APPENDIX 4.2-B

DRAFT REPORT: THE EFFECT OF BIAS TOWARDS ENERGY SAVINGS ON OCCUPANT'S DIMMING REQUIREMENTS

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Prepared by: Yukio Akashi, PhD
Jason Neches

1. Introduction

Load shedding ballasts could be used as an effective method for load management by reducing the peak electricity demand needed for lighting. However, before they are applied to the real world, it is important to understand occupants' light level requirements with respect to dimming.

A recent study at the Lighting Research Center (LRC) investigated a detectable range of illuminance change and suggested that occupants could not detect up to 20 % illuminance reduction regardless of initial illuminance or dimming speed within the experimental conditions (Kryszczuk, 2001). A similar study, in which the subjects were more sensitive to illuminance change than in Kryszczuk's study, also suggested that illuminance could be changed by up to 20% from the initial value without being detected by occupants when they were devoted to tasks (Shikakura, 2001). More recently, two studies at the LRC investigated what cues occupants used to detect illuminance change and whether the reducible illuminance range defined in the above studies, up to 20 % change from the initial illuminance, could be extended if slower dimming speeds or smoother dimming functions are employed (Akashi et al., 2002). The first Akashi et al. study sought to determine whether memory of the initial illuminance level is the main cue to detecting dimmed light levels. The results of this study suggested that occupants were able to memorize a room's brightness under the initial illuminance and could reliably detect reductions greater than 20% when the dimming period was relatively short. As the period of dimming increased, memory may have faded and therefore the sensitivity to illuminance change decreased. These results suggested that memory is the primitive decision factor. The results also led to a hypothesis that longer dimming periods, and therefore a slower rate of illuminance change, might lead to decreased sensitivity in detecting illuminance reduction.

With regard to the above question of whether slower dimming speeds and/or smoother dimming functions can extend the undetectable illuminance range, the second Akashi et al. study focused on the effect of dimming functions. The study also investigated acceptable range of illuminance reductions because, beyond detection, and perhaps more relevant to load shed dimming, is determining what level of dimming is acceptable to occupants. The results indicated that dimming function had little effect on the detectability and acceptability of illuminance change. The subjects accepted larger illuminance reductions than the above mentioned undetectable illuminance reduction—e.g., 50 % of the subjects accepted illuminance reductions up to about 40 % of the initial illuminance level while they could detect illuminance reductions greater than 15 % of the initial illuminance.

Since acceptability may vary according to one's motivation for energy savings, it is important to investigate the effect of subjects' bias on the acceptable dimming range. Therefore, in this study, the LRC attempted to investigate whether a pre-assigned bias towards energy savings could increase the acceptability of dimming through load shedding ballasts. Another objective of this study was to investigate how tasks performed by subjects influence the acceptability of illuminance change.

2. Experiment

Experimental setup:

The experiment used a windowless private office and an adjacent room. Figure 1 shows the private office viewed from the adjacent room. Although, in this picture the door is open, the door remained closed during the experiment. Figure 2 illustrates the plan of the private office and the experimental system in the adjacent room. The interior wall and ceiling of the private office was painted white (reflectance: 85%). The reflectance of the floor carpet was about 30 %. The office was furnished with a bookshelf, a desk and a chair. The office was equipped with three-direct/indirect pendant luminaires suspended from the ceiling. Figure 3 shows the ceiling with the luminaires and the luminous intensity distribution of the luminaires. The experimental apparatus in Figure 2 was composed of the above described luminaires with dimming ballasts and T8 fluorescent lamps; an operating system—a desktop computer, a picoammeter, a photo-sensor, and a DC power supply; a communication system—two telephone sets and a "hands-free" phone tool; and a monitoring system—a TV monitor, a digital video camera with a transmitter, and a receiver. Table 1 summarizes the details of the experimental system.

