

## DEMAND CHARACTERISTICS AND FULL SPECTRUM LIGHTING EFFECTS ON PERFORMANCE AND MOOD

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### Abstract

Beliefs about full spectrum lighting were manipulated to test the hypothesis that demand characteristics, not lamp type *per se*, underlie the anecdotal reports of beneficial effects of full spectrum lighting on performance and mood. The dependent measures were reading, arithmetic, noun underlining, and mood. Subjects worked under either full spectrum or cool white fluorescent lamps. Under full spectrum lamps they were given one of three instruction sets: 'Full spectrum lamps improve performance and decrease fatigue' (positive set); 'There is no evidence to support such claims' (negative set); or neutral information about light. The participants in the cool white condition received only the neutral information set. The results showed that when existing beliefs about lighting are controlled, both positive and negative information about full spectrum lighting effects lead to improved reading performance and increased self-reported arousal. No effect of lamp type was found, confirming previous research.

### Introduction

The benefits of full spectrum light to human health and well-being are widely assumed. Sunlight-simulating full spectrum fluorescent lighting has been widely recommended for offices and classrooms (Hughes, 1980; Henderson, 1986). This type of lighting is said to be less fatiguing than the more common cool white lighting (Maas *et al.*, 1974); the manufacturer of one full spectrum fluorescent lamp claims that its lamp improves morale and mood as well as increasing office productivity (reports cited by Pattison, unpublished data<sup>2</sup>). Many offices have switched from cool white lamps to the more expensive full spectrum fluorescents because of these claims.

Recent studies do not, however, support these claims. Blais (unpublished data<sup>3</sup>) found no effects of full spectrum light on actual or perceived examination performance in a university setting. Berry (1983) found no effects on either work performance or mood of electronic assembly workers. In a laboratory comparison of cool white, warm white, and full spectrum fluorescent lamps, using a number of cognitive, affective, and evaluative measures, Boray *et al.*, (1989) found no effects of lamp type on any variable. Furthermore, the U.S. Food and Drug Administration (FDA) issued a 'Health Fraud Notice' in 1986 against one manufacturer of full spectrum lamps. In its view, the claims made for the lamps are not supported by well-controlled scientific investigations (FDA, 1986).

Although considerable attention has been paid in recent years by both the scientific and the popular press to the topic of 'seasonal affective disorder' (SAD) and to the role

of phototherapy in its treatment, the present study does not touch on this issue. The incidence of seasonal affective disorder in the population has been estimated to be 5%, although non-clinical susceptibility to seasonal fluctuations in mood and behaviour may occur in 25% of the general population (cf. Blehar & Rosenthal, 1989). Phototherapy (exposure for 1–5 h each day to intense artificial light, usually from full-spectrum fluorescent lamps) has no effect on depressive symptoms in non-susceptible individuals (Kasper *et al.*, 1989); furthermore, there is no evidence to suggest that the hormone fluctuations believed to underlie the mood changes in SAD bear any relation to the type or intensity of lighting found in most workplaces.

Despite the lack of evidence for psychological benefits associated with the use in workplaces of full spectrum lamps rather than conventional cool white fluorescent lamps, anecdotal evidence and personal experience suggests that many people believe in the benefits of sunlight-simulating light for indoor work. This raises the possibility that demand characteristics mediate the reported full spectrum lighting effects. Demand characteristics are known to affect the supposed influence of colour on muscle strength (Smith *et al.*, 1986); it is therefore plausible that they might affect other environment-behaviour relationships. Another possibility is that people respond to any beliefs about the environment with increased effort and better performance.

The present study used a simple four-group experimental design to test three hypotheses. Three groups performed a variety of cognitive tasks and a mood questionnaire under full spectrum fluorescent lamps. They received an instruction set at the start of the session that contained positive, neutral, or negative information about full spectrum lamps. One group performed the same tasks under cool white lamps; they read the neutral information set. Planned comparisons were used to test three hypotheses:

- (1) Full spectrum lamps cause better performance and mood than cool white lamps (i.e. a lamp type effect).
- (2) Positive instruction sets about full spectrum lamps cause better performance and mood than negative instruction sets (i.e. a demand characteristics effect).
- (3) Belief sets (both positive and negative) about full spectrum lamps cause better performance and mood than a neutral set.

