

# Changes in Females' and Males' Positive and Negative Moods As a Result of Variations in CCT, CRI and Illuminance Levels

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## ABSTRACT

Knez (1995a) reported two experiments on the indirect, non-visual, psychological effects of the office lighting which varied correlated colour temperature (CCT), colour rendering index (CRI), illuminance and gender – in a factorial, between-subject, experimental design (Kirk, 1968). The separate analyses of these experiments did not, however, enable a conclusive interpretation of the CRI parameter's impact on subjects' emotional state. As a follow-up analysis, the present paper synthesised statistically the experiments reported in Knez (1995a) into one experiment. This revealed several new results, showing a combined impact of the CCT, CRI and illuminance parameters on females' and males' positive and negative mood.

## INTRODUCTION

Do people respond emotionally to luminous milieu? In other words, can indoor lighting change a person's mood? Sixteen years ago, in his now classical book *Human Factors in Lighting*, Peter Boyce (1981) pointed out, at that time, rightly that there were no reliable experimental data indicating such an indirect, non-visual effect. Indeed, even though some studies have recently revealed non-visual effects of lighting on intellectual performance and communication (Baron, Rea and Daniels 1992; Gifford, 1988), others have not been successful in demonstrating for example a direct impact of artificial light on mood (Baron et al 1992; Boray, Gifford and Rosenblood 1989).

Knez (1995a) outlined an experimental, psychological research on the non-visual effects of indoor lighting. The duration of the lighting exposure was set to two hours and the subjects' moods were measured in the beginning and

at the end of this exposure, as well as the performance on several intellectual tasks between the mood-measures. The experiments were run in an office-like climatized room where the noise and air temperature levels were controlled by a computerised system. Moreover, high-frequency control of the luminous flux was applied. The subsequent experiments revealed an impact of general ceiling-mounted lighting on persons' intellectual performance and emotional state. Interestingly, the effect of artificial light on subjects' psychological entities was shown to vary generally with the CCT (3000K vs. 4000K) and gender (Knez 1995a; Knez and Enmarker in press), and the CCT and age of the subjects (Knez and Kers 1997).

The first two experiments within the present approach were reported in Knez (1995a). They employed a factorial, between-subject, experimental design (Kirk 1968) where two key parameters of lighting (illuminance levels: 300lux vs. 1500lux by two CCTs: 3000K vs. 4000K) and gender were varied. Furthermore, in experiment 1 the illuminance and CCT levels were applied at a high CRI (95) and at a low CRI (55) in experiment 2. In general, the results revealed a two-way interaction between CCT and gender on mood and intellectual performance. More precisely, in experiment 1 the CCT which generated the *least negative* mood in each gender (3000K for females and 4000K for males) accounted for the intellectual performance enhancement in each gender respectively. In experiment 2, on the other hand, the CCT which produced the *best preservation of positive* mood yielded the same effects as in experiment 1.

What was the difference between these experiments? They were identical in all aspects, except for the different