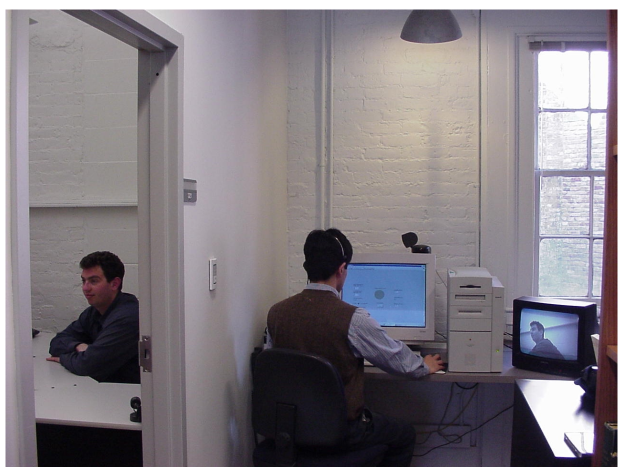

Figure 1. Windowless private office and adjacent room used in all three experiments

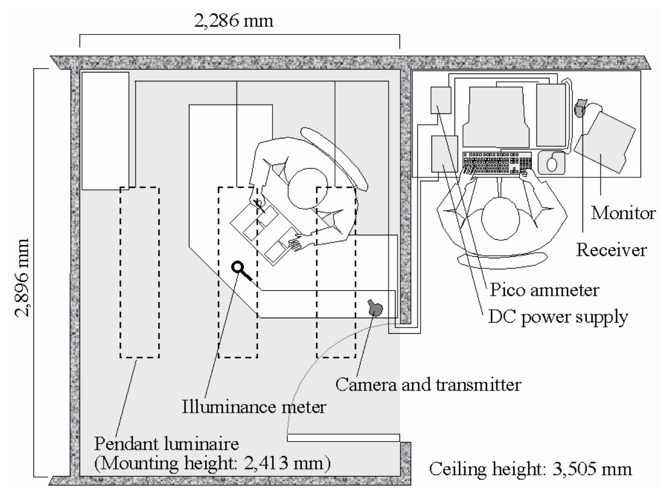

Figure 2. Room plan and experimental setup

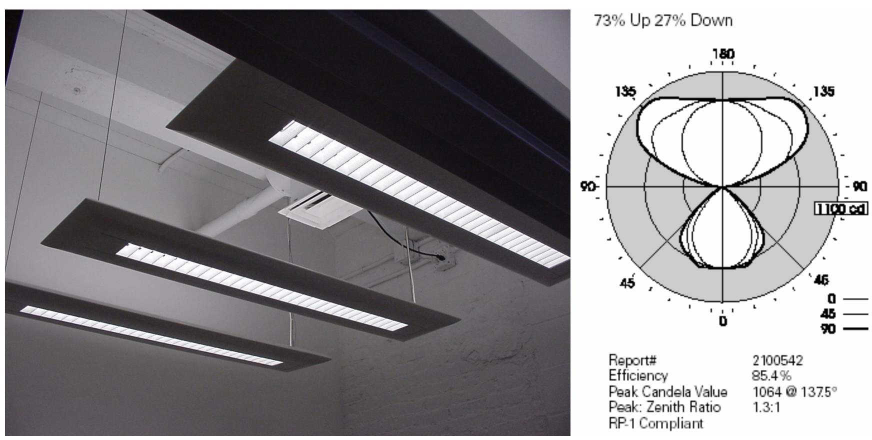

Figure 3. Direct/indirect pendant luminaires (Crescent, Ledalite)

Table 1. Experimental system.

