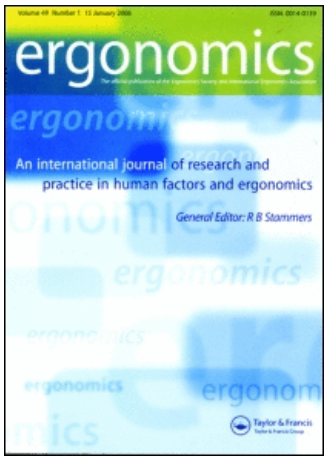

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The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments

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The aim of the study was to determine whether indoor lighting and colour would have any systematic impact on the mood of people working indoors. Earlier studies have mostly focused either on light, colour or windows in laboratory settings. The present study was carried out in real work environments at different seasons and in countries with different latitudes. A total of 988 persons completed all parts of the study. In the countries situated far north of the equator there was a significant variation in psychological mood over the year that did not occur in the countries closer to the equator. When all four countries were considered together, it became evident that the light and colour of the workplace itself also had an influence on the mood of persons working there. The workers' mood was at its lowest when the lighting was experienced as much too dark. The mood then improved and reached its highest level when the lighting was experienced as just right, but when it became too bright the mood declined again. On the other hand, the illuminance as measured in objective terms, showed no significant impact on mood at any time of the year. The relationship between mood and the distance to the nearest window was bimodal. The results also indicate that the use of good colour design might contribute to a more positive mood. It is suggested that in future research light and colour should be studied as parts of the more complex system making up a healthy building.

Keywords: Artificial lighting; Daylight; Interior colour; Psychological mood; Windows; Work environments

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1. Introduction

The effects of light acting via both retinal and extra-retinal routes indicate the great variety and complexity of its impact beyond the phenomena of vision, including, on one hand, effects on mood and behaviour and, on the other, physiological effects on autonomic arousal and hormones (for reviews, see Stone 1999, Küller and Küller 2001, Veitch *et al.* 2004). The main aim of the present study was to determine whether indoor lighting and colour would have any systematic impact on the mood of people working indoors.

Differences in the indoor lighting environment (levels, spectral distribution, temporal patterns, etc.) do seem to affect people in various ways. Daurat *et al.* (1993) found that subjects reported a more positive mood under 2000 than under 300 lux. Belcher and Kluczny (1987) proposed a model in which mood, visual performance and decision-making strategy are affected by the visual environment and compete for mental processing capacity. The mood shift for women was strongly negative for 'bright' conditions and near zero for 'dim' conditions, whereas men tended to respond in the opposite direction. Knez and Kers (2000) found that age and gender interacted with the illuminance and the colour temperature of the lighting, causing different kinds of mood shifts. McCloughan *et al.* (1999) showed the existence of systematic influences on mood from lighting parameters within the range encountered in everyday interior conditions. On the other hand, studies of the impact of full-spectrum lighting on mood have given controversial results (Boray *et al.* 1989, Baron *et al.* 1992, Küller and Wetterberg 1993, Rusak *et al.* 1996, Veitch and McColl 2001).

There is some evidence that the colours of an interior space might influence the psychological mood of individuals in that space (Küller and Mikellides 1993). Lightness, hue and saturation might be of importance, as might the combination and distribution of the colours in the interior space. A number of studies have compared the impact of 'warm' and 'cool' colours (e.g. reds and blues) (Stone 2001, 2003). Letting his participants work in either a red or a blue office space, Janssens (2000) found an interaction between psychological mood on one hand and performance on the other. Comparing nine monochromatic office colours, Kwallek *et al.* (1996) found that saturation was a salient predictor of differences in mood between males and females.