## Method

### *Subjects*

The participants were 86 undergraduate volunteers from a medium-sized university in Canada. They ranged in age from 18 to 24.

Although assignment to experimental conditions was random, the subjects were selected for participation on the basis of their responses to a lighting questionnaire administered in their classes. Respondents who scored above a cut-off score on a scale of lighting myth acceptance were eliminated as potential participants. This procedure was followed to ensure that the participants did not have strong initial beliefs about lighting that might have influenced their reactions to the instruction sets. Approximately 15% of the pool was removed using this procedure.

Respondents to the questionnaire were not informed of the connection between it and the laboratory study, which took place two to three weeks later. They volunteered for 'a study of the effects of lighting on how people work'. Those participants who remained after the selection procedure were contacted to arrange an appointment for

an experimental session. Each session was randomly assigned to an experimental condition after the appointments had been made. Each condition consisted of a lighting type and an instruction set.

### *Setting*

The study took place in a 5.18 m × 5.18 m windowless room with two rows of four chairs set facing in one direction. The lighting consisted of either eight General Electric cool white fluorescent lamps (GE F40CW/RS/WM, Correlated Colour Temperature 4150 K) or eight General Electric full spectrum lamps (GE Chroma 50 F40/C50, CCT 5000 K), set in recessed troffers with K-12 prismatic lenses. Details about the spectral power distribution of both lamp types are available in Boray *et al.* (1989).

The illuminance at each seat ranged from 380 to 415 lx, and had a mean illuminance of 400 lx, which is in accordance with the Illuminating Engineering Society of North America (IESNA) standards for young people reading high contrast printed materials (IESNA, 1987). The laboratory environment was identical in all conditions except for the lighting variations. Lapboards were provided for the subjects to use as work surfaces; the subjects were free to choose any posture.

### *Instruction sets*

There were three instruction set conditions under full spectrum lamps, and one under cool white lamps. All subjects in each session received the same instruction set.

The full spectrum instruction sets consisted of information sheets about the lighting in the room during the session. Subjects were informed about the lamp type, then asked to read some information about the lighting before beginning the experiment. The information was selected from sources believed to be credible while giving information of the appropriate emphasis for the condition. The *full spectrum positive* (FS+) set used advertising copy from one manufacturer of full spectrum lamps and quotations from Pattison (unpublished data) to foster the belief that full spectrum fluorescent lamps improve performance and mood. The *full spectrum negative* (FS-) set used the FDA Talk Paper (FDA, 1986) discussed above to foster the belief that claims of beneficial effects have been highly exaggerated.

The *full spectrum neutral* (FS) and *cool white neutral* (CW) sets used identical information, an excerpt from Kantowitz and Sorkin (1983) describing the spectral power distribution of radiation from artificial light sources. Subjects in these conditions were made aware of the lamp type in the room, but no belief set was induced in either case.

### *Dependent variables*

Three cognitive tasks and one mood questionnaire were administered. The cognitive tests were an edited portion of Test 1 (Reading Comprehension) and all of Test 7 (Fast Reading) of the Stanford Diagnostic Reading Test (SDRT) Blue Level (Karlsen *et al.*, 1977), and a timed underlining and arithmetic task. In the latter task, subjects were allowed two minutes to complete a page of alternating noun underlining and successive subtraction items. The reading test score was the sum of the items answered correctly on both the reading comprehension and fast reading tests. The maximum possible was 55. The arithmetic measure was the number of correct subtractions of the 23 possible; similarly, the underlining score consisted of the number of correctly underlined nouns of the 24 in the test.

