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Summary Reports of the effects of lighting on mood are mainly at an anecdotal level. There is little by way of empirical support and the existing evidence is problematic and contradictory. This experimental study shows that there are systematic influences of lighting on mood from lighting parameters within the range of those encountered in everyday interior conditions. The nature of the lighting effects is complex and is best summarised as initial effects and longer-term effects. Initial effects link illuminance with sensation seeking and correlated colour temperature (CCT) with hostility. Longer-term effects involve complex interactions between gender, illuminance and CCT. The results are consistent with Küller's proposal for short-term and long-term lighting effects.

The impact of lighting on mood

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1 Introduction

Apart from anecdotal reports of the influences of lighting on mood, there has been relatively little by way of empirical support. These anecdotal reports form part of a broad set of assumptions about lighting that inform daily practice for lighting installations varying from domestic conditions to restaurants and offices. There is an acknowledged need for more work in this area[1]. The study reported here is part of a wider investigation to establish whether artificial interior lighting influences mood and behaviour. Within the scientific community, nonvisual effects of lighting have been viewed with a degree of scepticism. Reported effects of either illuminance or spectral composition on mood have been dismissed by some[2,3] and viewed as problematic by others[1,4] as a consequence of habituation effects or complex interactions with other variables. At an empirical level, the prevailing literature contains a mix of contradictory evidence of effects on mood from lighting. This paper attempts to structure and to provide a framework for some of these contradictions on the basis of recent experimental studies.

For the purpose of this paper, mood or affect is defined as 'the core feelings of a person's subjective state at any given moment' and is not necessarily 'about anything'[5]. It can be distinguished from emotion, which may have identifiable causes and is more variable, less intense and less transient than mood.

2 Background

2.1 *Positive or negative affect*

Veitch[4] provides a summary of many attempts to manipulate illuminance level or correlated colour temperature (CCT) to investigate positive affect (good mood) or negative affect (bad mood). Any effects of lighting upon mood are more likely to be due to illuminance than lamp type, but the combined findings are far from clear. Becher and Kluczny [6] found an inverse relationship between illuminance level and positive affect. Further analysis of mood change under either 215 lx or 2175 lx showed a gender difference in which women's positive mood decreased in the higher illuminance condition yet stayed the same in the lower illuminance condition, whereas men 'reacted in the opposite direction'. On the other hand, Baron and colleagues[7] found no sex difference in reactions to lighting. In their study there was an interaction between correlated colour temperature and illuminance such that under warmer CCT (3000 K) subjects had a tendency to be both 'calmer and more awake' under 150 than under 1500 lx. In Baron's study, mood was measured at one instant during the experiment. More complex findings have resulted from studies by Knez[8], who assessed mood twice and could therefore measure mood change across the course of his experiment. When subjects were exposed to high (95) CRI (colour rendering index) lamps, women's negative mood decreased under warm CCT (2950 K), but men's negative mood decreased most under the cool CCT condition. At low (51–58) CRI, an interaction effect between illuminance and correlated colour temperature was found. Good mood was preserved best under conditions of low illuminance (300 lx) combined with a cool correlated colour temperature (4000 K) or in the higher illuminance level (1500 lx) combined with the warmer CCT (2950 K).

At the same time, other studies have found no difference in mood between different illuminance levels or lamp types[9]. One contributory factor to these contradictory reports is the variety of experimental procedures used, differences in independent variables manipulated and differences in mood-measuring instruments used.

2.2 *Arousal*

In many theories of emotion, arousal features with affect as a component of mood[10,11]. Arousal is defined as a continuum of state of alertness ranging from a comatose state to one of extreme excitement. Evans[12] defines three types of arousal as behavioural (measured by behaviour or self-report), autonomic (measured by indices such as an electrocardiogram) and cortical (reflecting activity in the brain). Effects of both illuminance and lamp type have been found on two of these types of arousal: cortical and behavioural. For example, while measuring the effects of illuminance and correlated colour temperature upon cortical arousal, Küller and Wetterberg[9] found that 700 lx had a waking effect on the central nervous sytem when compared to 450 lx and that a cool colour temperature (5500 K) at low illuminances is more restful than at high illuminance. Various effects of lighting upon behavioural arousal have also been found, mostly through observation studies. Gifford[13] reported that communication exchanges (interpreted as an index of arousal) were lower at 60 lx than 90 lx. A similar inference may be drawn from the findings of Nelson[14], who reports a tendency for individuals to be less fatigued under 300 lx than 100 lx. Fatigue has also been

