Journal of Environmental Psychology (1989) **9**, 297–308

EFFECTS OF WARM WHITE, COOL WHITE AND FULL-SPECTRUM FLUORESCENT LIGHTING ON SIMPLE COGNITIVE PERFORMANCE, MOOD AND RATINGS OF OTHERS

PAUL F. BORAY, ROBERT GIFFORD and LORNE ROSENBLOOD

Department of Psychology, University of Victoria, P.O. Box 1700 Victoria, Canada V8W 2Y2

Abstract

Fluorescent illumination has become common, but its alleged effects on behavior are still controversial. This experiment was designed to determine whether warm white, cool white, and full-spectrum fluorescent spectra at approximately equal illuminances differentially affect performance on simple verbal and quantitative tasks, salary recommendations, rated attractiveness and friendliness of others, judged room attractiveness, estimated room size, and self-reported pleasure and arousal. The results showed no significant differences among the three lighting types on any of the dependent measures. A subsequent power analysis indicated that if differences actually do exist, they are quite small. Cool white or warm white lamps are recommended because they are much less expensive than full-spectrum lamps.

Humans are primarily visual beings (e.g. Gifford & Ng, 1982). We rely on optical information for most aspects of our daily functioning. The relevance of vision and, by implication, lighting, to everyday life makes them both important research topics. Early research found that increasing the quantity of light (illuminance) resulted in dramatic productivity gains (Hollingworth & Poffenberger, 1926; Luckiesh, 1924; cited in Sundstrom, 1986). Recent attention has shifted away from the quantity of light towards the quality of light (Megaw & Bellamy, 1983). We focus in this study on one particular aspect of lighting quality: fluorescent illumination.

Fluorescent lamps have become the standard source of general illumination in modern buildings. However, fluorescent illumination is the subject of controversy. Some surveys suggest that most employees find their lighting quite adequate (Louis Harris and Associates, 1978) or even completely satisfactory (Langdon, 1966). Other surveys report that sizable proportions of employees are critical of it (e.g. Hedge, 1982).

As for performance and health, both claims (e.g. Hughes, 1980; Rosenthal *et al.*, 1985) and counterclaims (e.g. FDA, 1986) primarily focus on the alleged effects of full-spectrum fluorescent lamps. Just as the spectrum of the natural light they seek to

We wish to thank Steve Eso and Terri Buller for bravely serving as targets of the participants' ratings, Joe Ecclestone and Canadian General Electric for supplying the full spectrum bulbs, and several anonymous reviewers for their constructive comments. The study is based on an Honours thesis by the first author, supervised by the other authors.

Reprint requests and other correspondence should be directed to Dr. Robert Gifford, Department of Psychology University of Victoria, P.O. Box 1700, Victoria, BC, Canada V8W 2Y2.

0272-4944/89/040297 + 12 $03.00/0

emulate varies (with time of day, latitude, and cloud cover), full-spectrum lamps vary, but they typically include more blues than standard cool white or warm white lamps do (Correlated Color Temperature (CCT) of 5000–5500 K) and they render colors well (Color Rendering Index (CRI) of 90 or higher).

Maas, Jayson and Kleiber (1974) examined the effects of different fluorescent spectra on fatigue after a period of studying. They compared full-spectrum lamps with cool white fluorescent lamps and found no differences between the two groups on self-reported fatigue. However, objective measures revealed less perceptual fatigue and better visual acuity in the full-spectrum condition. Nevertheless, the U.S. Food and Drug Administration cautioned consumers that claims made for one brand of full-spectrum lamps based in part on this study are 'unsubstantiated and misleading', and that much more research is required (FDA, 1986).

London (1987) reported that full-spectrum light was beneficial for a group of elementary school children in Brattleboro, Vermont. Students in the full-spectrum light classrooms had fewer illness-related absences than a control group exposed to cool white fluorescent light. Ferguson and Munson (1987) report a decrease in grip strength and an increase in hand steadiness among school children who worked in full-spectrum light compared to those who worked in cool white fluorescent light. However, these changes occurred only after several weeks, and no effects on reaction time, attention or gross motor behavior were found. Also, although careful control was exercised over most possibly confounding factors, all testing occurred in classrooms with large windows.