One outstanding relationship between daylight and mood is the prevalence of seasonal affective disorder (SAD) in countries far from the equator during the dark season. Amongst the well-known symptoms of SAD are reduced activity, social withdrawal and changes in mood, such as increased sadness (Küller 2002). The results of several epidemiological studies indicate the existence of seasonal variations in psychological mood, the respondents generally 'feeling worst' during autumn and winter (Kasper *et al.* 1989, Harris and Dawson Hughes 1993, Eagles *et al.* 1997). Thus, depending on the latitude, season, weather conditions and distance to windows, the occupants might respond differently to indoor lighting. Furthermore, most studies show that people prefer to work in environments with windows and that lack of windows and a view to the outside may have a negative impact on well-being and performance (Küller and Wetterberg 1996). There are, however, very few studies of the impact of windows on psychological mood and the little there is has been inconclusive (Tennessen and Cimprich 1995, Stone 2003).

2. Problem

Most of the studies cited above have focused on light, colour or windows in laboratory settings. Even if some of these studies involved highly elaborate experimental designs and

measurements, it was felt appropriate to consider all these visual factors simultaneously under realistic working conditions and over a prolonged period of time. In order to ensure the validity of the outcome, the study was carried out in a number of countries situated at different latitudes.

In the present study it was hypothesized that dark and/or windowless, indoor spaces and lack of colour will have a depressing influence on the mood of people in those spaces. It was further hypothesized that the seasonal variations in length of day may modify the mood of people working indoors, with a negative impact during the dark season, and that the impact on mood might be mediated by individual characteristics, such as age and gender.

3. Method

3.1. *Participants, settings and climatic conditions*

The study was part of an international project carried out in real work environments at different times of the year in four different countries with different latitudes (Argentina, Saudi Arabia, Sweden and the UK). Employees at a number of larger, as well as smaller, indoor work environments (offices, schools and industrial premises) were included in the study. The sampling criteria included male and female personnel generally working at least three-quarters of full time, during daytime. Night-shift workers were excluded and so were those with previous records of prolonged illness. A total of 988 persons (468 females and 520 males) aged 18 to 65 years completed all parts of the study (mean 39.4 SD 9.85 years), (table 1).

The Swedish sites were situated in the southern part of the country (56° N), where the length of day varies between 7 h during winter and more than 17 h during summer. In the UK the sites were in the southern part (52° N) with a length of day that varies between 8 h in winter and more than 16 h in summer. In Saudi Arabia, the sites were in the Greater Dammam area, by the Arabian Gulf in the eastern part of the country (26° N). The length of day varies from 10.5 h in winter to almost 14 h in summer. In Argentina, the study was carried out in Tucuman in the northwestern part of the country (27° S). The length of day varies between 10.5 and almost 14 h. The difference in day length between summer and winter varied from more than 10 h in Sweden to only 3.5 h in Argentina and Saudi Arabia.

3.2. *Procedure*

A questionnaire consisting of seven or eight pages was used in this study. Most of the scales had been pre-tested in a pilot study at three Swedish hospitals. The questions were originally drafted in English, then translated into Swedish, Arabic and Spanish and

Table 1. Number of participants and dropout.

Country	Approached (n)	Took part at least once (n)	Initial dropout (%)	Took part on all occasions (n)	Lost in follow-up (%)
Argentina	308	303	2	222	27
Saudi Arabia	369	324	12	253	22
Sweden	661	609	8	406	33
UK	239	229	4	107	53

re-translated to English for a final check. In Saudi Arabia, both English and Arabic versions were used. The questionnaires were administered to the participants on five different occasions during one of 2 consecutive years, including both the light and dark seasons. In Sweden, the UK and Saudi Arabia the data collection took place in the middle of September, December, February, April and June, whereas in Argentina the corresponding months were March, June, August, October and December. Great care was taken to avoid vacations and religious holidays, as well as shifts between standard time and daylight saving time. With regard to the provision of siestas in Saudi Arabia and Argentina, all participants were requested to answer the forms at 11.00 hours and because the answers should reflect the conditions at work, Tuesdays and Wednesdays were selected as alternative days. If for various specified reasons a participant was not well or fit, the form could be answered 1 week later. Indoor lighting was measured at each workplace. Additional information was obtained from meteorological data.