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measured with respect to lamp colour. Maas *et al.*[15] found that subjects were 'less lively' after being exposed to cool white lights as opposed to Vitalite lamps (no objective values are given). In summary, although there are few studies on correlated colour temperature, it does appear that higher illuminances are more arousing both cortically and behaviourally than lower illuminances. In addition to the possible effect of lighting on hedonic tone (e.g. from low positive affect to high positive affect), lighting may shift already positive states that can be described as calm or relaxed to more excited states or vice versa.

2.3 *Subjective impressions*

A number of investigators have suggested (implicitly or explicitly) that subjective responses to the environment are indicative of states of mood even though overt measurements of mood response have not detected this. For example, 'preference judgements are sometimes taken as a proxy for mood'[8]. This type of subjective response can be described as an 'affective appraisal'[5], which is a judgement of something as pleasant attractive, likeable, etc. Baron *et al.*[7] found that observers were more likely to ascribe terms like relaxing or pleasing to an experimental room when under warm rather than cool CCT conditions or under low rather than high illuminance. However, Boyce and Cuttle[16] found no effects of correlated colour temperature upon subjective impressions, but (within the range 30–600 lx) found higher illuminances rated as more pleasant and comfortable, whereas the lower illuminances were described as hostile. The authors warn that subjective impressions of correlated colour temperature may be affected by incomplete adaptation, depending on the conditions from which the observer is adapting. Again the issue of exposure to lighting appears critical. While Baron *et al.*[7] found more positive appraisals at lower illuminances, Boyce and Cuttle[16] found this occurring at higher illuminances. A comparison of illuminance levels in the two experiments showed that it was the mid-range illuminances that elicited most positive appraisals. This mid range may be the familiar range for pen-and-paper tasks, resulting in the 'mere exposure effect' — 'the more you see it, the more you like it'.

Other factors have been found to influence lighting effects on affective appraisals. Perhaps not surprisingly, the activity being performed influences appraisal[17], with participants preferring higher illuminances for reading tasks than for listening tasks. Gender also influences preferences, although the direction of the effect is not clear. Leslie and Hartleb[18] state that males prefer higher levels of illuminance than females, while Butler and Biner[17] found the opposite.

Against this confused background there are calls for more research in the area. As Baron[7] put it: 'further research is necessary to . . . determine the relative contribution of familiarity . . . of various lighting conditions themselves to affective reactions to indoor illumination'. There is also a need to investigate mood effects under less extreme illuminance levels, those that are commonly encountered in the range of practical artificial lighting conditions.

3 Method

3.1 *Experimental conditions*

Sixty-four participants (38 male and 26 female) from the university population were used in the study including postgraduate students, lecturers, administrators, librarians, students, and ancillary staff. The age range was from 24 to 65 years with an estimated mean of 37 years. The experimental laboratory contained two identical rooms that were mirror images of each other. Two subjects were tested simultaneously, one in each room. Each room measured 6.25 × 4.1 m with a 2.2 m high ceiling. The walls and ceiling were painted white and the windows were covered by shutters. Each room contained two desks, three chairs and posters and plants in identical positions in each room. The luminaires used were Philips TLD surface luminaires with p3 standard prismatic controllers, six in each room. The lamps used were Philips TLD 58w/colour 84 (cooler colour temperature) and Philips TLD 58w/colour 83 (warm colour temperature). The illuminance, colour temperature and uniformity measures are given in Table 1. All lamps were new and were operated for 30 min prior to the start of each experimental session to stabilise illuminance levels. Illuminance was varied by removing lamps from the luminaires, while correlated colour temperature was varied by changing the lamps. The lamp ballasts were of the conventional type.