Components	Product name	Manufacturer
3 Luminaires	Crescent (8316T02PN)	Ledalite
3 Ballasts	M2-PD-T8-5C-B-120 Gold Edition Programmed Start, dimming 5 ~ 110%	Motorola
6 Fluorescent lamps	FO32/835/XP	Osram Sylvania Inc.
1 Computer	P5-166	Gateway
1 Picoammeter	485 Auto ranging Picoammeter	Keithley
Software	Lab View 6.0	National Instruments
1 DC power supply	E3632A	Hewlett Packard
1 Photo sensor	268P photopic, cosine response	Graseby Optronics
1 Color TV monitor (13”)	PC1342	CRAIG
1 Camera and transmitter	XC10A	X10, Inc.
1 Receiver	VR30A	X10, Inc.
2 Telephones	DX2NA-12CTXH TEL (BK)	Nitsuko America Co.
1 Hands-free phone tool	Vista, M12	Plantronics

Experimental Conditions:

Table 2 summarizes the experimental conditions. As independent variables, the target illuminance, task condition, font size, and bias condition varied. Both the paper and VDT tasks used a word puzzle as shown in Figure 4. The VDT task used a desktop personal computer (DELL, OptiPlex) with a 16” CRT screen. The dimming period and initial illuminance were constant at 10 seconds and 500 lx respectively. The dependent variables were an evaluation of whether the illuminance level at a given moment was higher, lower, or identical to the initial illuminance level and whether the illuminance change was acceptable. The subjects also evaluated the acceptability using an eleven-step scale, from zero (very unacceptable) to five (neutral) and ten (very acceptable).

Table 2. Experimental conditions

Variables	Range
Target illuminance (lx)	1000, 900, 820, 740, 660, 580, 500, 420, 340, 260, 180, 100, 20
Task condition	Paper task, VDT task
Font size (point)	6, 12
Bias	Non-biased, biased

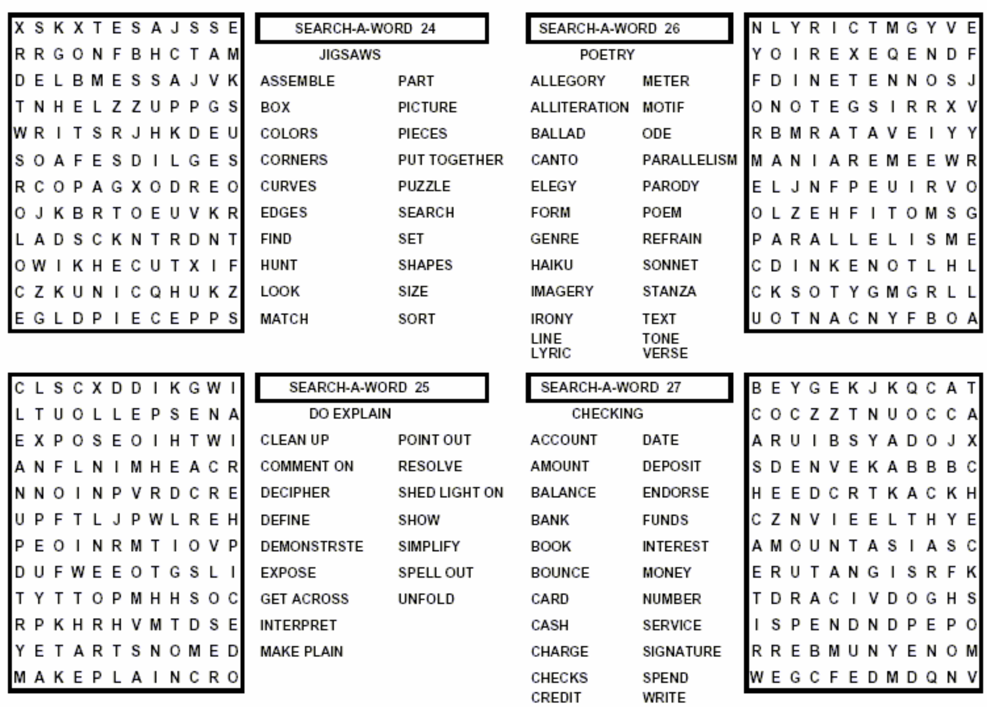

Figure 4. Word puzzle on a page.

