
Before personal adjustment	Subject is informed that the illuminance of 700 lx with general lighting + 200 lx with task light can be decreased by task light	900 lx stable condition + perceived control 200 to 0 lx		4.77	
Before personal adjustment	Subject is informed that the illuminance of 700 lx with general lighting + 400 lx with task light can be decreased by adjusting task light	1100 lx stable condition + perceived control 400 to 200 lx or 400 to 0 lx		4.63	
After personal adjustment	Subject decreases the illuminance by adjusting task light by 200 lx from the illuminance of 700 lx attained by general lighting + 200 lx attained by task light	700 lx stable condition + change 200 to 0 lx + behavioral control 200 to 0 lx		3.78	0.18
After personal adjustment	Subject decreases the illuminance by adjusting task light by 400 lx from the illuminance of 700 lx attained by general lighting + 400 lx attained by task light	700 lx stable condition + change 400 to 0 lx + behavioral control 400 to 0 lx		3.84	0.18
After personal adjustment	Subject decreases the illuminance by adjusting task light by 400 lx from the illuminance of 700 lx attained by general lighting + 400 lx attained by task light	900 lx stable condition + change 400 to 200 lx + behavioral control 400 to 200 lx		4.28	0.03 *
After adjustment by experimenter	Experimenter decreases the illuminance by adjusting task light by 200 lx from the illuminance of 700 lx attained by general lighting + 200 lx attained by task light	700 lx stable condition + change 200 to 0 lx		3.50	
After adjustment by experimenter	Experimenter decreases the illuminance by adjusting task light by 400 lx from the illuminance of 700 lx attained by general lighting + 400 lx attained by task light	700 lx stable condition + change 400 to 0 lx		3.39	
After adjustment by experimenter	Experimenter decreases the illuminance by adjusting task light by 400 lx from the illuminance of 700 lx attained by general lighting + 400 lx attained by task light	900 lx stable condition + change 400 to 200 lx		4.22	
Calculated data		Perceived control 200 to 0 lx		0.42	0.43
		Perceived control 400 to 200 lx or 400 lx to 0 lx		-0.08	0.18
		Behavioral control 200 to 0 lx		0.28	0.13
		Behavioral control 400 to 0 lx		0.45	0.08
		Behavioral control 400 to 200 lx		0.07	0.42
		Change 200 to 0 lx		-0.18	0.22
		Change 400 to 0 lx		-0.30	0.21
		Change 400 to 200 lx		-0.14	0.26

Table 10 Difference in evaluation values before and after lighting.

Raising illuminance (of desk top) by general lighting (Lighting pattern A)	Raising illuminance (of desk top) by task light (Lighting pattern B)	Decreasing illuminance (of desk top) by task light (Lighting pattern C)
<div>Before personal adjustment General lighting 300 lx Evaluation value 2.67</div> <div>200 lx</div> <div>After personal adjustment General lighting 500 lx Evaluation value 3.40 * *</div>	<div>Before personal adjustment General lighting 500 lx Evaluation value 2.48</div> <div>200 lx</div> <div>After personal adjustment General lighting 300 lx, task light 200 lx Evaluation value 3.75</div>	<div>Before personal adjustment General lighting 700 lx, Task light 400 lx Evaluation value 4.63</div> <div>200 lx</div> <div>After personal adjustment General lighting 700 lx, task light 200 lx Evaluation value 4.28</div>
<div>Before personal adjustment General lighting 300 lx Evaluation value 2.67</div> <div>400 lx</div> <div>After personal adjustment General lighting 700 lx Evaluation value 4.27 * *</div>	<div>Before personal adjustment General lighting 300 lx Evaluation value 2.48</div> <div>400 lx</div> <div>After personal adjustment General lighting 300 lx, task light 400 lx Evaluation value 4.08 * *</div>	<div>Before personal adjustment General lighting 700 lx, Task light 400 lx Evaluation value 4.63</div> <div>200 lx</div> <div>After personal adjustment General lighting 700 lx, task light 0 Evaluation value 3.84</div>
<div>Before personal adjustment General lighting 500 lx Evaluation value 3.57</div> <div>200 lx</div> <div>After personal adjustment General lighting 700 lx Evaluation value 4.00 * *</div>	<div>Before personal adjustment General lighting 500 lx, Task light 200 lx Evaluation value 3.57</div> <div>200 lx</div> <div>After personal adjustment General lighting 300 lx, task light 400 lx Evaluation value 3.86 *</div>	<div>Before personal adjustment General lighting 700 lx, Task light 200 lx Evaluation value 4.77</div> <div>200 lx</div> <div>After personal adjustment General lighting 700 lx, task light 0 Evaluation value 3.78</div>

Table 11 Effect of perceived control.