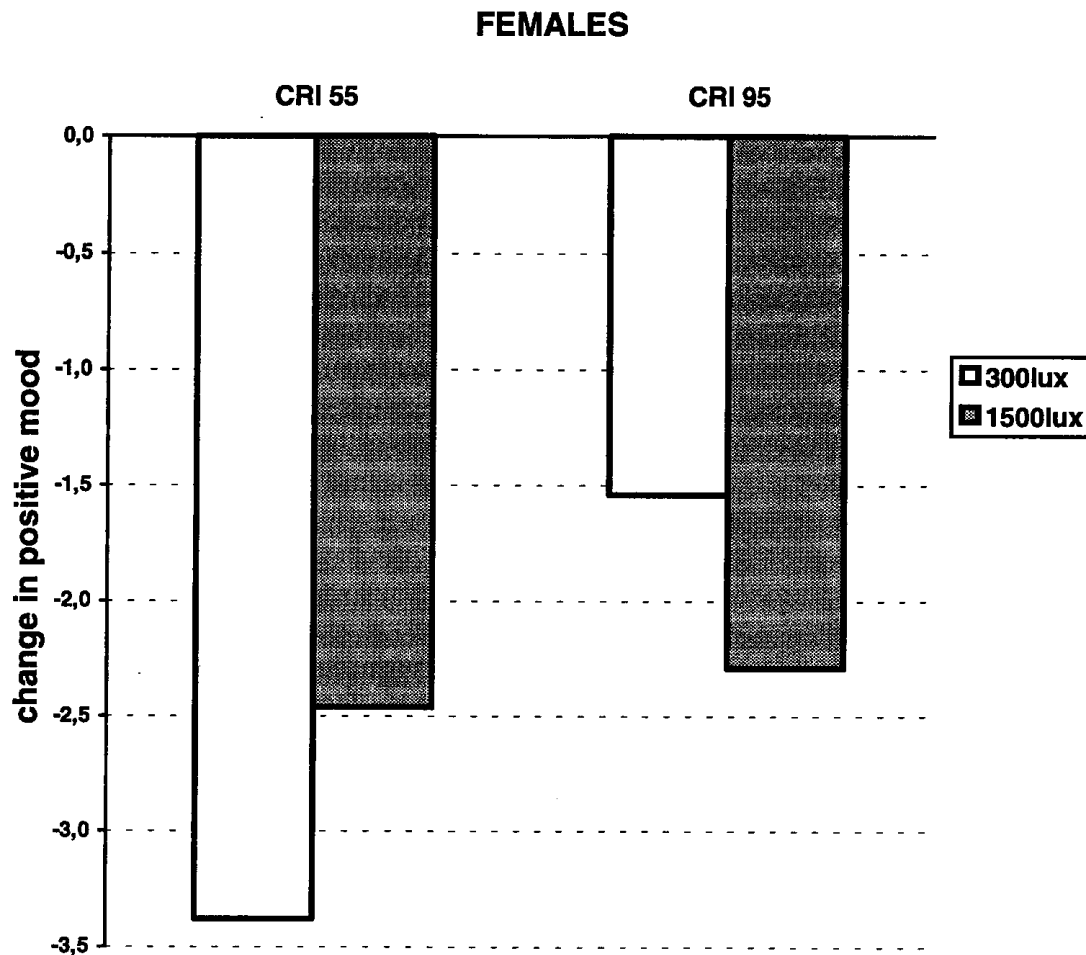


Figure 1: Mean change in positive mood in females, in 300lux and 1500lux lighting as a function of low and high CRI.

levels of the CRI. This brings the objective of the present paper; namely, a follow-up statistical analysis of the two experiments reported in Knez (1995a) yielding *one* large experiment. Strictly speaking, in contrast to Knez (1995a) two separate experiment analyses, this synthesised statistical arrangement enables a far more conclusive analysis and interpretation regarding the non-visual impact of all three parameters of indoor lighting.

It must be noted that the attention is focused on the earlier *not*-reported data on the effects of the general, ceiling-mounted office lighting on positive and negative mood in women and men. Especially those involving the CRI. Previously, this parameter has been addressed mostly in relation to the colour discrimination task performance (see Boyce 1981 for a review) and the development of the adequate colour rendering indices (Embrechts 1984; 1985; Halstead 1976; Opstelten 1980; Seim 1985; Schanda 1985; Xu 1983). Consequently, more research is needed to examine the behavioural effects of the CRI parameter.

#### METHOD

##### Subjects

One hundred ninety-two subjects participated. They were randomly assigned to eight luminous settings with twelve females and males in each. Subjects aged from 18 to 55 and were paid approximately 30 US dollars to participate. They were recruited through advertisements in a local

newspaper and radio.

##### Environmental Setting

Subjects worked in a climatized room (3.9m X 3.8m X 2.5m). The walls and ceiling were off-white, and the floor had grey trailing patterns on its surface. The air temperature and humidity were controlled by a computerised climate system. This experimental room was furnished as a *neutral* office as regards the decor and colour. It had two false windows with green curtains, and a big green plant was placed in front of the subjects in a corner. Furthermore, a personal computer (PC) was placed in front of the subjects (on which one of the intellectual tasks was run).