Research on differences among fluorescent spectra has also examined the estimation of room size. Watson and Payne (1968, cited in Kuller, 1981), using scale models, found that white fluorescent lamps tending towards the blue end of the spectral range gave an impression of a larger volume than white fluorescent lamps tending towards the red end of the spectral range. They suggested that a further experiment be conducted because these results were unexpected.

Cockram, Collins and Langdon (1970) studied subjects' preferences for four fluorescent spectra (CCT 6500 K, 4300 K, 4000 K and 3500 K) in an office environment. They concluded that the Daylight (CCT 4300 K) lamp is best for daylight compatibility and high luminous efficiency. The White (CCT 3500 K) lamp was in general the second choice. However, because the lamps differ in efficiency, they produced different levels of illuminance. Cockram *et al.* (1970) made no attempt to equalize illuminance, and concluded that this may have significantly influenced preference ratings.

Blackwell (1985) reports, in the last study of his distinguished career, that a form of visual performance based on viewing Landolt rings was better under full-spectrum lamps than under four other light sources. However, none of the other sources were fluorescent and only five subjects were studied, albeit with many observations per subject.

The present study

This study cannot address all the questions raised by previous research. However, it will attempt to clarify several possible effects of spectral differences among fluorescent lamps. We chose a setting and tasks that are both reasonably realistic and reasonably well-controlled, rather than an extremely controlled approach at the expense of realism (e.g. Blackwell, 1985) or a field setting where experimental control is difficult (e.g. London, 1987). We selected tasks in which immediate or short-term effects might reasonably be expected, although long-term exposure to different spectra may also affect behavior.

The effects of cool white, warm white, and full-spectrum lamps on simple cognitive performance, ratings, and moods are compared. Warm white and cool white fluorescent lamps were chosen for study because of their widespread use, which is partly because of their considerably lower initial and operating costs compared to full-spectrum lamps. Full spectrum lamps were included because of their recent popularity and the claims made on their behalf (e.g. Hughes, 1980).

We chose the following dependent variables because they closely resemble, or form the basis of, common work and school activities: performance on simple verbal and quantitative tasks, recommended salary levels based on reading resumes, rated attractiveness and friendliness of others, rated attractiveness of the experimental room, estimation of room size, and self-reported pleasure and arousal. We chose not to examine specialized tasks in which visual performance is particularly difficult, favoring instead tasks similar to those found in everyday workplaces.

Some hypotheses may be offered. First, concerning performance on simple verbal and quantitative tasks, we hypothesize null results based on the results of studies by Smith and Rea (1979) and Rowlands, Loe, Waters and Hopkinson (1973).

Second, impressions of the room's aesthetic qualities should be different in the three lighting conditions. Cockram *et al.* (1970) found that a 4300 K lamp produced higher preference ratings than 4000 K and 3500 K lamps did.

Finally, based on the work of Watson and Payne (1968, cited in Kuller, 1981), it is hypothesized that subjects will estimate the room to be larger in the cool white fluorescent light condition that in the warm white fluorescent light condition. Because of the paucity of research on the effect of spectral differences on the remaining dependent variables, no specific hypotheses concerning them are offered.

The main independent variable of interest is fluorescent spectral power distribution (see Figure 1). A second variable, sex, is included because males and females differ in many other ways and because some buildings contain different proportions of males and females (e.g. an auto assembly line versus a women's clothing store). If there are sex differences in response to different fluorescent spectra, lamp type could be matched with gender to produce desired effects.