3.2 *Procedure*

The experiment employed a fully randomised factorial design with repeated between-subjects measures across two illuminance levels, two CCT levels and two experimenters. The full sequence of experimental conditions was determined by a series of Latin squares across the independent variables. Mood was assessed using the Multiple Affect Adjective Checklist — Revised.[19] The MAACL-R scale (which contained 132 items) assesses five major components of mood: anxiety, depression, hostility, positive affect and sensation seeking. The MAACL-R has been shown to be a sensitive indicator of the effect of experimental or natural conditions upon mood[19] and has psychometric properties such as reliability and validity equivalent to other similar tests[21]. In addition, subjects evaluated the lighting and the room on a series of five bipolar point scales for liking, comfort, pleasantness, brightness attractiveness, clarity and warmth.

Participants were randomly assigned to one of the four lighting conditions and were tested on their own. The experimenters were unaware of which lighting condition was being tested and the subjects were unaware that the effects of lighting were being assessed at all. The reason given to subjects for carrying out the experiment was to gather data on a new computerised vision test and it was stated that as a break between tests some simple pen-and-paper psychological questions would be asked. This was done to reduce expectation effects, which are common in psychological testing and are reported to occur in lighting research[4]. Taking the focus off the main tasks of interest reduces the chance of subjects giving answers they think the experimenter wants. The experimental order was as follows:

(1) A 'dummy' computer vision test on contrast sensitivity[20]

(2) Mood assessment 1 (at 5 min)

(3) Simple decision tasks

Table 1 Summary of lighting conditions

Lighting condition	Colour temperature (K)	Average room illuminance (lx)	Desk illuminance (lx)	Uniformity ratio
1	3000	266.67	306.00	0.81
2	3000	807.74	731.25	0.80
3	4000	269.25	321.75	0.70
4	4000	821.00	749.50	0.72

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(4) Room appraisals

(5) Mood assessment 2 (at 40 min)

(6) Computer vision test (at different spatial frequencies from (1))

The time between the first and second mood assessments was approximately 35 min. The computer vision test took 5 min and the whole experiment 45 min. At the end of the experiment subjects were given a £4 book token and thanked for their efforts. The reward was advertised as part of the recruitment of subjects.

4 Results

The data were analysed by multivariate analysis (MANOVA) and univariate analysis (ANOVA) on each variable separately. As the psychometric properties of the MAACL-R mood assessment test have been assessed independently[21], the established subscales of the test (i.e. Anxiety, Depression, Hostility, Positive affect and Sensation seeking) and their simplified general combinations Dysphoria (an additive combination of Anxiety, Depression and Hostility) and PASS (an additive combination of Positive affect and Sensation seeking) were chosen as the dependent variables. Mean *t* scores on these scales for the experimental subjects showed the results were well within the normal range on the test. As a further check, a principal-component analysis followed by varimax rotation on mood assessment at time 1 confirmed the overall MAACL-R test structure in the current data. Two main factors emerged that accounted for 73.9% of the total variance, these being Dysphoria (Anxiety, Depression and Hostility, which accounted for 52.7%) and PASS (Positive affect and Sensation seeking, which accounted for 21.2% of total variance). (Factors with eigenvalues <1.0 were selected for inclusion and variables with loadings >0.7 were included for factor description.) The present data therefore compare favourably with the assertion of the creators of MAACL-R that Anxiety, Depression and Hostility correlate significantly and may represent subfactors of a larger Dysphoria (negative mood) factor and that Positive affect and Sensation seeking also correlate to warrant an additive scale of PASS.

Prior to the main analysis, a logarithmic transformation was performed to normalise the data. A multivariate analysis of variance that assessed all the mood variables simultaneously across all experimental conditions was carried out. Results showed that the only significant effect was the complex triple interaction term sex × illumination × CCT ($F = 2.32$, df $= 7{,}50$ $p<0.05$).

A univariate analysis assessing each of the dependent mood variables separately under each experimental combination was performed. This was carried out on mood data at time 1 and on the differences in mood data between time 1 and time 2. Results are given in Tables 2 to 7.

First, in Table 2 each of the five main mood variables and their two combined measures were assessed against the independent variables. For all measures at time 1 (i.e. 5 min into the experiment) there were main order effects, which are summarised in Table 3, but no significant interaction effects.

For example, Table 2 shows a highly significant gender effect (on Positive affect and its correlate PASS); a significant relationship between illuminance and Sensation seeking; and a significant relationship between CCT and negative mood, i.e. Hostility.

The directions of the influences as shown by the means in Table 4 were as follows.