##### Apparatus

Six ceiling-mounted fluorescent luminaries containing four fluorescent tubes each were installed. The *eight* indoor lighting milieus were constituted by two illuminance levels by four different types of tubes: (1) General Electric, 36W, F36/29, 2950K, CRI 55; (2) Osram, 36W, L36/32, 3000K, CRI 95; (3) General Electric, 36W, F36/33, 4200K, CRI 58; (4) Osram, 36W, L36/22, 4000K, CRI 95.

The CCT and CRI were varied by changing the tubes and the illuminance level was varied by using two or four tubes in each luminary combined with high-frequency control of the luminous flux. The illuminance level was measured on the subjects' tables (horizontal surface) by a

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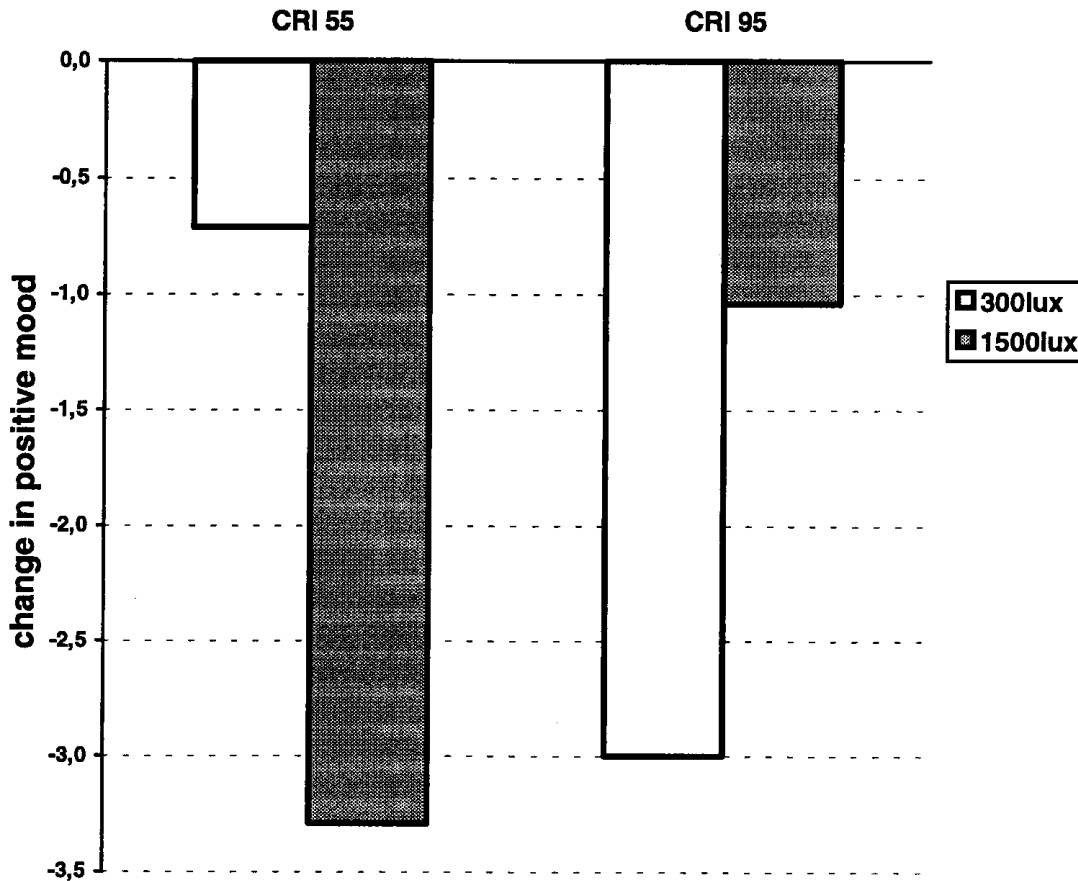


Figure 2: Mean change in positive mood in males, in 300lux and 1500lux lighting as a function of low and high CRI.