Experimental procedure:

Twenty subjects, ranging from 20 to 40 in age, participated in the experiment. In the experiment, an experimenter escorted a subject to the private office and seated the subject in the chair. The subject adapted himself/herself to the brightness of the initial illuminance, 500 lx, for about five minutes. During the adaptation, the subject read and signed an informed consent form. The experimenter gave instructions about the experimental procedure to the subject. The experiment was divided into two sessions, one for a non-biased session and the other for a biased session. Half the subjects started with the non-biased session, the other half started with the biased section. In each session, the subject conducted a paper task and a VDT task. Both tasks used word puzzles. Two font sizes, 6 and 12 points were used for the puzzles in both the tasks. The order of the tasks and font sizes were counterbalanced across subjects. For each of the four combinations (2 tasks × 2 font sizes), thirteen target illuminance levels were presented to the subject. In each presentation, the illuminance was gradually increased or reduced from the initial illuminance (500 lx) to each of the thirteen target illuminance levels for ten seconds following linear dimming functions. The order of the target illuminance levels was randomized. The subject started performing either the paper task or the VDT task under the initial illuminance level, 500 lx. After the ten-second dimming presentation, the experimenter asked the subject whether the illuminance change was detectable, and if so, acceptable ("yes" or "no"). Before undertaking the biased session, the experimenter gave an instruction sheet to the subject. The instructions given to subjects are listed below. All three following paragraphs were given to the subject as one general bias:

Economic effect: *Assume you are working for a firm in the capital district of New York . This area is on the verge of a power shortage. Power shortages cause an increase in the price of electricity due to the laws of supply and demand. Some feasibility studies have shown that dimming the lighting is an effective way to cut the peak electricity load without compromising worker productivity. Such load shedding could reduce your company's electricity bill by about $1,500/10kW/year.*

Global effect: *Simulations show that every new power plant will lead to an increase in CO2 gas, which will cause a global warming effect. We have already seen such greenhouse effects such as an increase in the sea level, climatic change, and more frequent floods. Electricity demand side management through load shedding ballasts can reduce the number of new power generators and therefore reduce your contribution to the greenhouse effect.*

Local effect: *New power plants and transmission lines need to go somewhere. For a variety of reasons, health, aesthetic and economic, people generally do not want such structures built near them. The reality is that people have little control over their community, and a new plant or transmission line may be built near you. Knowing that managing electricity demand through lighting will reduce the number of new plants and transmission lines needed, how acceptable are the following dimming levels?*

After reading the instructions, the subject followed the same procedure as the non-biased session. Each session took a subject about 30 to 40 minutes. The subject conducted the two sessions (biased and non-biased) on different days.

Experimental results:

Figure 5 shows the results of the detectability of illuminance change. Figure 5 confirmed the results of the former studies that occupants could not detect up to 20 % illuminance reduction and obviously shows that detectability of illuminance reduction is unaffected by bias. This should be the case, as detectability is a lower order response unrelated to bias feelings.