Raising illuminance (of desk top) by general lighting (Lighting pattern A)	Raising illuminance (of desk top) by task light (Lighting pattern B)	Decreasing illuminance (of desk top) by task light (Lighting pattern C)
<div>Stable condition General lighting 300 lx Evaluation value 2.49</div> <div>Perceived Control ↓ +0.18 *</div> <div>Before personal adjustment General lighting 300 lx Perceived control Evaluation value 2.49</div>	<div>Stable condition General lighting 300 lx Evaluation value 2.38</div> <div>Perceived Control ↓ +0.10</div> <div>Before personal adjustment General lighting 300 lx Perceived control Evaluation value 2.48</div>	<div>Stable condition General lighting 700 lx, task light 200 lx Evaluation value 4.35</div> <div>Perceived Control ↓ +0.18 *</div> <div>Before personal adjustment General lighting 700 lx, task light 200 lx Perceived control Evaluation value 4.77</div>
<div>Stable condition General lighting 500 lx Evaluation value 3.28</div> <div>Perceived Control ↓ +0.28 *</div> <div>Before personal adjustment General lighting 500 lx Perceived control Evaluation value 3.57</div>	<div>Stable condition General lighting 300 lx Evaluation value 2.49</div> <div>Perceived Control ↓ +0.41 * *</div> <div>Before personal adjustment General lighting 300 lx, task light 200 lx Perceived control Evaluation value 2.48</div>	<div>Stable condition General lighting 700 lx, task light 400 lx Evaluation value 4.70</div> <div>Perceived Control ↓ +0.18 *</div> <div>Before personal adjustment General lighting 700 lx, task light 400 lx Perceived control Evaluation value 2.48</div>

evaluation value of Type 5 from the evaluation value of Type 4.

T-test (one-side) is conducted using the data obtained from the above experiment. The overall evaluation is represented as a mean of the evaluation values of viewpoints No.4 -14 in Table 7. The same applies to chapters 5-2 and 5-3. The results are shown in Table 9.

Table 10 shows the difference in evaluations before and after the adjustments. When illuminance is increasing, the evaluation value after the adjustment tends to become greater than prior to the adjustment. Particularly, when the initial illuminance is 300 lx, which is rather low, the evaluation value increases with 1 % significance level. However, when initial illuminance is 500 lx, the rate of increase is smaller than for 300 lx and significance level is 5%. Perhaps this is due to the fact that the initial illuminance level is already high enough for carrying out visual tasks. On the other hand, when illuminance is decreasing, the evaluation value after adjustment tends to become smaller than prior to the adjustment. Yet, there is no significant difference in the values of evaluation before and after adjustment. It can be inferred that the effect of the

adjustment is not perceived because the environment is bright enough to pursue visual tasks, in both desk top illuminance of 1100 lx initially and 900 lx or 700 lx after the adjustment. This indicates that the effect of adjustment would be observed only when the initial condition is unfavorable and requires adjustment.

5.2 Effect of Perceived Control by Initial Illuminance Level

In this section, the degree of change in the evaluation for the same lighting condition by perceived control, i.e., personal adjustment can be made if necessary, is described (Table 11).

Perceived control has a positive effect on the evaluation value, when the subject makes an upward adjustment of the illuminance by general lighting (pattern A). In the case where desktop illuminance is raised from 300 lx to 500 lx or to 700 lx, the evaluation value increases 0.18 (the evaluation value is ranked on a scale of 1-7) with 5% significance level. In the case when desktop illuminance is raised from 500 lx to 700 lx, the evaluation value increases 0.28 without significant difference.