(*a*) Females were significantly higher in positive affect than males.

(*b*) Sensastion seeking was significantly higher under low than under high illuminance.

(*c*) Hostility was significantly greater under the warm rather than under the cool CCT.

(*d*) Females had significantly higher Postive affect and Sensation seeking (PASS) than did males

In Table 5, representing change in mood between time 1 (after 5 min) and time 2 (after 40 min), there are both main order and interaction effects. These are summarised in Table 6 and the means of the differences values given in Table 7.

It is apparent that, while main order effects characterise the mood at time 1, the changes taking place in mood after 40 min in a room were more complex and involved mostly interaction affects. Furthermore, the significant changes in mood were all associated with negative mood and its elements. These are shown graphically below and are derived from the table of means in Tables 4 and 6.

The first two graphs (Figures 1 and 2) show a similar trend for both anxiety and hostility mood changes across illuminance and CCT. The measure of mood change on the vertical axis is mood at time 1 minus mood at time 2. Positive values of change therefore indicate a reduction in, say, hostility, while negative values of change indicate its increase. The results

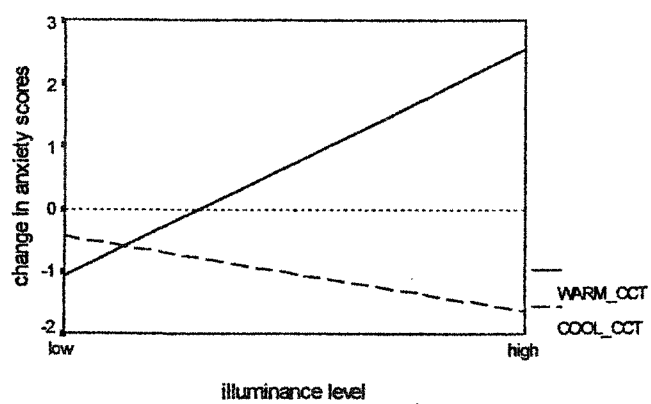

Figure 1 The effects of the interaction between illuminance and sex upon change in dysphoria scores

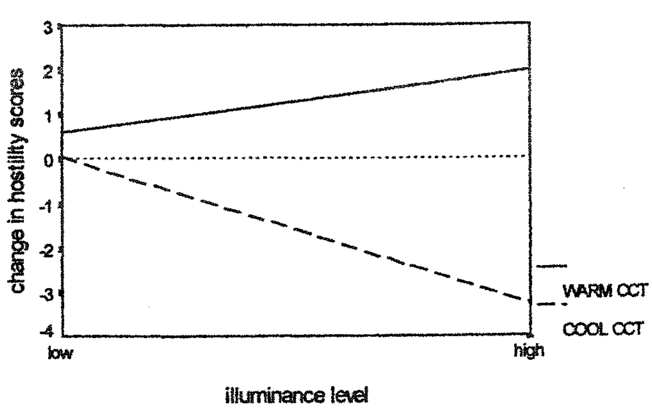

Figure 2 The effects of the interaction between sex and CCT upon change in hostility scores

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Table 2 Univariate analysis of mood at time 1

Variate: Positive affect (Pa)

Source of variation	df	*F*	*p*
Sex	1	9.14	0.004
Illuminance	1	0.13	0.723
CCT	1	0.04	0.841
Sex × illuminance	1	0.86	0.358
Sex × CCT	1	0.41	0.522
Illuminance × CCT	1	1.24	0.269
Sex × illuminance × CCT	1	2.83	0.098
Residual	56		
Total	63		

Variate: Anxiety (Anx)

Source of variation	df	*F*	*p*
Sex	1	0.68	0.413
Illuminance	1	1.53	0.221
CCT	1	3.08	0.085
Sex × illuminance	1	0.28	0.598
Sex × CCT	1	0.00	0.960
Illuminance × CCT	1	0.38	0.541
Sex × illuminance × CCT	1	0.01	0.944
Residual	56		
Total	63		

Variate: Depress (Dep)

Source of variation	df	*F*	*p*
Sex	1	2.28	0.137
Illuminance	1	0.46	0.501
CCT	1	2.68	0.107
Sex × illuminance	1	0.15	0.697
Sex × CCT	1	1.58	0.214
Illuminance × CCT	1	0.25	0.620
Sex × illuminance × CCT	1	0.45	0.504
Residual	56		
Total	63		