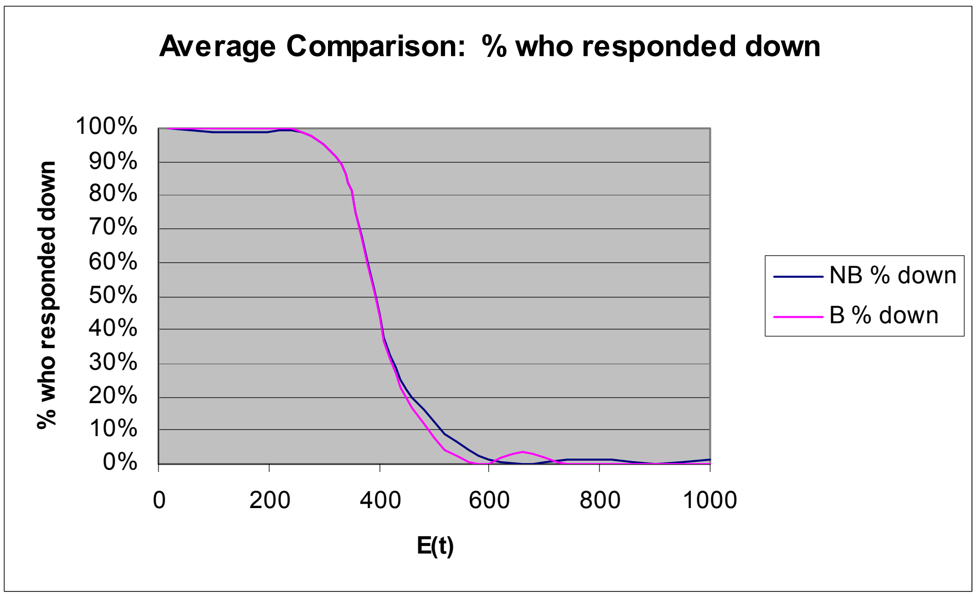

Figure 5. Detectability of illuminance change in the bias study for biased (B) and non-biased (NB) subjects

Figures 6 and 7 show the results of acceptability evaluations to illuminance changes under the four task conditions—(1) paper task with 6-point font size, (2) paper task with 12-point font size, (3) VDT task with 6-point font size, and (4) VDT task with 12-point font size. Figures 6 and 7 suggest that the instruction given to subjects between the two sessions somewhat affected their responses. It is apparent that the acceptable dimming range for biased subjects is wider than that for non-biased subjects. Figure 8 compares acceptable dimming ranges between biased subjects and non-biased subjects, averaged for all four task conditions. Figure 8 shows that the acceptable target illuminance of biased subjects was lower (by approximately 80 lux) than that of non-biased subjects. For instance, 50 % of the biased subjects accepted illuminance reduction by 380 lx (76 % of the initial illuminance from 500 lx) while 50 % of the non-biased subjects accepted illuminance reduction by 300 lx (60 % of the initial illuminance from 500 lx). The 80^{th} percentile acceptable illuminance reductions are 270 lx for biased subjects and 190 lx for non-biased subjects. Comparison of Figures 6 and 7 suggests that the acceptable target illuminance for the VDT task tends to be lower than that for the paper task. We can assume that this difference was due to the self-luminous VDT screen. Interestingly, very little effect was shown with reducing the font size within a given task. Most likely, for both the point sizes of 6 and 12, the visual performance was already plateaued for such short-term tasks. Figures 9 through 11 show subjective ratings (scale 0 – 10) which where asked of subjects as a method to verify acceptability evaluations. These figures indicate similar tendencies to the above results of the yes/no appraisals.