Hagner Luxmeter (Model E2). All the lamps were new and were on for two weeks before the experiments started. Furthermore, before each experimental session the lamps were turned on for 20-30 minutes in order to stabilise the illuminance level.

### Experimental Design

The *combined* experiment analysis employed a factorial, between-subject design (Kirk, 1968) with four independent variables: 2 CCTs (approximately 2975K vs. 4100K - henceforth labelled 3000K vs. 4000K) X 2 illuminance levels (300lux vs. 1500lux) X 2 CRIs (approximately 54.5 vs. 95 - henceforth labelled 55 vs. 95) X 2 gender (females vs. males).

### Dependent Measures

Knez (1995a) experiments comprised six tasks, namely: Four intellectual (cognitive) tasks, a self-rating mood measure and a room light evaluation questionnaire. The results concerning the cognitive and the room light evaluation tasks have already been reported and discussed in Knez (1995a; 1995b). As mentioned in the introduction section, only the mood measure and the data in regard to this task and the CRI parameter will be described in this paper.

### Procedure

Subjects were told that their general task was to participate

in an investigation concerning peoples' intellectual performance. They were also informed that they would receive instructions at the outset of each new task and a time limit to accomplish the task. The time limit was very generous, and was applied in order to implement an even-time-light-exposure across subjects and lighting conditions. The experiments lasted for approximately two hours and two to four subjects were run at each session (see Knez 1995a for more details).

## RESULTS

### Mood Measure

At the outset of the experiment and after approximately 80 minutes of artificial light exposure and intellectual work (which also affected, regardless of the lighting, the subjects' moods - see Knez and Enmarker in press & Knez and Kers 1997 for this discussion), the subjects completed a self-rating mood measure developed by Watson, Clark and Tellegen (1988). It comprises two mood dimensions, a positive and a negative. They are orthogonal (independent, not correlated) and incorporate 10 adjectives (item-dimensions) each. Ratings were made on a 5-point scale (from 1 "little or not at all" to 5 "very much") related to the question: "How do you feel now?". According to Watson et al (1988 p. 1063) the positive mood dimension "...reflects the extent to which a person feels enthusiastic, active and alert..." and the negative mood dimension..."is a general