3.3. *Self-reported mood*

Based on concepts brought from neuro-psychology, the emotional well-being of the participants was assessed with the following 12 scales: rested/tired; alert/drowsy; awake/sleepy; interested/bored; efficient/inefficient; devoted/indifferent; secure/anxious; friendly/angry; happy/sad; confident/hesitating; independent/dependent; strong/weak (Küller 1991). Each of the four-grade rating scales was to be answered in terms of 'How did you feel most of the time during the last few days?' The scales were combined into a total index of emotional status (coefficient $\alpha = 0.82$).

3.4. *Appraisal of the visual environment*

The current lighting conditions in the workplace were assessed by the participants on a four-graded scale including the following steps: 1) clearly insufficient, much too dark; 2) slightly insufficient, a little bit too dark; 3) just right, neither too bright nor too dark; 4) very bright and glaring, too much light (between seasons consistency coefficient $\alpha = 0.82$). The interior decoration was assessed on a similar scale including the steps: 1) no colour at all, very subdued and monotonous; 2) colours are rather neutral; 3) some colour but not very vivid; 4) very colourful and vivid (between seasons consistency coefficient $\alpha = 0.86$). In addition, the subjects estimated the physical distance from their workplace to the nearest window.

3.5. *Measurements of indoor lighting*

Physical light measurements in terms of horizontal illuminance values (lux) were carried out with calibrated luxmeters in the rooms or spaces where the subjects worked. The measurements, which were carried out around noon with a clear or light overcast sky, were functionally related to the subject's work site, that is, if the person normally was sitting at a desk, the luxmeter was placed on the desktop in front of the person. The artificial illumination was generally left on, provided this was normal for that time of the year. However, all kinds of desktop lamps were turned off during measurements.

3.6. *Meteorological data*

Length of day was computed from sunrise to sunset for each region at five times of the year corresponding to the times of data collection.

3.7. *Statistics*

The data were treated by means of parametric statistical tests such as Pearson correlation and ANOVA (Norusis and SPSS Inc. 1993). The data treatment was based on those participants who took part on all five occasions. In analyses related to the impact of age, the participants were partitioned into two groups of equal size, younger (18–38 years) and older (39–65 years). The data from the Argentinean study were recoded in order to correspond to the data from the northern hemisphere. Due to the large number of comparisons the statistical level of acceptance was set to $p = 0.01$.

As a special precaution, the partial dropout group was compared in a number of respects to those who completed the study. Out of a total of 17 statistical comparisons, including age, gender and emotionality, none reached the stipulated significance level. Amongst those who completed the study missing values on the separate scales generally amounted to less than 1/1000 in Saudi Arabia and Sweden, 3/1000 in the UK and 1/100 in Argentina. These missing values were replaced by total mean or median values in a conservative way in respect of the various hypotheses.

4. Results

The indoor environments in the vast majority of cases consisted of cell offices and open-plan offices, illuminated by fluorescent lamps, and most of the personnel worked with visual display units. In addition there were some factory plants with large open areas lit by high-pressure sodium lamps. The distance between the individual workplace and the nearest window varied from less than 0.5 to 100 m with a median value of 2.0 m (table 2).

The indoor illuminance values were mostly higher during the summer than the winter months (table 3). Deviations from this pattern generally depended on the use of curtains and other shading devices in order to avoid excessive heat and annoyance from direct sunlight. This was specially so in Argentina, where illuminance was often lower than the values recommended by the common standards for office tasks, that is, 500 lux.

Table 2. Distance from workplace to nearest window (n = 988).

Distance (m)	0–1.0	1.1–2.0	2.1–5.0	5.5–10	11–100
Work sites (%)	28.5	25.0	25.4	9.6	11.5

Table 3. Illuminance values (lux) at workplaces during different seasons.

Country		February (August)*	April (October)*	June (December)*	September (March)*	December (June)*
Argentina	Mean	309	316	368	265	277
n = 222	SD	135	145	183	95	134
Saudi Arabia	Mean	429	487	534	345	420
n = 253	SD	211	236	272	167	302
Sweden	Mean	643	658	751	621	465
n = 406	SD	170	269	276	188	92
UK	Mean	579	869	517	572	364
n = 107	SD	74	419	190	94	57

*The corresponding month in Argentina.