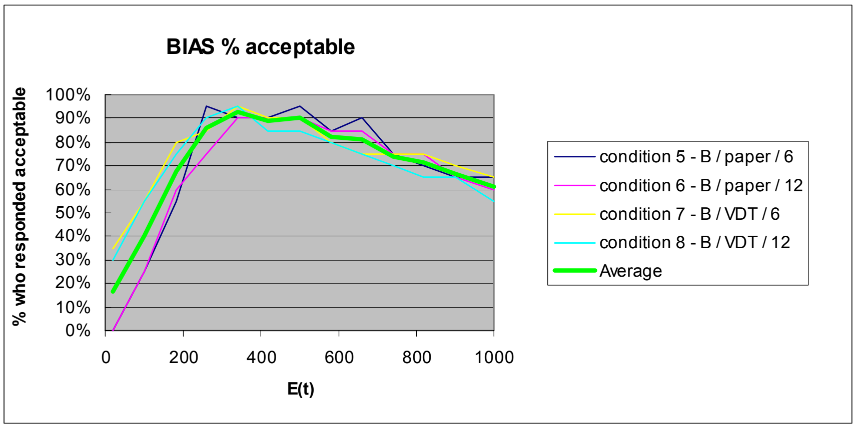

Figure 6. Acceptability of illuminance change for biased (B) subjects

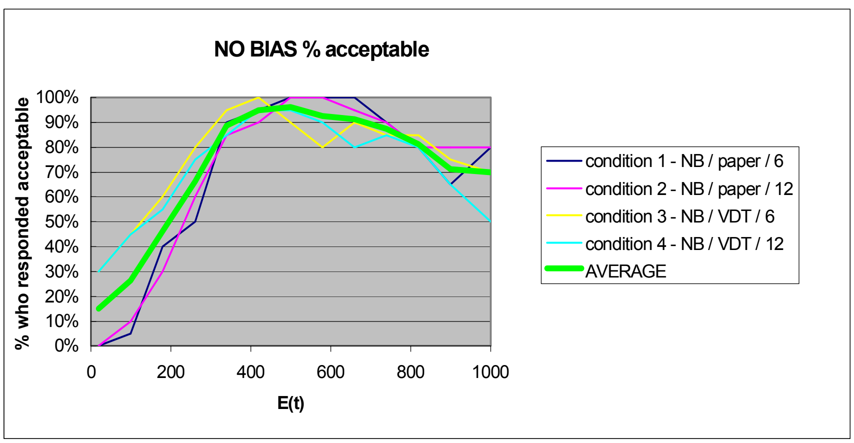

Figure 7. Acceptability of illuminance change for non-biased (NB) subjects

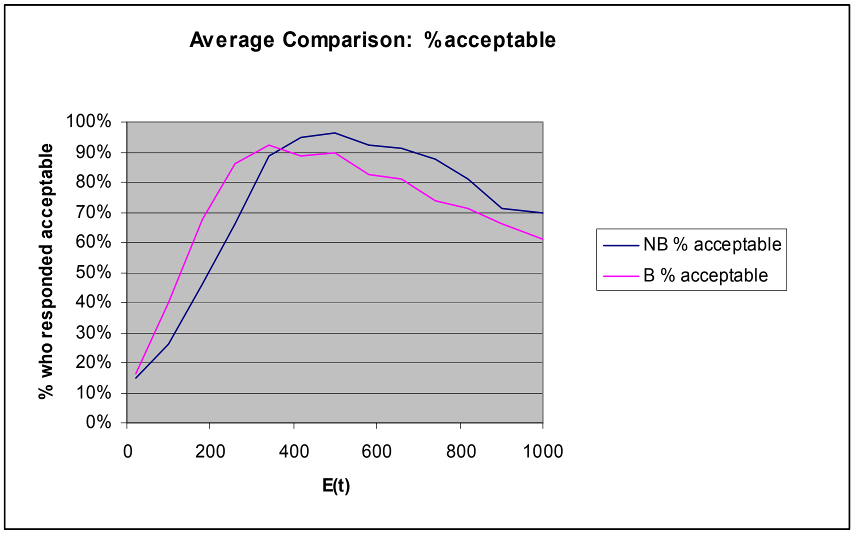

Figure 8. Acceptability of illuminance change for biased (B) and non-biased (NB) subjects, averaged for all four tasks