Variate: Dysphoria (Dysph)

Source of variation	df	*F*	*p*
Sex	1	1.20	0.278
Illuminance	1	1.23	0.273
CCT	1	3.66	0.061
Sex × illuminance	1	0.05	0.829
Sex × CCT	1	0.08	0.776
Illuminance × CCT	1	0.52	0.473
Sex × illuminance × CCT	1	0.08	0.783
Residual	56		
Total	63		

Variate: Sensation seeking (Ss)

Source of variation	df	*F*	*p*
Sex	1	2.35	0.131
Illuminance	1	4.49	0.038
CCT	1	0.22	0.641
Sex × illuminance	1	0.20	0.658
Sex × CCT	1	1.09	0.302
Illuminance × CCT	1	0.21	0.650
Sex × illuminance × CCT	1	0.42	0.520
Residual	56		
Total	63		

Variate: Hostility (Host)

Source of variation	df	*F*	*p*
Sex	1	0.17	0.679
Illuminance	1	1.01	0.318
CCT	1	4.88	0.031
Sex × illuminance	1	0.33	0.570
Sex × CCT	1	0.64	0.428
Illuminance × CCT	1	1.35	0.250
Sex × illuminance × CCT	1	0.26	0.610
Residual	56		
Total	63		

Variate: PASS

Source of variation	df	*F*	*p*
Sex	1	10.71	0.002
Illuminance	1	1.32	0.255
CCT	1	0.01	0.924
Sex × illuminance	1	1.95	0.168
Sex × CCT	1	0.69	0.409
Illuminance × CCT	1	1.17	0.285
Sex × illuminance × CCT	1	0.92	0.341
Residual	56		
Total	63		

Table 3 Significance levels for mood assessment at time 1

	Variable		
Mood measure	Illuminance	CCT	Sex
Positive affect (Pa)			0.004
Sensation seeking (Ss)	0.030		
Anxiety (Anx)			
Hostility (Host)		0.030	
Depression (Dep)			
PASS			0.002
Dysphoria (Dysph)			

Table 4 Table of mean mood scores (raw data transformed to logarithmic values)

Mood	Gender		Illuminance		CCT	
	M	F	Low	High	Low	High
Positive affect (Pa)	3.98	4.12	4.05	4.03	4.04	4.05
Sensation seeking (Ss)	3.92	3.86	3.93	3.84	3.88	3.90
Anxiety (Anx)	3.83	3.88	3.82	3.89	3.90	3.81
Hostility (Host)	3.83	3.85	3.82	3.66	3.87	3.81
Depression (Dep)	3.84	3.95	3.88	3.93	3.96	3.84
PASS	4.08	3.96	4.03	3.99	4.01	4.02
Dysphoria (Dysph)	3.80	3.87	3.81	3.87	3.90	3.78

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Table 5 Univariate analysis of mood differences between time 1 and time 2[a]

Variate: Pa1 − Pa2

Source of variation	df	F	p
Sex	1	1.04	0.312
Illuminance	1	0.10	0.759
CCT	1	0.06	0.804
Sex × illuminance	1	0.41	0.522
Sex × CCT	1	0.20	0.659
Illuminance × CCT	1	0.10	0.751
Sex × illuminance × CCT	1	2.42	0.126
Residual	56		
Total	63		

Variate: Anx 1 − Anx 2

Source of variation	df	F	p
Sex	1	0.73	0.397
Illuminance	1	0.27	0.607
CCT	1	4.46	0.039
Sex × illuminance	1	2.00	0.162
Sex × CCT	1	0.79	0.378
Illuminance × CCT	1	2.98	0.009
Sex × illuminance × CCT	1	7.10	0.001
Residual	56		
Total	63		

Variate: Dep 1 − Dep 2

Source of variation	df	F	p
Sex	1	0.03	0.868
Illuminance	1	0.31	0.580
CCT	1	0.93	0.339
Sex × illuminance	1	3.45	0.069
Sex × CCT	1	1.18	0.281
Illuminance × CCT	1	0.06	0.814
Sex × illuminance × CCT	1	2.36	0.130
Residual	56		
Total	63		