When the subject makes an upward adjustment of the illuminance by task light (pattern B), perceived control has both positive and negative effects on the evaluation value. In the case where desktop is illuminated by general lighting at illuminance of 300 lx and the illuminance is raised to 500 lx or to 700 lx by task light, the evaluation value increases 0.10 without significant difference. However, in the case where desktop is illuminated by both general lighting at illuminance 300 lx and task light at illuminance 200 lx and the illuminance is raised to a total of 700 lx by increasing task light illuminance by 200 lx, the evaluation value decreases 0.45 without significant difference. In the former case, consideration is given to the fact that the subject predicts that the initial dim condition would be improved by turning on the task light. However, in the latter case, the subject may have judged that brightening the task light further could possibly cause an unfavorable ambient ratio.

Perceived control, when the subject makes a downward adjustment to the illuminance by task light (pattern C), has both positive and negative effects on the evaluation value. In the case where desktop is illuminated by both general lighting at 700 lx and task light at 200 lx and illuminance is decreased to a total of 700 lx by adjusting the task light, the evaluation value increases 0.42 without significant difference. However, in the case where desktop is illuminated by both general lighting at 700 lx and task light at 400 lx and the illuminance is decreased to a total of 900 lx or 700 lx by adjusting the task light, the evaluation value decreases 0.08 without significant difference. In the former case, it could be interpreted that perceived control positively affects some of the subjects as they mentioned that it is better not to have the task light on if it is only dim. In the latter case, it could be inferred that many subjects are dissatisfied by the fact that a brightly lit task light can be dimmed.

As described above, it can be thought that, the impact of perceived control to the evaluation is positive when illuminance of general lighting can be increased and is influenced by the initial task ambient ratio when illuminance of the task light can be increased. Further, when task light illuminance can be decreased, it can be inferred that the impact of perceived control to the evaluation is always negative if the task light is initially lit brightly, perhaps because it gives the subjects an impression of becoming dark, and is positive if the task light is initially dim, perhaps because the subjects decided that it is better to turn off the task light than to have it dim.

5.3 Effects of Behavioral Control and Illuminance Change

Effects of behavioral control and illuminance change are shown in Table 12. The overall trend is described below.

Both behavioral control and illuminance change have a positive effect on the evaluation when the subject makes an upward adjustment of the illuminance by general lighting (pattern A). The effect of behavioral control has 5% significance level when the upward adjustment is 400 lx and

Table 12 Effects of behavioral control and illuminance change.

	Evaluation details	Evaluation change	P value
Raising illuminance (of desk top) by general lighting (Lighting pattern A)	Behavioral control 300 to 500 lx	0.09	0.37
	Behavioral control 300 to 700 lx	0.26	0.05 *
	Behavioral control 500 to 700 lx	0.10	0.29
	Change 300 to 500 lx	0.02	0.13
	Change 300 to 700 lx	0.22	0.18
	Change 500 to 700 lx	0.10	0.34
Raising illuminance (of desk top) by task light (Lighting pattern B)	Behavioral control 0 to 200 lx	-0.13	0.32
	Behavioral control 0 to 400 lx	-0.15	0.31
	Behavioral control 200 to 400 lx	-0.35	0.07
	Change 0 to 200 lx	0.07	0.39
	Change 200 to 400 lx	0.20	0.20
	Change 300 to 500 lx	0.24	0.34
Decreasing illuminance (of desk top) by task light (Lighting pattern C)	Behavioral control 200 to 0 lx	0.28	0.13
	Behavioral control 400 to 0 lx	0.45	0.08
	Behavioral control 400 to 200 lx	0.07	0.42
	Change 200 to 0 lx	-0.18	0.22
	Change 400 to 0 lx	-0.30	0.21
	Change 400 to 200 lx	-0.14	0.26

effect of illuminance change has no significant difference.

Behavioral control has a negative effect and illuminance change has a positive effect on the evaluation when the subject makes an upward adjustment by task light (pattern B). When the subject is presented with only illuminance change, the evaluation value increases as the illuminance increases. This is a rather general reaction among people. On the other hand, if the subject participates in the brightness change himself, behavioral control is thought to cause the subject to be stricter in his evaluation when compared to a situation where only illuminance change is presented, because the subject states, "the brightness of the task light is more of a concern than brightness of the environment". Both effects of behavioral control and illuminance change do not have significant difference.

Behavioral control has a positive effect and illuminance change has a negative effect on the evaluation when the subject makes a downward adjustment by task light (pattern C). When the subject is presented with only illuminance change, the evaluation value decreases as the illuminance decreases. This is a rather general reaction among people. On the other hand, if the subject participates in the brightness change himself, behavioral control is thought to cause the subject to adjust brightness more carefully and to exaggerate the evaluation on improved viewpoints when compared to a situation where only illuminance change is presented, because the subject states, "I wish to turn off the task light". Both effects of behavioral control and illuminance change do not have significant difference.