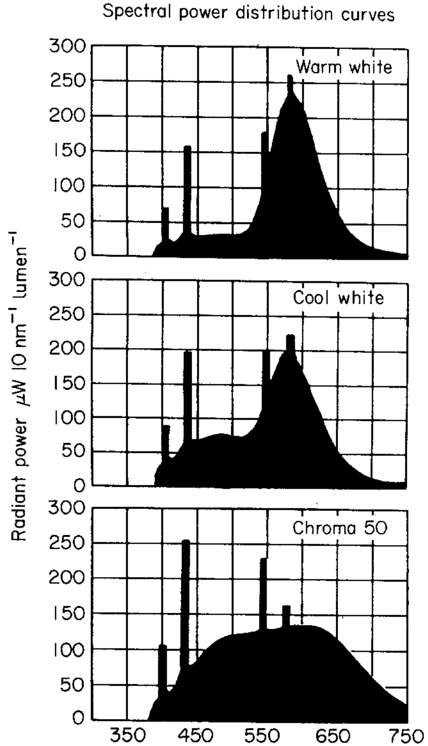
Method

Design

The experiment employed a two-factor between-subjects multivariate analysis of variance design. Spectra (cool-white, warm-white, and full-spectrum) and Sex (males, females) were the independent variables, and there were (originally) ten dependent variables (cognitive performance, ratings of others' recommended salary, male friendliness, female friendliness, male attractiveness, female attractiveness, self-rated pleasure and arousal, and ratings of room size and room attractiveness).

Subjects

One hundred and seventeen psychology students (43 males and 74 females) from a medium-sized university participated in this study. They volunteered (no pay or course credit) for an experiment which was described as 'a study which asks you to make salary recommendations based on reading resumés, and asks for your answers to several



Lamp color specifications

Lamp	Nomina LPW	x, y (approx.)	CRI (approx.)	CCT (K) (approx.)	Whiteness	Colors enhanced	Colors greyed
WW	81·3	$x = 0{\cdot}440$ $y = 0{\cdot}403$	52	3000	yellowish	orange, yellow	red, blue green
CW	78·8	$x = 0{\cdot}372$ $y = 0{\cdot}375$	62	4150	white white	yellow, orange, blue	red
C50	55·3	$x = 0{\cdot}346$ $y = 0{\cdot}359$	90	5000	white bluish	all	none

FIGURE 1. Characteristics of the lamps. LPW is lumens per watt, a measure of efficiency (higher figures indicate greater efficiency). X, Y co-ordinates specify lamp color in terms of the C.I.E. (International Commission on Illumination) color triangle. CRI or color rendering index is a measure of the lamp's ability to render colors accurately when compared to the way outdoor north sky daylight or incandescent light (both of which have DRI values of 100). CCT or correlated color temperature is another measure (in Kelvins) of lamp chromaticity, which is suggested by the hues listed under Whiteness.

simple questions.' Because we did not want expectancy effects to play a role in the results, subjects were not informed about the lighting variable before they participated. (They were informed during debriefing at the end of the study.)

Room

The study took place in a windowless laboratory room (carpeted, framed art on walls, wall color off-white) measuring 5·28 m by 5·13 m, with a height of 2·84 m. The room contained 14 ceiling light fixtures each normally holding two 4-foot fluorescent lamps. The lamps were covered in all conditions with standard K-12 clear acrylic lens panels.

Illumination

Unequal illuminance has been a problem in some previous studies (e.g. Cockram *et al.*, 1970). Because the three fluorescent lamps to be used vary in efficiency, different numbers of 40-watt lamps were required to obtain nearly equal illuminance. In the warm white condition, 14 lamps (GE F40WW/RS/WM, CCT 3000 K) were used. In the cool white condition, 12 lamps (GE F40CW/RS/WM, CCT 4150) were used. In the full-spectrum condition, 16 lamps (GE F40C50, CCT 5000) were required to produce approximately the same illuminance. Further details about the lamps may be found in Figure 1. Illuminance was measured at nine seats around the room using a Weston Sight Meter (Model 703-60, Type 6A). The average illuminance in the three conditions were 487 lux (cool white), 512 lux (warm white), and 526 lux (full-spectrum). These small differences in intensity among conditions would not warrant consideration as causes of any significant differences in outcomes. An illuminance of about 500 lux is appropriate for the tasks, based on the (U.S.) Illumination Engineering Society's 1981 Application Volume (cf. Kantowitz and Sorkin, 1983, p. 560). Horizontal illuminance on the walls ranged from 300 to 320 lux.