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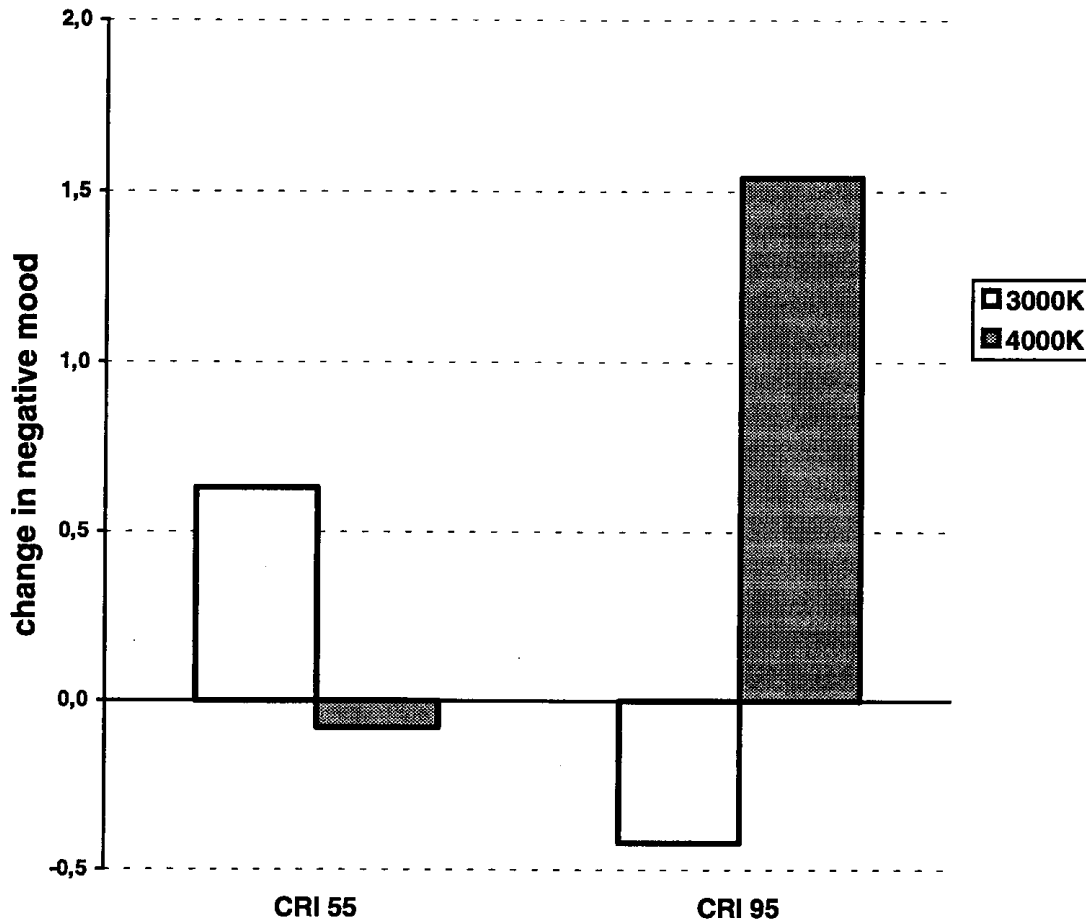


Figure 4: Mean change in negative mood in males, in 3000k and 4000k lighting as a function of low and high CRI.

dimension of subjective distress and unpleasurable engagement that subsumes a variety of aversive mood states". Finally, an univariate analysis of variance (ANOVA) was computed on subjects' *delta* mood scores (*a change* = how they felt at the end minus how they felt in the beginning of the light exposure).

### Positive Mood

A three-way interaction between gender, illuminance and CRI ( $F(1,176) = 6.47, p < 0.01$ ) showed that, for females the lighting condition that accounted for the best preservation of positive mood was the 300lux illuminance at high CRI, and the worst condition was the 300lux lighting at low CRI. Furthermore, the 1500lux lighting at both CRI levels affected similarly positive mood in females (see Figure 1).

As can be seen in Figure 2, for males, on the other hand, the 300lux lighting at low CRI and 1500lux lighting at high CRI accounted for the best preservation of positive mood.

### Negative Mood

A three-way interaction between gender, CCT and CRI ( $F(1,176) = 6.36, p < 0.01$ ) showed that at low CRI, for females the 4000K lighting accounted for a decline in negative mood and the 3000K lighting accounted for an opposite direction of the negative mood production. At the high

CRI level, however, the opposite result was obtained. That is, the 3000K lighting decreased and the 4000K lighting increased the negative mood in females (see Figure 3).

As can be seen in Figure 4, for males no change in negative mood was registered between the CCTs at low CRI. However, at high CRI the 4000K lighting induced less change in negative mood than the 3000K lighting did.

### CONCLUSIONS

The main objective of this paper was to perform a detailed follow-up statistical analysis of the two experiments reported in Knez (1995a) by analysing these two experiments as one large study. Thus, to enable, for example, an investigation of the CRI parameter's effect on positive and negative mood in women and men. The results revealed several not previously shown, combined effects of CCT, CRI and illuminance on females' and males' moods.