In 2% of all responses the participants experienced the lighting conditions at their workplace as much too dark, whereas in 15% they were considered a little too dark, in 74% as just right and in 9% as too bright. About 14% thought the colours were very subdued, 60% considered them to be neutral, 22% reported some colour and 5% thought their workplace was very colourful. The inter-correlations between the different estimates of the visual environment were mostly low. There was a modest negative correlation between workplace illuminance and the distance to the nearest window, which varied between $r = -0.18$ and $r = -0.27$ for the different occasions ($n = 988$, $p < 0.01$). The correlation was most pronounced during the summer season.

Before looking into the major hypotheses, a multivariate ANOVA with repeated measures (occasion) was carried out with gender, age and country as grouping factors, and with the emotional responses of the participants as the dependent variable. There were minor differences between males and females ($F(1, 972) = 6.72$, $p < 0.01$) and between the younger and older participants ($F(1, 972) = 6.69$, $p < 0.01$). There were also differences between the four countries; however, since this may reflect semantic differences in the translated scales, these will not be reported in detail. (The seasonal effect for each country will be discussed below.)

In addition to the main effects, there were interactions between season and country ($p < 0.001$), between age and country ($p < 0.001$), between gender and country (tend) and between age, gender and country ($p < 0.01$). As seen in table 4, the male participants in Argentina and Saudi Arabia reported more well-being than the females, and in Saudi Arabia the older participants reported more well-being than the younger ones. There were no significant interactions between age and gender, on one hand, and season, on the other.

To investigate whether seasonal variations in length of day will modify the mood of people working indoors, separate ANOVA with repeated measures were carried out for each country. As seen in figure 1 there were considerable seasonal differences in Sweden ($F(4, 1620) = 46.2$, $p < 0.001$) and in the UK ($F(4, 424) = 6.70$, $p < 0.001$) with positive values in summer and negative values in winter. In Argentina and Saudi Arabia the seasonal differences were much smaller, with somewhat depressed values in summer, but these variations did not reach significance. In addition to the total emotional index, separate analyses were carried out for the sub-scales. All in all, these analyses rendered little new information. However, the scales related to arousal were somewhat more differentiating than the other scales. In Sweden and the UK the participants felt considerably more tired, drowsy and sleepy during the winter season.

In order to test the hypotheses that light and colour in the workspaces will influence the mood of people working there, a number of analyses were performed with the index of emotional status as the dependent variable (table 5).

Table 4. The index of emotional status for different sub-groups in the four countries.

	n	Males	Females	Younger	Older	Total
Argentina	222	2.98	2.84	2.93	2.92	2.92
Saudi Arabia	253	3.09	3.00	2.96	3.21	3.04
Sweden	406	2.95	2.93	2.92	2.95	2.94
UK	107	2.71	2.70	2.71	2.70	2.71
Total	988	2.96	2.91	2.91	2.96	2.94

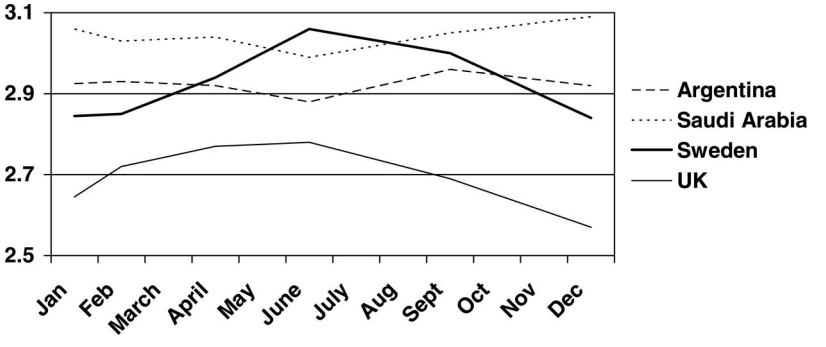

Figure 1. There were large seasonal differences in Sweden and the UK, whereas in Argentina and Saudi Arabia the differences were much smaller (In Argentina the corresponding months were July through June. Notice that the figures cover only the central portion of the index scale 1–4).