Procedure

In this between-subjects design, subjects participated in groups of six to nine in one of the three lighting conditions (cool white $n = 37$, warm white $n = 39$, full-spectrum $n = 41$). They were greeted by the experimenter and invited to come into the room and sit down. Two confederates were already seated at the front of the room. One was male, age 23 years; the other was female, age 22 years. Each confederate wore the same clothing and read a book in all sessions; thus their appearance and behaviour was consistent. The seating position of the confederates was counterbalanced, as was the order of testing the three types of fluorescent lamps. Horizontal illuminance on the confederates' faces was 320 lux.

After the subjects were seated, the experimenter read a script explaining how the approximately 35-minute session was to be run. Subjects began with a simple cognitive task (underlining nouns and subtracting numbers), described later as Cognitive Performance. After exactly three minutes, they were asked to stop.

The second task consisted of a scenario in which each subject had the simulated job of assigning a starting salary to each of three people supposedly hired by the subject's boss, based on reading three resumes (later referred to as Recommended Salary; this task was modeled after Sauser, Arauz, and Chambers, 1978).

The third task consisted of rating the two confederates and the room. The confederates were each judged on two 9-point bipolar scales: how attractive-unattractive and how friendly-unfriendly they appeared to the subjects (Male and

Female Attractiveness and Friendliness). The room was rated on aesthetic qualities using four 9-point bipolar scales: comfortable-uncomfortable, like-dislike, pleasant-unpleasant, and beautiful-ugly (Room Attractiveness). Additionally, subjects were asked to estimate the length, width, and height of the room (Room Size).

Finally, the subjects were asked to match their moods with six words on 8-point bipolar scales ranging from 'not at all' to 'very much'. These items were selected from Mehrabian and Russell's pleasure-arousal scales (Mehrabian & Russell, 1974). Pleasure, dissatisfied (reverse scored), and happy were used to produce the Pleasure score. Sluggish (reverse scored), lively, and frenzied comprised the Arousal score.

Results

Reliability

The reliability (internal consistency) of the rating scales was estimated. Cronbach's alpha for the 3-item Pleasure scale was 0·81; that for the 3-item Arousal scale was 0·29; that for the 4-item Room Attractiveness scale was 0·89. The Pleasure and Room Attractiveness scales were deemed to have adequate reliability and were retained for further analysis; the Arousal measure was dropped, leaving nine dependent variables.

The reliability of the participants' ratings in the simulated salary (Recommended Salary) and room estimation (Room Size) tasks was estimated using Shrout and Fleiss' (1979) formula (2, K). Both sets of ratings were very reliable (0.99), and were retained for further analysis.

Multivariate analysis of variance

The means and standard deviations of the nine dependent variables for each lighting condition appear in Table 1. As a group, the subjects were quite accurate in estimating

TABLE 1
Means and S.D. for the three illumination types

Dependent variable	Cool white	Warm white	Full-spectrum
Cognitive performance	16·81/ 8·95	20·38/ 8·79	19·90/ 8·46
Recommended salary	829·51/73·12	845·31/79·23	839·88/86·88
Male attractiveness	4·24/ 1·23	4·54/ 1·50	4·02/ 1·31
Male friendliness	4·08/ 1·30	3·69/ 1·49	3·54/ 1·58
Female attractiveness	3·19/ 1·05	3·20/ 1·17	2·83/ 1·02
Female friendliness	4·51/ 1·32	4·00/ 1·24	4·15/ 1·56
Room attractiveness	20·30/ 5·59	20·69/ 5·56	22·66/ 5·48
Room size	12·86/ 2·59	14·40/ 3·63	13·71/ 2·47
Pleasure	15·03/ 3·82	15·8/ 3·90	16·15/ 3·55

Note: For all dependent measures, higher numbers indicate more of the quality mentioned. Cognitive performance is computed as the number of correct answers minus the number incorrect. Recommended salary is the sum of the three recommendations, in hundreds of dollars. Attractiveness and Friendliness were rated on 9-point bipolar scales. Room Attractiveness is the sum of four 9-point bipolar scales, forming a 36-point scale: like, beautiful, uncomfortable (reverse scored), and unpleasant (reverse scored). Room Size is the sum of the judged length, width, and height in metres. Pleasure is the sum of pleased, dissatisfied (reverse scored), and happy. Each was on an 8-point bipolar scale, resulting in a 24-point scale.