As described above, it can be thought that the impact of both illuminance change and behavioral control to the evaluation is positive when illuminance of general lighting can be increased. When illuminance of task light is adjustable, the effect of illuminance change is positive if illuminance increases, which is a generally accepted aspect. Yet, the behavioral control has a negative effect when

increasing illuminance, and causes the subject to exaggerate the evaluation on improved viewpoints when decreasing illuminance.

5.3.1 Effects of Behavioral Control and Illuminance Change Relative to the Illuminance Change Level

The difference in the effects of behavioral control and illuminance change relative to the amount of illuminance change is observed by comparing different levels of increase (or decrease) in illuminance change, namely 200 lx or 400 lx, all with the same initial lighting condition (Table 13).

When making an upward adjustment by general lighting (pattern A) where desktop is initially illuminated at 300 lx by general lighting, effects of both behavioral control and illuminance change are greater when the level of increase is 400 lx than when the level of increase is 200 lx (behavioral control +0.09, illuminance change +0.02 when up 200 lx; behavioral control +0.26, illuminance change +0.22 when up 400 lx; both without significant difference). It is thought that the above result is due to the fact that 400 lx increase is more preferable for subjects to conduct tasks.

When making an upward adjustment by task light (pattern B) where desktop is initially illuminated at 300 lx by general lighting, the effect of behavioral control is smaller while the effect of illuminance change is greater when the level of increase is 200 lx than when it is 400 lx (behavioral control -0.13, illuminance change +0.07 when up 200 lx; behavioral control -0.15, illuminance change +0.20 when up 400 lx; both without significant difference). It is inferred that the negative impact of behavioral control grows according to task ambient ratio.

When making a downward adjustment by task light (pattern C) where desktop is initially illuminated at 700 lx by general lighting and at 400 lx by task light, the effect of behavioral control is greater while the effect of illuminance change is smaller when the level of decrease is 400 lx than when it is 200 lx (behavioral control +0.28, illuminance change -0.18 when down 200 lx; behavior control +0.45, illuminance change -0.30 when down 400 lx; both without significant difference). It is inferred that the negative impact of illuminance change is greater when illuminance decreases by 400 lx, as the darkness is more obvious and the evaluation is exaggerated due to the effect of behavioral control.

With the same initial illuminance and in the above three cases, the impacts of both illuminance change and behavioral control are greater when the level of illuminance change is 400 lx than when that is 200 lx, regardless of the effects being negative or positive.

5.3.2 Effects of Behavioral Control and Illuminance Change Relative to Initial Illuminance

In this section, the difference in the effects of behavioral control and illuminance change relative to initial illuminance is considered by comparing different initial illuminance conditions all with the same level of illuminance increase (or

Table 13 Effects of behavioral control and illuminance change relative to the illuminance change level.

	Evaluation details	Evaluation change	P value
Raising illuminance (of desk top) from 300 lx by general lighting (Lighting pattern A)	Behavioral control 300 to 500	0.09	0.37
	Behavioral control 300 to 700	0.26	0.05 *
	Change 300 to 500	0.02	0.13
	Change 300 to 700	0.22	0.18
Raising illuminance (of desk top) from 300 lx by task light (Lighting pattern B)	Behavioral control 0 to 200	-0.13	0.32
	Behavioral control 0 to 400	-0.15	0.31
	Change 0 to 200	0.07	0.39
	Change 0 to 400	0.20	0.20
Decreasing illuminance (of desk top) from 1100 lx by task light (Lighting pattern C)	Behavioral control 200 to 0	0.28	0.13
	Behavioral control 400 to 0	0.45	0.08
	Change 200 to 0	-0.18	0.22
	Change 400 to 0	-0.30	0.21

Table 14 Effects of behavioral control and illuminance change relative to initial illuminance.