The mood questionnaire was the Russell and Mehrabian (1977) three-factor semantic differential scale. This 18-item scale yields scores on three independent mood subscales: Arousal, Pleasure and Dominance.

#### *Procedure*

The experimental sessions were carried out by a research assistant who was naive to the hypotheses and independent variables in the study. To maintain his ignorance, the instruction sets were presented to the subjects face down on lapboards. Taped instructions dictated by another experimenter directed the subjects to turn over the material on the lapboards and read it, but not to disclose it to the experimenter.

Five minutes were allowed for the subjects to read the instruction set material. The experimenter then collected the material and distributed the reading test booklet and answer sheet. Fifteen minutes were allowed for the 25 questions of the reading comprehension test. All the subjects completed the test within this time.

At the end of the 15 minutes, the experimenter explained and administered the fast reading test. The test protocol was unaltered from the SDRT Manual (Karlsen *et al.*, 1977). None of the subjects completed the 30 items in the two minutes allowed for the test.

Two minutes were also allowed for the underlining/arithmetic test, which followed the fast reading test. No one completed the page.

The mood questionnaire was the last dependent measure. Subjects were given five minutes to complete it; when they had finished, the experimenter gave them a post-experimental questionnaire which sought their impressions of the credibility of the instruction set information, the difficulty of the tasks, and the purpose and hypotheses of the experiment. Other items probed subjects' beliefs concerning the importance of lighting to their studying effectiveness, well-being and mood.

Following the post-experimental questionnaire, the participants received a written debriefing from the experimenter, who had been instructed not to read it. Questions were directed to the principal investigators. The entire session lasted from 45 to 50 minutes.

## **Results**

#### *Manipulation checks*

The post-experimental questionnaire incorporated both open-ended and Likert items (scaled 1, 'not at all credible' to 5, 'very credible') to ascertain whether or not the subjects had accepted the instruction set information as credible and whether they were aware of having tried to meet experimenter expectations. The responses to the open-ended items indicated that few ( $N = 7$ ) of the subjects suspected the hypothesis that lighting beliefs (not type of lighting *per se*) affect performance and mood. None reported having attempted to fulfil expectations based on the content of the instruction sets, so their data were retained for analysis.

In general, subjects found the lighting information to be somewhat credible (mean = 2.95). There were no significant differences in credibility across conditions. Subjects in all conditions, however, believed that lighting is important to studying effectiveness, well-being and mood. The ratings were scaled from 1, 'strongly disagree' to 5, 'strongly agree'. The means and standard deviations for these variables by condition are shown in Table 1. The overall means for the lighting belief ratings were 4.04, 3.65 and 3.77 respectively.

TABLE 1  
Means and standard deviations of postexperimental lighting beliefs

Factors to which light is important	FS + <sup>a</sup>	FS <sup>b</sup>	FS - <sup>c</sup>	CW <sup>d</sup>
Studying	mean = 4.00	4.10	4.06	4.00
Effectiveness	S.D. = 0.77	0.79	0.93	1.07
Well-being	3.17	3.95	3.63	3.68
	0.86	0.76	1.09	0.89
Mood	3.72	3.75	3.81	3.69
	1.02	0.97	0.98	1.18

Notes: Items were coded from 1, 'strongly disagree' to 5, 'strongly agree' that lighting is important.  $N = 86$ . Key: <sup>a</sup>Full spectrum positive set; <sup>b</sup>Full spectrum neutral; <sup>c</sup>Full spectrum negative set; <sup>d</sup>Cool white neutral set.

### *Mood scale reliability*

Reliability analyses were conducted for the three subscales of the Russell and Mehrabian three-factor mood questionnaire. The poles of the pairs of semantic differentials are scaled 1 and 9; each subscale score is the mean of the scores for the 6 relevant items. Higher values indicate stronger feelings on each dimension.