TABLE 2
Power for the main effect of lighting condition

Dependent variable	Grand Mean	Standard deviation	Range	Detectable effect size
Cognitive performance	19·08	8·80	−10–10	6·42
Recommended salary	838·41	79·75	670–1040	58·92
Male attractiveness	4·29	1·36	1–9	1·00
Male friendliness	3·77	1·47	1–9	1·08
Female attractiveness	3·10	1·09	1–7	0·80
Female friendliness	4·22	1·39	1–7	1·02
Room attractiveness	21·15	5·59	6–33	4·08
Room size	13·25	3·00	7·92–27·1	2·18
Pleasure	15·35	3·76	3–23	2·76

Note: Power = 0·83, $n = 39$, alpha = 0·05. See Table 1 for a description of the units of measurement.

the size of the experimental room. Their average estimate (length + width + height) was 13·7 m, compared to the actual room of 13·3 m.

A two (Sex) by three (Spectra) between-subjects multivariate analysis of variance (MANOVA) procedure was used to analyse the data. The Sex main effect was not significant [$F(20{,}206) = 0{\cdot}92$, $p > 0{\cdot}05$], the Spectra main effect condition was not significant [20, $G(206) = 1{\cdot}00$, $p > 0{\cdot}05$], and the Sex X Spectra interaction was not significant [$F(20{,}206) = 1{\cdot}12$, $p > 0{\cdot}05$].

Because none of the multivariate F's were significant, data analysis should stop at this point because it is inappropriate to report significant univariate F's when the multivariate F is nonsignificant (Hummel & Sligo, 1971). However, recognizing this important limitation, post hoc analyses were conducted to make the results more specific, in the interest of future research.

Of the nine univariate F-tests on the main effect of Spectra, none were significant at the 0·05 level. Similarly, there were no significant ($p < 0{\cdot}05$) univariate F's for the nine main effects of Sex. Finally, there were no significant ($p < 0{\cdot}05$) univariate F's for the Spectra X Sex interaction. These are the results which would have been obtained using an ANOVA on each dependent variable. Note that even with the inflated alpha level, no significant results appear.

Power analysis

Non-significant findings can result from an experimental design with too little power (usually resulting from an inadequate sample size) to detect a true effect in the population. Therefore, a power analysis (Cohen, 1977) was performed to determine whether a reasonable effect size could have been detected by this study's design. Power is a function of sample size, variability of the data, alpha level, and the size of the effect of the independent variable. When values of four of these are set, the fifth is determined.

In this experiment, the sample sizes were already determined, as was the variability of each dependent variable. An alpha level of 0·05 was chosen. Power was set a reasonably high level of 0·83. Table 2 shows, for each dependent variable, the effect size that this experiment had an 83% chance of detecting. As may be seen from the table, this study had the power to detect moderately small effects. If there are any effects of different fluorescent spectra on the dependent variables in this study, they would have to be quite small.

Discussion

Myths and realities

That no statistically significant differences on any of the nine dependent variables were found is surprising, given the perception in some quarters that full-spectrum lighting is broadly beneficial, and that advertisements for one brand have claimed that full-spectrum lighting is 'perceived as significantly more pleasant... and stimulating' than other types of fluorescent light and that the lamps 'make people feel better'. Such advertisements lead some readers to believe that full-spectrum fluorescent lighting will have a meaningful impact on their lives. For example, during the planning process for a new school in our community, many staff members specifically required full-spectrum lighting. We are also acquainted with numerous professionals (librarians, teachers, health care workers, etc.) who have installed full-spectrum lighting in their work places at their own (considerable) expense. These individuals believe that 'research has proved its benefits.'