	Evaluation details	Evaluation change	P value
Raising illuminance (of desk top) by general lighting by 200 lx (Lighting pattern A)	Behavioral control 300 to 500	0.09	0.37
	Behavioral control 500 to 700	0.10	0.29
	Change 300 to 500	0.02	0.13
	Change 500 to 700	0.10	0.34
Raising illuminance (of desk top) by task light by 200 lx (Lighting pattern B)	Behavioral control 0 to 200	-0.13	0.32
	Behavioral control 200 to 400	-0.35	0.07
	Change 0 to 200	0.07	0.39
	Change 200 to 400	0.24	0.34
Decreasing illuminance (of desk top) by task light by 200 lx (Lighting pattern C)	Behavioral control 200 to 0	0.28	0.13
	Behavioral control 400 to 200	0.07	0.42
	Change 200 to 0	-0.18	0.22
	Change 400 to 200	-0.14	0.26

decrease) by 200 lx (Table 14).

When making an upward adjustment by 200 lx by general lighting (pattern A), effects of both behavioral control and illuminance change are greater when the desktop is initially illuminated at 500 lx by general lighting than when it is at 300 lx (behavioral control +0.09, illuminance change +0.02 when initial illuminance 300 lx; behavioral control +0.10, illuminance change +0.10 when 500 lx; both without significant difference). It is thought that the impacts of behavioral control and illuminance change are greatly affected by the illuminance level obtained after the adjustment. When making an upward adjustment by 200 lx by task light (pattern B), the effect of behavioral control is smaller while the effect of illuminance change is greater in the case where desktop is illuminated by both general lighting at 300 lx and task light at 200 lx than in the case where desktop is illuminated only by general lighting at 300 lx (behavioral control -0.13, illuminance change +0.07 when 300 lx general lighting; behavioral control -0.35, illuminance change +0.18 when 300 lx general lighting and 200 lx task light; both without significant difference). It can be inferred that the effect of illuminance change is greater because the subject's evaluation is more general, i.e., brighter the better. On the other hand, when the subject participates in the adjustment, it can be assumed that the subject is stricter in the evaluation of lighting environment and is more concerned about task ambient ratio. Thus in this

comparison, the value of the effect of behavioral control is higher when the desktop is initially darker.

When making a downward adjustment by task light by 200 lx (pattern C), the effect of behavioral control is greater while the effect of illuminance change is smaller in the case where desktop is illuminated by both general lighting at 700 lx and task light at 200 lx than in the case where desktop is illuminated by both general lighting at 700 lx and task light

at 400 lx (behavioral control +0.07, illuminance change -0.14 when 700 lx general lighting and 400 lx task light; behavioral control +0.28, illuminance change -0.18 when 700 lx general lighting and 200 lx task light; both without significant difference). It can be inferred that the effect of illuminance change is greater because the subject's evaluation is more general, i.e., brighter the better. On the other hand, when the subject participates in the adjustment,

Table 15 Questions asked and instructions given to subjects before and after the experiment.

	No.	Questions	notes
Before	Q1	What types of "lighting adjustments" can you think of?	
	Q2	How often do you make the following lighting adjustments or do so to achieve the following purposes? Rank them on a scale of 1 to 7. 1. Make general brightness adjustments such as turning on the lights in the evening. 2. Make brightness adjustments to change the atmosphere to refresh oneself. 3. Make brightness adjustment for energy saving purposes such as allowing sunlight to enter the room. 4. Make adjustments to light direction to prevent being troubled with one's hand creating a shadow or to reduce the level of reflection.	7=very frequently on a daily basis 4=neither very frequently nor not at all 1=not at all
	Q3	How important are the above to you? Rank them on a scale of 1 to 7.	7=very important 4=neither very important nor not at all important 1=not at all important
After	I 1	Please adjust the lighting from the current condition.	Adjustment to be made from the condition that lighting is reflected to VDT.
	I 2	Please adjust the lighting to create an optimal condition to refresh yourself from the current condition.	Adjustment to be made from the condition that the lighting in the room is at its maximum brightness.
	I 3	Please adjust the lighting from the current condition.	While allowing daylight to enter the room, subjects are asked to make adjustment at the seat near the window.
	Q1	Rank the importance level of the following lighting adjustments on a scale of 1 to 7.	Items in Q2 prior to experiment are used and evaluated on the same scale

Table 16 Situations related to lighting adjustments by subjects.