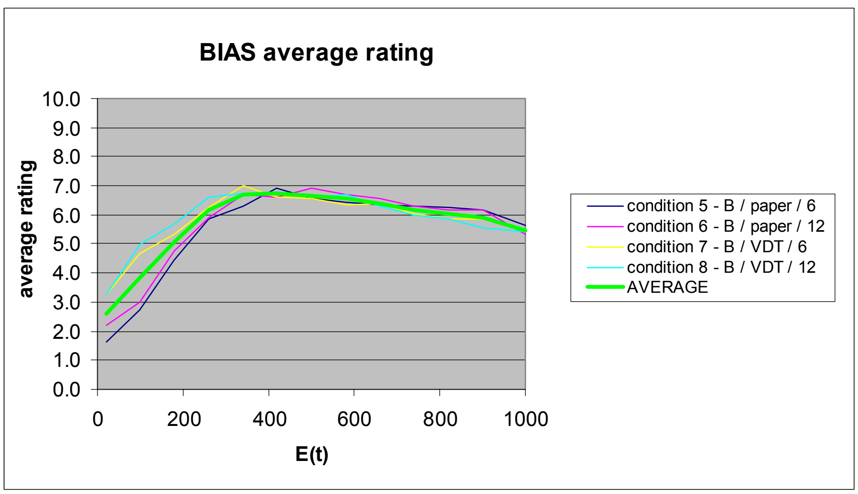

Figure 9. Subjective rating of illuminance change for biased (B) subjects

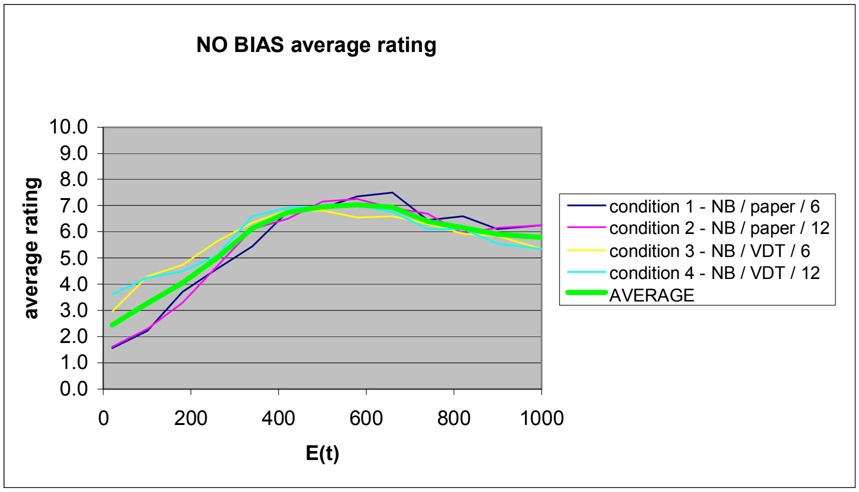

Figure 10. Subjective rating of illuminance change for non-biased (NB) subjects

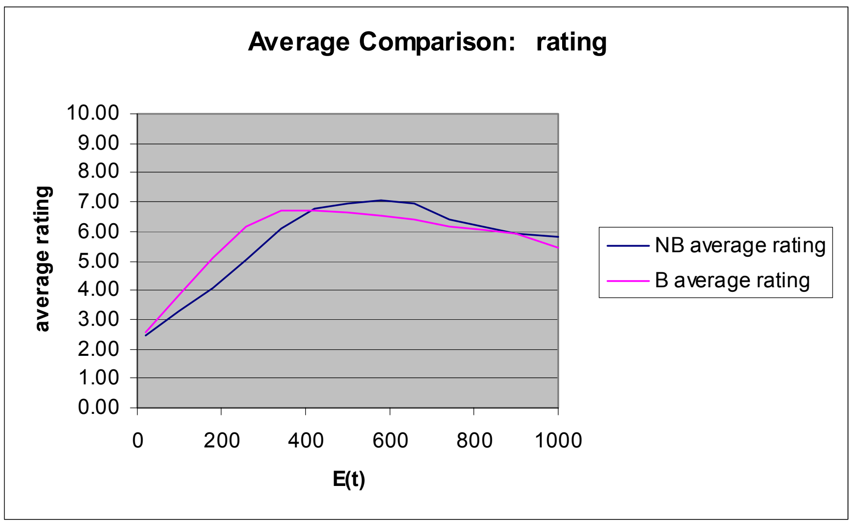

Figure 11. Average rating of illuminance change for biased (B) and non-biased (NB) subjects, averaged for all four tasks

3. Conclusions

The results of this study on detectability were similar to the results of the previous studies—occupants detected illuminance reductions greater than 15 % of the initial illuminance. This detectable range of illuminance change was not influenced by the bias given to subjects. This study also found that the acceptable dimming range of biased subjects was wider than that of non-biased subjects. For instance, the 50th percentile acceptable illuminance reduction was 380 lx (76 % of the initial illuminance) for the biased subjects while 300 lx (60 % of the initial illuminance) for the non-biased subjects. The 80th percentile acceptable illuminance reductions are 270 lx for the biased subjects and 190 lx for the non-biased subjects. These results imply that if the motivation of occupants towards energy savings is raised, occupants may accept larger reductions in illuminance.

References

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