The results of this experiment do not support these beliefs. The subsequent power analysis indicated that the null findings are not likely to be due to inadequate sample size. The power of this experiment to detect a meaningful effect for each dependent variable are discussed next.

No differences were found in performance on simple verbal and quantitative tasks among the three lighting conditions. This experiment had an 83% chance of detecting a 6·42-unit difference between any two lighting conditions on a scale with a range of 50, a mean of 19·08, and a standard deviation of 8·73. This is consistent with the findings of Smith and Rea, who studied digit checking, and those of Rowlands *et al.* (1973), who studied searching through charts of Landolt rings (Megaw & Bellamy, 1983). Both these studies used lamps emitting even more diverse spectra than those in the present study. Taken together, these studies suggest that the spectral composition of fluorescent illumination has little or no effect on the performance of simple cognitive tasks. Of course, this conclusion may not apply to tasks with stronger chromatic components, particularly in low luminance conditions.

No differences were found in the starting salaries recommended by the subjects for newly hired employees. This study had an 83% chance of detecting a difference in recommendations of $5,892 or more from the overall mean (i.e. the sum of the three recommendations) of $83,841. The $5,892 represents 7% of the mean, so it is unlikely that fluorescent lighting would change a recommended starting salary by more than 7%. However, because 7% might be considered a meaningful salary difference, this aspect of the study may deserve further examination. We emphasize, however, that no significant differences emerged in this study.

We turn now to the subjects' ratings of the confederates. The male confederate was not judged differently on attractiveness or friendliness. This study would likely have detected a difference of 1·00 unit on a nine-point scale for attractiveness, and a difference of 1·08 unit on a similar nine-point scale for friendliness. The female confederate was also not judged differently on attractiveness or friendliness in the three lighting conditions. This experiment would likely have detected effect size of 0·80 unit (attractiveness) and 1·02 unit (friendliness) on the nine-point bipolar scales.

These results indicate that if differences in fluorescent spectra do affect ratings of others the effects are not very large. This is perhaps more surprising than the other null results, because the lamps' chromatic differences render the color of skin and clothing differently. However, from a psychological point of view, fluorescent illumination type does not appear to be an important influence on impression formation.

Impressions of the room's aesthetics were not different in the three lighting conditions. A difference between any two conditions of 4·07 units out of the 36 units which made up the room attractiveness measure had an 83% chance of being detected. Once again, if there are different effects on rated room attractiveness among these fluorescent spectra, they are likely to be very small. Room impressions *might* change, of course, in very colorful settings.

We should note that Cockram *et al.* (1970), in addition to using different illuminances, made the differences in illumination spectra clear to their subjects before asking for their preference ratings. This, or the differences in quality of illumination in that study, may have accounted for the differences in preference they found. In the present investigation, no attention was drawn to the lighting because we sought to generalize to typical instances in which no one draws particular attention to the spectral qualities of the ambient light. We were surprised to discover how little awareness of the lighting differences was shown by the subjects. When, during debriefing, subjects were asked what they thought the experiment was about, not one of the 117 participants mentioned lighting.

Of course, in a between-subjects design, one might not expect participants to notice. One could argue that a within-subjects design might have yielded differences because participants would notice the change in lighting. However, our confederates, who sat for hours under each of the three types of lighting, also never remarked on the lighting differences. Even at the end of data collection, when we asked the confederates to guess the independent variable (they had been kept blind to the hypotheses), neither of them could guess that it was lighting.

In sum, full-spectrum, cool white, and warm white fluorescent lighting appear to have no differential effects on how people perceive others or the environment, at least when no attention is drawn to the room's illumination. Yet once attention *is* drawn to the lighting differences, settings do appear quite different. When we demonstrated these differences for our confederates, they were amazed they had not noticed the changes on their own. Once attention is drawn to a setting's illumination, perhaps expectations based on media reports and hearsay influence attitudes and behavior.