Variate: Dysph 1 − Dysph 2

Source of variation	df	F	p
Sex	1	0.43	0.514
Illuminance	1	0.54	0.464
CCT	1	3.07	0.085
Sex × illuminance	1	5.97	0.018
Sex × CCT	1	2.47	0.122
Illuminance × CCT	1	1.59	0.213
Sex × illuminance × CCT	1	1.64	0.205
Residual	56		
Total	63		

Variate: Ss − Ss2

Source of variation	df	F	p
Sex	1	0.23	0.631
Illuminance	1	0.80	0.374
CCT	1	0.08	0.785
Sex × illuminance	1	0.33	0.566
Sex × CCT	1	0.46	0.499
Illuminance × CCT	1	0.27	0.606
Sex × illuminance × CCT	1	0.68	0.413
Residual	56		
Total	63		

Variate: Host 1 − Host 2

Source of variation	df	F	p
Sex	1	0.00	0.969
Illuminance	1	0.50	0.482
CCT	1	5.70	0.020
Sex × illuminance	1	1.48	0.228
Sex × CCT	1	4.00	0.050
Illuminance × CCT	1	4.17	0.046
Sex × illuminance × CCT	12	0.93	0.339
Residual	56		
Total	63		

Variate: Pass 1 − Pass 2

Source of variation	df	F	p
Sex	1	1.50	0.225
Illuminance	1	0.00	0.975
CCT	1	0.01	0.934
Sex × illuminance	1	0.03	0.871
Sex × CCT	1	0.62	0.435
Illuminance × CCT	1	0.03	0.860
Sex × illuminance × CCT	1	0.62	0.435
Residual	56		
Total	63		

show an increase in anxiety and hostility at high illuminances for cool CCT lamps. At the same time the levels of anxiety and hostility are reduced for warm CCT lamps at high illuminance. Figure 3 shows a significant interaction between colour temperature and gender. Females' negative mood (i.e. hostility) decreased in warm and increased in the cool white light source, while the male response is similar under both light sources. The result for females is similar to that found by Knez[8], while the similar response by males contrasts with his findings of an increase in males' negative mood under the warm CCT condition. Finally, Figure 4 shows a reduction in general negative mood (i.e. dysphoria) at high illuminance levels for females but an increase in negative mood for males under higher illuminance.

All subjects assessed the room on first entering it on a set of 5-point bipolar semantic scales for liking pleasantness, attractiveness, comfort, brightness, clarity, glare, warmth. t-Tests showed no significant differences across any of the scales with either illuminance or CCT. The only exception was the rating of brightness with illuminance ($F = 7.68$, df = 1,63, $p<0.01$). A factor analysis (with varimax rotation) of the room and lighting appraisals produced just two factors accounting for 66% of the variance (see Table 8). Factor 1 appears to be a general evaluation factor including judgements such as attractiveness, comfort, liking, pleasantness and warmth while factor 2 is a brightness and clarity factor. Of interest is the observation that the aesthetic judgement of attractiveness is independent of appraisals of brightness, whereas pleasantness

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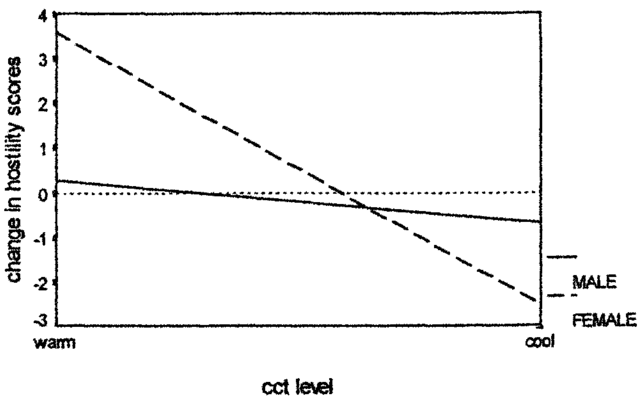

Figure 3 The effects of the interaction between illuminance and CCT upon change in hostility scores