According to the positive mood results, for females the most optimal lighting combination in preserving that mood over a period of 80 minutes intellectual work was the 300lux at CRI 95 lighting (see Figure 1). For males, on the other hand, the 300lux by CRI 55 and 1500lux by CRI 95 lightings accounted for a similar effect (see Figure 2). As regards the negative mood, for females the 3000K increased and the 4000K decreased this mood at CRI 55 level. However, the opposite relation was yielded at CRI

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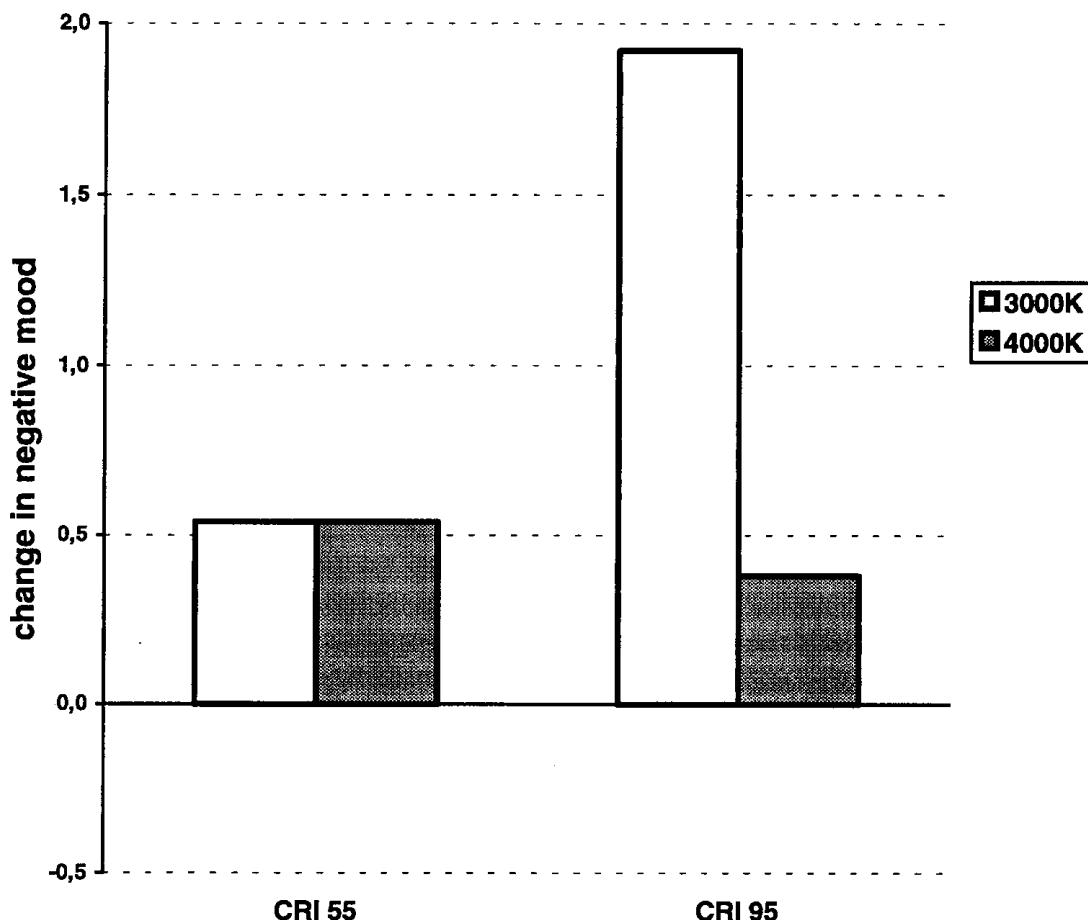


Figure 3: Mean change in negative mood in females, in 3000k and 4000k lighting as a function of low and high CRI.

95 level (see Figure 3). Finally, the 3000K lighting at CRI 95 induced the highest amount of negative mood in males (see Figure 4).

In sum, the reported results together with Knez (1995a), Knez and Enmarker (in press) and Knez and Kers (1997) findings provide an empirical basis for the indirect, non-visual, psychological effects of the indoor, general, ceiling-mounted lighting. In addition and as noted elsewhere (Knez 1995b; Knez 1996; Knez 1997) all this emphasises the importance of the *colour parameters* in the design of office lighting as related to an occupant's *individual*, psychological lighting-demands. ●

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