We tried to confirm Watson and Payne's (1968) unexpected findings that subjects rated a room as larger in cool white fluorescent light than in warm white fluorescent light. Watson and Payne's result, obtained using scale models, was not supported in this experiment, which used a full-sized room. This experiment had an 83% chance of detecting a difference of 2·18 m or more around a mean room size of 13·25 m, computed as length + width + height. This amount, 2·18 m, is about 16% of room size. As with salary recommendations, there may be room for further study when power is only sufficient to limit certainty to a 16% range. In this study, however, estimates of the size of full-scale rooms were not significantly affected by cool white, warm white, or full-spectrum fluorescent lighting.

The participants did not describe themselves as more pleased in cool white fluorescent light than in warm white fluorescent light. A difference of 2·76 units or more on a 24-point scale had an 83% chance of being detected. If the three types of lights cause different levels of pleasure, once again the effects are small.

In sum, no significant differences were found between full-spectrum, cool white, and warm white fluorescent illumination in simple cognitive performance, mood, or ratings. This experiment did have the power to detect reasonably small effect sizes for most of the dependent variables. Birren (1969) and Hughes (1980) have suggested that a balanced spectral composition be used (i.e. full-spectrum lamps). This study indicates that for the three types of common fluorescent lamps and the nine dependent variables tested, this is an unimportant issue.

Economic implications

These null results are not unimportant in economic terms. If differences caused by fluorescent spectral type actually do exist, they are likely to be so small that they are unimportant for most, if not all, lighting situations where simple cognitive functioning, mood, and evaluations are important considerations, such as in offices, schools, and residential dwellings. In these settings, the most economical lamps (either cool white or warm white) would probably be the most appropriate choice. In addition to being less expensive to purchase, cool white and warm white lamps (at about 80 lumens per watt) are also more efficient and therefore more economical to operate than full-spectrum lamps (at about 55 lumens per watt). Finally, full-spectrum lamps typically have shorter lives, which also increases costs because replacement is more frequent and, installations large enough that time spent on lamp replacement is a factor, labor costs are higher.

Final considerations

The possibility remains that long-term exposure to different fluorescent spectra might make some difference, and this question deserves further study. Most of the tasks in this study, such as simple verbal and quantitative cognitive processing and judgements of one's mood, other people, or the room, typically occur over short periods of time. If there are any important short-term or long-term behavioral effects of full-spectrum lighting, they remain to be discovered.

A second possibility is that fluorescent spectra differentially affect certain kinds of individuals, differences that might be masked by group means. Given the greater costs associated with full spectrum lamps, however, more and clearer demonstrations of their benefits for identifiable sub-groups of the population are necessary before organizations can be advised to invest in them.

Although fluorescent spectra appear to have few differential effects, we believe that lighting research in general is important. For example, lighting has been shown to interact with other aspects of the physical setting, such as temperature, to influence behavior (Nelson, Nilsson & Johnson, 1984). Also, illuminance appears to affect communication and conversation, although not always in predictable ways (Gifford, 1988; Veitch & Kaye, 1988).

References

Birren, F. (1969). *Light, Color and Environment.* New York: Van Nostrand Reinhold.

Blackwell, H. R. (1985). Effects of light sources spectral distribution upon visual functions. *Annals of the New York Academy of Sciences*, **453**, 340–353.

Cockram, A. H., Collins, J. B. & Langdon, F. J. (1970). A study of user preferences for fluorescent lamp colours for daytime and night-time lighting. *Lighting Research and Technology*, **4**, 249–256.

Cohen, J. (1977). *Statistical Power Analysis for the Behavioral Sciences* (rev. ed). New York: Academic Press.

Ferguson, R. V. & Munson, P. A. (1987). *The Effects of Artifical Illumination on the Behavior of Elementary School Children.* Victoria, BC: Extramural Research Programs Directorate, Health Services and Promotions, Health and Welfare Canada.