Adjustments that subjects were able to think of	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5	Subject 6	Subject 7	Subject 8	Subject 9	Subject 10	Subject 11
1 Turning on lights when it becomes dark in the evening	1	1	1	1	1			1	1	1	1
2 Turning on or off lights in the living room									1		
3 Turning on lights when entering a room	1					1					1
4 Turning off lights when going to bed	1										
5 Turning on or off bed lamps							1				
6 Adjusting the living room lighting							1				
7 Placing a light on the desk									1		
8 Leaving on only a small lamp when going to sleep						1					
9 Adjusting brightness in Karaoke room by a rotating dimmer											
10 Adjusting brightness of the monitor		1							1		
11 Opening or closing curtains in daylight						1					

Table 17 Frequency of lighting adjustments conducted on a daily basis and their importance levels before and after the experiment.

Evaluation viewpoints	Frequency before experiment	Importance level before experiment	Importance level after experiment	Difference between frequency and importance level before experiment	Difference between importance levels before and after experiment
General brightness adjustment	6.00	6.27	6.45	-0.27 *	0.18
Change of atmosphere	5.45	5.73	6.27	-0.27 **	0.55 *
Energy saving purposes	4.82	5.64	5.73	-0.82 **	0.09
Changing light direction	5.45	5.73	6.27	-0.27	0.55 *

it can be assumed that because the subject mentions that he wishes to turn off the task light, the effect of behavioral control is greater in the situation where the task light is completely turned off after the adjustment.

As described above, it is inferred that the effects of both behavioral control and illuminance change are positive and the illuminance level obtained after adjustment has greater impact on the evaluation when general lighting can be raised at a uniform rate. When the task light is adjusted at the same rate, the subject's evaluation is more general, i.e., brighter the better regardless of upward or downward adjustment. On the other hand, when the subject participates in the adjustment, one is stricter in the evaluation of whether or not the lighting environment is suitable for the task. In this experiment, the effect of behavior control tends to become greater when the initial illuminance is lower and is possibly adequate to execute the task.

5.4 Relationship between Adjustment and Other Office Lighting Viewpoints

Surveys were conducted and instructions were given to the subjects before and after the experiment on adjustment in order to clarify their views on "adjustment."

There are other reasons for lighting adjustment besides adjusting the brightness because the environment is simply dark or too bright. Other purposes are to save energy, to benefit the atmosphere, to give directivity to the light and so forth. However, people are not normally aware of all of these purposes. Therefore, the intention is to clarify on which purposes people place most emphasis in daily life. Based on the assumption that people will become aware of the importance of lighting adjustment to achieve a particular purpose only after they have actually experienced the adjustment, it is attempted to examine how people will come to place more importance on the purpose of adjustment, which was not regarded as important before the experiment. Details of the survey and instructions are provided in Table 15.

Situations that subjects could think of in relation to lighting adjustment prior to the adjustment experiment are shown in Table 16. As shown in the table, the majority of the situations such as from 1 to 7 are related to turn on-turn off lights. Situation 8 is related to intermittent lighting adjustment and 9 to continuous lighting adjustment. Very few respondents listed situations seen in the experiment and

most of the situations were related to mere adjustment of brightness. Only one response was related to other purposes, that is "open/close of curtains in daylight." Furthermore each respondent could only think of two or less situations on average.

Table 17 shows the frequency of adjustments made on a daily basis and the results of the evaluation that ranks the importance level of adjustment on a scale of 1-7 before and after the adjustment experiment. *T*-test (one-side) is applied to the data. Respondents with a higher frequency of adjustment tend to place more importance on adjustment. Yet, compared to the evaluation of importance level prior to the experiment, the evaluation of the frequency of adjustment is low (significance level is 1% or 5%) except for the adjustment of the direction of the light. Thus, it could be judged that in spite of more importance placed on adjustment, actual adjustments are not made.

Importance level of adjustment of lighting in general and for energy-saving purposes does not change much before and after the experiment (+0.18 and +0.09, respectively on a scale of 7). The reason for this is that the importance of lighting adjustment in general is already understood prior to the experiment and that most days in which the experiment was conducted were cloudy so there is a possibility that respondents could not fully understand the importance of energy-saving. Meanwhile, the importance level of adjustment of the direction of the light increased after the experiment perhaps because respondents found that it was necessary to execute their tasks during the experiment (+0.55 and +0.55, respectively; both 5% significance level).