Cronbach's alpha for the Arousal subscale was 0.87 ( $N = 85$ ); for the Dominance subscale, alpha = 0.89 ( $N = 86$ ). Alpha for the Pleasure subscale was 0.87 ( $N = 86$ ). These values were judged to be adequate.

### *Instruction set effects*

The post-experimental questionnaire results suggested that despite the initial screening of the subjects, existing beliefs about lighting might have influenced their responses. Therefore, a new measure of lighting beliefs was constructed from the available selection questionnaire data; this new variable comprised nine items related to beliefs about the effects of specific lighting types (e.g. 'Natural daylight is better for working under than artificial light') and the importance of lighting to well-being and mood (e.g. 'Lighting is important to my sense of well-being'). The theoretical range of the scale is from -9 (low acceptance of common lighting beliefs) to +9 (high acceptance of common lighting beliefs). Reliability analysis showed Cronbach's alpha to be 0.64 ( $N = 76$ ; 10 subjects were dropped because of missing data).

Recall that the original design included one independent variable (Instruction set) and six dependent measures (Reading, Arithmetic, Underlining, Arousal, Dominance and Pleasure). Orthogonal planned comparisons were used to test the three hypotheses listed above. The revised design added Lighting Beliefs as a covariate in order to remove any bias caused by pre-existing between-group differences on this variable.

The mean reading score was 31.72 (S.D. = 3.47;  $N = 76$ ). Participants overall averaged 9.03 correct subtractions on the arithmetic test (S.D. = 4.23) and 11.41 correctly underlined nouns (S.D. = 4.05). The mood factors Arousal, Dominance and Pleasure had means of 5.22 (S.D. = 1.51), 5.22 (S.D. = 1.40), and 4.15 (S.D. = 1.28) respectively. Descriptive statistics for all variables by Instruction Set are shown in Table 2.

The multivariate analysis of variance (MANOVA) results produced multivariate  $F$  tests for the Light Type and Instruction Set comparisons (corresponding to hypotheses 1 and 2, respectively) that were both nonsignificant [ $F(6,66) = 1.43$  and  $F(6,66) = 2.11$ ; both  $p > 0.05$ ]. Only the Set/No Set comparison (hypothesis 3) showed a statistically

TABLE 2  
Means and standard deviations of dependent variables by condition

	FS+ <sup>a</sup>	FS <sup>b</sup>	FS- <sup>c</sup>	CW <sup>d</sup>
<i>N</i>	18	20	16	22
Reading	mean = 32.11 S.D. = 3.31	30.55 4.10	32.69 3.00	31.77 3.24
Arithmetic	9.89 4.20	9.90 3.96	8.88 3.61	7.64 4.78
Underlining	11.22 3.32	10.50 3.65	12.00 4.20	11.96 4.87
Arousal	4.46 1.27	2.96 1.22	3.35 1.51	4.27 1.57
Pleasure	5.31 1.09	4.88 1.30	4.03 1.08	5.06 1.33
Dominance	3.95 1.55	3.90 1.29	3.41 1.33	3.80 1.45
Lighting beliefs	2.58 3.99	3.80 2.95	3.16 2.61	3.52 2.58

Notes: Maximum Reading score = 55. Maximum Arithmetic score = 23. Maximum Underlining score = 24. Arousal, Pleasure and Dominance coded 1-9; Lighting Beliefs coded -9 to +9, where higher scores indicate more of the construct. *N* = 76. Key: <sup>a</sup>Full spectrum positive set; <sup>b</sup>Full spectrum neutral set; <sup>c</sup>Full spectrum negative set; <sup>d</sup>Cool white neutral set.

significant multivariate [ $F(6,66) = 2.50$  ( $p < 0.05$ )]. Examination of the univariate tests for the six dependent measures revealed two statistically significant effects: These were for Reading ( $F(1,71) = 4.59$ ;  $p < 0.05$ ) and Arousal ( $F(1,71) = 6.17$ ;  $p < 0.02$ ). These effects are illustrated in Figures 1 and 2. Reading performance was lower in the FS condition than in either FS+ or FS-; similarly, Arousal was higher in both FS+ and FS- than in the FS condition.