Food and Drug Administration. (1986, September 10). *Lamp's Labeling Found to be Fraudulent.* (Talk paper T86–69). Rockville, MD: Author.

Gifford, R. (1988). Light, decor, arousal, comfort, and communication. *Journal of Environmental Psychology*, **8**, 177–189.

Gifford, R. & Ng, C. F. (1982). The relative contribution of visual and auditory cues to environmental perception. *Journal of Environmental Psychology*, **2**, 275–284.

Hedge, A. (1982). The open-plan office: a systematic investigation of employee reactions to their work environment. *Environment and Behavior*, **14**, 519–542.

Hughes, P. C. (1980). The use of light and color in health. In A. C. Hastings, J. Fadiman & J. S. Gordan, Eds., *The Complete Guide to Holistic Medicine: Health for the Whole Person.* Boulder, CO: Westview.

Hummel, T. & Sligo, J. (1971). Empirical comparison of univariate and multivariate analysis of variance procedures. *Psychological Bulletin*, **76**, 49–57.

Kantowitz, B. H. & Sorkin, R. D. (1983). *Human factors: Understanding People-system Relationships.* New York: Wiley.

Kuller, R. (1981). *Non-visual Effects of Light and Color. Annotated Bibliography.* The Swedish Council of Building Research, Lund, Sweden.

Langdon, F. J. (1966). *Modern Offices: A User Survey.* National Building Studies Research Paper No. 41. Ministry of Technology, Building Research Station. London: Her Majesty's Stationery Office.

London, W. P. (1987). Full-spectrum classroom light and sickness in pupils. *The Lancet*, 1205–1206.

Louis Harris & Associates Inc. (1978). *The Steelcase National Study of Office Environments: Do they Work?* Grand Rapids, MI: Steelcase.

Maas, J. B., Jayson, J. K. & Kleiber, D. A. (1974). Effects of spectral differences in illumination on fatigue. *Journal of Applied Psychology*, **59**, 524–526.

Megaw, E. D. & Bellamy, L. J. (1983). Illumination at work. In D. J. Oborne & M. M. Gruneberg, Eds., *The Physical Environment at Work.* pp. 109–141. Chichester: Wiley.

Mehrabian, A. & Russell, J. A. (1974). *An Approach to Environmental Psychology.* Cambridge: MIT Press.

Nelson, T. M., Nilsson, T. H. & Johnson, M. (1984). Interaction of temperature, illuminance and apparent time on sedentary work fatigue. *Ergonomics*, **27**, 89–101.

Oborne, D. J. & Gruneberg, M. M. (1983). *The Physical Environment at Work.* Chichester: Wiley.

Rosenthal, N. E., Sack, D. A., Carpenter, C. J., Parry, B. L., Mendelson, W. B. & Wehr, T. A. (1985). Antidepressant effects of light in seasonal affective disorder. *American Journal of Psychiatry*, **142**, 163–170.

Rowlands, E., Loe, D. L., Waters, I. M. & Hopkinson, R. G. (1973). Visual performance in illuminance of different spectral quality. *Proceedings of the CIE 17th Session*, Barcelona.

Sauser, W. I., Arauz, C. G. & Chambers, R. M. (1978). Exploring the relationship between level of office noise and salary recommendations: a preliminary research note. *Journal of Management*, **4**, 57–63.

Shrout, P. E. & Fleiss, J. L. (1979). Intraclass correlations: uses in assessing rater reliability. *Psychological Bulletin*, **2**, 420–428.

Smith, S. W. & Rea, M. S. (1979). Relationships between office task performance and ratings of feelings and task evaluations under different light sources and levels. *Proceedings of the CIE 19th Session*, Kyoto.

Sundstrom, E. (1986). *Workplaces: The Psychology of the Physical Environment in Offices and Factories.* Cambridge: Cambridge University Press.

Veitch, J. A. & Kaye, S. M. (1988). Illumination effects on conversational sound levels and job candidate evaluation. *Journal of Environmental Psychology*, **8**, 223–233.

Manuscript received 17 *May* 1989
Revised manuscript received 10 *October* 1989