The surveys show that the importance of office lighting adjustment can be understood only by experience and only then can people become aware of "adjustment" as a requirement for office lighting. In other words, it can be inferred that unless people are provided with an opportunity to make the actual adjustment, the concept of adjustment will not be newly cultivated in people's awareness toward office lighting.

6. Conclusion

The following information is obtained from the study.

It is observed, through the interview-type survey, that "brightness," "glare" and "natural lighting" are commonly regarded by all subjects as the three most important evaluation viewpoints for office lighting. The order of ranking after 4th varies according to subjects' attributes. "Adjustment" is ranked 7th among the 14 viewpoints, which is not too high, in the importance level. Yet it can be assumed that for designer and general office worker, this viewpoint is an important one to be studied, as adjustment acts as liaison to other viewpoints in trying to understand office lighting.

Brightness, which is ranked as the most important viewpoint by all subjects, is evaluated by presenting photos to the subjects, and having them position the photos on a scale from bright to dark. Even when presenting the same photo, the evaluations varied among subjects. Thus, to

realize the office lighting environment with a high satisfaction level, the necessity to consider adjustment of lighting environment according to individual preferences is proven.

The effects of brightness adjustment are quantitatively studied through the experiment and the following points are clarified.

Perceived control positively affects the evaluation when an upward adjustment can be made to the illuminance of general lighting. Yet its effect varies according to the initial condition of task ambient ratio, when an upward adjustment can be made to the illuminance of task light. Further, its effect also varies according to the illuminance level, when the task light illuminance can be adjusted downward. It affects positively when task light illuminance is high (400 lx), and does negatively when task light illuminance is low (200 lx).

When upward adjustment can be made to general lighting, both the effects of illuminance change and behavioral control have a positive impact on the evaluation. Yet, when the illuminance of task light can be changed, the evaluation of the same lighting environment differs depending on whether or not the individual is capable of making the adjustment himself. As to the effect of illuminance change, the evaluation made is somewhat general, i.e., the brighter the better. Meanwhile, the effect of behavioral control is negative.

When the initial illuminance is the same (illuminance adjusted upward from 300 lx, illuminance adjusted downward from 1100 lx), the effects of both illuminance change and behavioral control are positive and become greater when the amount of illuminance change becomes larger, under the condition where the illuminance of general lighting can be adjusted upward, or the condition where the task light can be adjusted both upward and downward.

When the level of illuminance adjustment is the same by 200 lx, illuminance level attained after the adjustment largely impacts the effects of both behavioral control and illuminance change, in the case where general light illuminance can be increased. In the case where task light illuminance can be adjusted both upward and downward, the effect of illuminance change is higher when the initial illuminance is higher, and the effect of behavioral control is higher when the initial illuminance (in this study, the lower one) is one which has a possibility of becoming a suitable environment to work in after the adjustment.

Hardly any significant difference exists for effects of both behavioral control and illuminance change, and those effects are extremely small.

Comparing the survey on lighting adjustment conducted before and after the brightness adjustment experiment, it is observed that the importance level of adjustment became higher after the experiment. From this, it can be inferred that the importance of office lighting adjustment is understood through experience and that the adjustment has been newly cultivated in office lighting awareness.

Thus, it is clarified that the initial illuminance and the level of upward and downward adjustments affect

brightness adjustment in office lighting, and that evaluation differs depending on whether or not the individual is involved in the change of brightness. In order to make personal adjustment of office lighting more practical, it is necessary to clarify the effects of both illuminance change and behavioral control by selecting a variety of initial illuminance and amount of illuminance change. Furthermore, sufficient study must be devoted on how individuals are affected by adjustments made by others in the same room, or changes in brightness that are controlled by sensors or timers.

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Quotations

- (1) "a determinant of the cognitive appraisal of threat" Corah, N. L., & Boffa, J. Perceived control, self-observation, and response and cognitive processes, *Journal of Personality and Social Psychology*, 16, pp.1-4(1970); 4 pages.
- (2) "direct action on environment" Averill, J. R. :Personal control over aversive stimuli and its relationship to stress, *Psychological Bulletin*, 80, pp.286-303(1973); 286pages.
- (3) "perceived control is perception that one's choices determine outcomes" Barnes, R. D., Perceived freedom and control in the built environment. In J. Harvey, Ed., *Cognition, Social Behavior, and the Environment*. Hillsdale, NJ: Erlbaum, pp.409-422(1981).