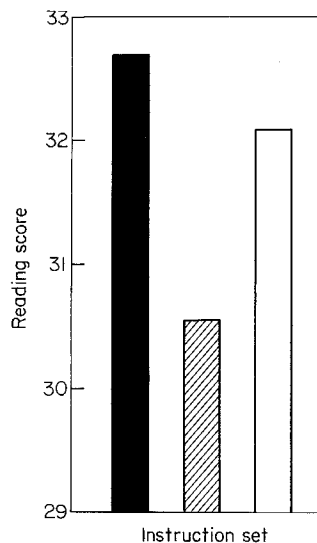


FIGURE 1. Instruction Set/No Set effect on reading scores. Key: ■ = Full spectrum negative set; ▨ = Full spectrum neutral set; □ = Full spectrum positive set.

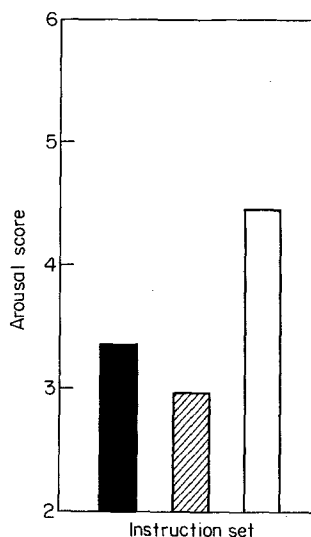


FIGURE 2. Instruction Set/No Set effect on Arousal scores. Key: ■ = Full spectrum negative set; ▨ = Full spectrum neutral set; □ = Full spectrum positive set.

### Discussion

The results show that instruction sets (even those that are merely 'somewhat' credible) about lighting effects will influence reading performance and arousal. The arousal and reading performance increases in the present study are reminiscent of the Yerkes-Dodson inverted-U relationship between arousal and task performance. It is possible that the instruction sets increased arousal sufficiently to improve reading performance. Future research might examine this possibility more closely.

It is also possible that the higher reading performance and arousal scores for the positive and negative belief set conditions reflect two different mechanisms. The effect of the positive set is consistent with the hypothesis that demand characteristics might underlie the anecdotal reports of beneficial effects caused by full spectrum lighting. When informed that they were working under full spectrum lighting and that this type of lighting can cause performance and mood improvements, subjects performed better on one performance measure and reported higher scores on one mood measure.

The negative set effect might reflect psychological reactance (Brehm, 1966) on the part of the participants. The negative set attempted to discredit the advertising claims made for full spectrum lighting benefits. Perhaps the participants responded to this information with increased effort and arousal, instead of less, as had been expected.

The effect of the positive and negative sets, of course, occurred in the context of a short term exposure. One obvious direction that future research might take would be to extend the duration of the study to determine whether these effects might be maintained over the longer term.

The present study also replicated earlier research concerning the direct effects of full spectrum versus cool white fluorescent light. Boray *et al.* (1989) failed to find any statistically significant lamp type effects (when subjects were unaware of lamp type) on a variety of cognitive and affective measures that included the underlining/arithmetic

task and the mood questionnaire used in the present study. Thus, the evidence mounts against the claims that full spectrum light is intrinsically better for office and school work.

The results might have a practical value for facilities management. If information, positive or negative, is provided to employees concerning the lighting installation and its effects on people, performance and mood might improve, at least temporarily. More powerful effects, however, might depend on other factors, such as the fit between the lighting design and individual preference, which were not addressed by this study. Future research will examine these questions.

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### Notes

- (1) Reprint requests and other correspondence should be directed to Dr. Robert Gifford, Department of Psychology, University of Victoria, P.O. Box 3050, Victoria, B.C., V8W 3P5 Canada.
- (2) Pattison, D. B. (1985). Full spectrum lighting: a review of the literature.
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