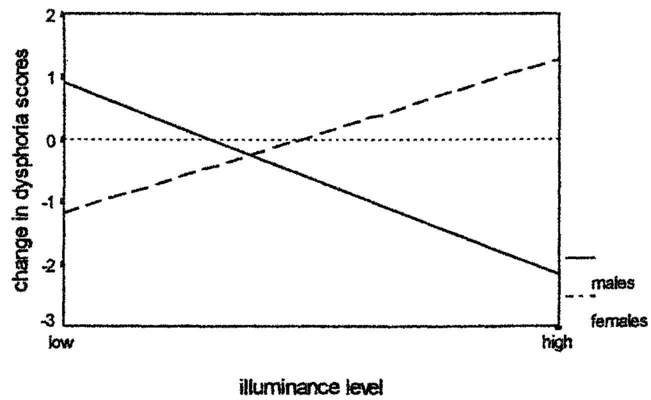

Figure 4 The effects of the interaction between illuminance and CCT upon change in anxiety scores

Table 6 Significance levels for mood difference ($T_1 - T_2$)

Mood	Source of variation						
	Illuminance	CCT	Sex	Sex × illuminance	Sex × CCT	Illuminance × CCT	Sex × illuminance × CCT
$Pa_1 - Pa_2$							
$Ss_1 - Ss_2$							
$Anx_1 - Anx_2$						0.05	0.01
$Host_1 - Host_2$		0.02			0.05	0.04	
$Dep_1 - Dep_2$							
$Pass_1 - Pass_2$							
$Dysph_1 - Dysph_2$				0.01			

Table 7 Mean mood scores for difference in mood for ($T_1 - T_2$)

Mood	Gender		Illuminance		CCT	
	M	F	Low	High	Low	High
$Pa_1 - Pa_2$	0.31	−1.29	−1.01	−0.27	−0.38	−0.90
$Ss_1 - Ss_2$	−8.40	−6.30	−6.30	−8.00	−7.40	−6.90
$Anx_1 - Anx_2$	0.50	−0.58	−0.72	0.44	0.88	−1.16
$Host_1 - Host_2$	−0.15	−0.13	0.35	−0.63	1.37	−1.65
$Dep_1 - Dep_2$	0.20	1.90	2.20	0.20	2.70	−0.30
$Pass_1 - Pass_2$	0.35	−1.34	−0.67	−0.65	−0.69	−0.63
$Dysph_1 - Dysph_2$	0.15	−0.55	0.15	−0.68	0.93	−1.46

Table 8 Factor structure of room appraisals following varimax rotation

	Factor 1	Factor 2
Brightness	0.02	0.82
Attractiveness	0.86	0.02
Clarity	0.16	0.78
Comfort	0.76	0.19
Liking	0.71	0.36
Pleasantness	0.80	0.35
Warmth	0.67	−0.22
Total variance accounted for = 66%		

and liking are moderately loaded on the second factor (0.36 and 0.35, respectively).

5 Discussion

The experimental work reported in this paper has demonstrated that there are systematic influences of lighting on mood from lighting parameters within the range of those encountered in everyday interior conditions. The nature of the lighting effect is complex and is best summarised under two separate headings, initial effects and longer-term effects.

5.1 *Initial effects*

When assessments of mood are made within 5 min of first entering a room, there are two main order effects and no interactions. The main effect of illuminance is on the mood variable of Sensation seeking. Sensation seeking is significantly higher under lower than under higher illuminance. That Sensation seeking would be influenced by an illuminance change from 280 to 770 lx was not hypothesised and is a novel finding. The described shift is, however, in the direction anticipated from previous work on arousal[2]. The main effect of CCT relates to the negative mood of hostility, which was significantly higher under the warm than under the cool CCT condition. Finally, there were clear gender differences in Positive affect, with females being significantly higher in positive aspect than males, and in the general positive mood assessment of PASS (i.e. Positive affect and Sensation seeking).

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5.2 *Longer-term effects*

When mood assessments were made after a period of over 30 min in the room, complex interactions between the lighting parameters and the mood subscales were present. The overall characteristic of the change that had taken place was that it was confined to negative aspects of mood only. The fact that there were no differences in mood assessment between time 1 and time 2 on Positive affect or Sensation seeking meant that the effects recorded at time 1 were still in place. However, measures of Anxiety and Hostility and the composite negative mood measure Dysphoria showed complex interactions with gender, illuminance and CCT as can be seen from Figures 1 to 4. Lighting effects on Sensation seeking therefore appear more stable across a 45 min period, while negative mood changes appear to be more complex and volatile.

The overall picture presented here of a two-stage influence of lighting on mood is consistent with an explanation of environmental effects put forward by Küller[22]. Küller suggested two mechanisms for mood change linked to notions of phasic and tonic arousal. Phasic arousal is an initial response to an environmental setting, while tonic arousal is a longer-term habituation effect. There is, of course, no way of knowing whether the structure of the interaction effects within the experimental period of 45 min subsequently changes over longer periods; only longitudinal studies would determine this. Secondly, with regard to the initial effects, there is a general explanation of mood effects due to discrepancies between stored expectations in memory and current information input[23]. Purcell[23] hypothesised (and subsequently provided supportive evidence) that there is an emotional component directly linked to these discrepancies. When the discrepancy is minor, there is a positive hedonic response; but as the discrepancy increases, there is an increasingly negative emotional response. It is interesting to note that the experimental subjects were taken to the laboratory via an external walk during the period between 12.00 and 14.00 during the working day. Whatever the weather conditions, the sky illuminance and CCT, the results show that it is the greater difference from the exposure conditions (i.e. daylight) that resulted in greater sensation seeking or greater negative mood. Purcell's hypothesis is closely linked with prior expectations and these are of course unknown for the experimental subjects. None the less, the subjects were told they would be taken to an 'office-like' room. Furthermore, the higher experimental values of illuminance and CCT were closer to the norm for offices than the lower illuminance, which was deliberately set at the lower limit of acceptability. On these grounds, therefore, the lower settings exaggerated by the high pre-exposure conditions would be the more deviant office settings from normal expectations.

As mentioned above, it is under the lower illuminance that sensation seeking (a correlate of arousal) is highest. For the MAACL-R many items used to measure sensation seeking might be interpreted as arousal. The behavioural consequence of this is that risk-taking (associated with arousal) may be increased under lower illuminances. While sensation seeking is not the same as positive mood, the creators of the MAACL-R report that the two mood types correlate significantly[20], and this is borne out by the factor structure in which Positive affect and Sensation seeking load on the same factor. Therefore, although direct measures of Positive affect were not affected by illuminance, correlates of Positive affect were affected. This is in keeping with the finding of other studies that lower illuminance leads to more positive hedonic tone[6,7].

Following the work of Knez[8], it was hypothesised that CCT may be implicated in mood differences. In Knez's study there were interactive effects of CCT with illuminance and sex of subject to influence negative mood. In the present study, there are again similar interactive effects between illuminance, CCT and gender to influence negative mood. This replication of general negative mood shifts with lighting is worth noting. The direction of the hostility shifts for females is exactly that reported by Knez[8]. However, the present study did not confirm the increase in negative mood for males. Behavioural consequences from increased negative mood are difficult to assess. In particular because of the ethical problems inherent in inducing unpleasant moods, experimentally there is very little literature regarding the consequences of temporary increases in negative mood state. However, where negative moods have been assessed, they have been shown to induce more stereotypic thinking in social judgements[24] and to influence confidence and self esteem[25], risk estimations for unpleasant events[26] and even willingness to pay for insurance[27]. Of course, the degree of negative mood induced is critical to whether any of these behaviours would be affected.

It is important to emphasise that the mood effects present in this study occurred under moderate differences in illuminance and CCT that were well within the ranges normally encountered in artificially lit environments. Direct effects of illuminance or CCT on positive mood that have been reported in other studies, but that were only indirectly supported here, may depend on greater illuminance and CCT differences. Indeed, most experiments (e.g. Baron[2]) in which a shift in positive mood occurred had similar low illuminance levels but employed high illuminances in excess of 1500 lx. The initial impact of an environment and the pre-exposed conditions requires further investigation. In addition, the role of expectations at the initial stage needs to be considered. The second-stage mood changes, with their complex interactions, point to the need for new longitudinal studies in which mood is monitored over considerably longer time intervals.

Finally, the results from the experiment did not support the notion that an affective appraisal must occur as a precursor to lighting-induced mood effects. No differences in 'aesthetic' ratings (i.e. attractiveness) were observed between any of the lighting conditions despite the occurrence of mood effects. This is relevant for further research in the area, as appraisal studies have routinely been used as a proxy for mood measurement.

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