Table 5. Means and standard deviations of the dependent and independent variables (n = 988).

		February (August)*	April (October)*	June (December)*	September (March)*	December (June)*
Emotional index	Mean	2.90	2.94	2.97	2.97	2.89
	SD	0.45	0.44	0.47	0.42	0.45
Illuminance (lux)	Mean	506	560	584	465	400
	SD	215	311	291	221	191
Distance to window	Mean	8.08	8.67	9.14	8.78	9.21
	SD	19.9	21.0	22.0	21.2	22.0
Subjective lighting	Mean	2.90	2.92	2.93	2.88	2.87
	SD	0.54	0.53	0.53	0.57	0.55
Subjective colour	Mean	2.20	2.18	2.23	2.14	2.17
	SD	0.72	0.69	0.69	0.78	0.73

*The corresponding month in Argentina.

A two-way ANOVA with illuminance and distance to nearest window as grouping factors was performed separately for each occasion. Illuminance was partitioned into three groups (28–300, 301–600, 601–2150 lux) and distance into four groups (0–2, 2.1–5, 5.5–10, 11–100 m). The impact of illuminance on the participants' mood was not significant at any time and there were no significant interaction effects. The distance to the nearest window, on the other hand, had a significant impact on mood in February (August in Argentina; $F(3, 976) = 5.90$, $p = 0.001$) and there were similar tendencies in April (October; $p = 0.06$), June (December; $p = 0.03$) and September (March; $p = 0.08$). Figure 2 shows that distances up to 2 m from the window had the most beneficial effect on the emotions. However, being very far from a window seemed better than being 5–10 m away.

Concerning subjective lightness a one-way ANOVA was performed for each occasion. As shown in table 6, the participants' emotional status was at its highest when the lightness was considered to be just right.

Concerning interior decoration, the ratings of each individual were averaged over the five occasions and partitioned into three groups with no colour (22%), neutral colour

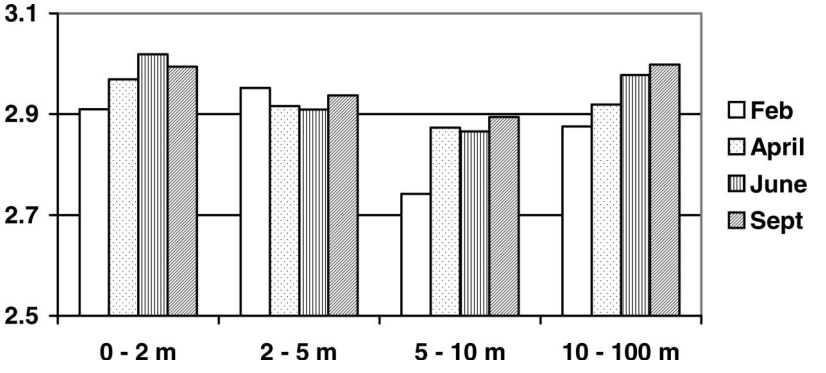

Figure 2. The distance to the nearest window had a significant impact on mood in February (August in Argentina), and there were similar tendencies at three of the other four occasions.

Table 6. The participants' emotional status as a function of subjective lightness (n = 988).

	February (August)*	April (October)*	June (December)*	September (March)*	December (June)*
Much too dark	2.72	2.78	2.80	2.90	2.60
A little too dark	2.79	2.90	2.89	2.89	2.77
Just right	2.93	2.96	3.00	3.01	2.94
Too much light	2.86	2.88	2.88	2.83	2.76
F(3, 987) =	5.15	2.05	4.09	7.82	12.1
Significance	$p = 0.002$	$p = 0.105$	$p = 0.007$	$p < 0.001$	$p < 0.001$

*The corresponding months in Argentina.

(53%) and some or much colour (25%). These groups were then entered into an ANOVA with repeated measures for the different seasons. In addition to the seasonal effect ($F(4, 3940) = 9.02$, $p < 0.001$) there was a highly significant difference in mood between the three groups ($F(2, 985) = 18.9$, $p < 0.001$). As seen in figure 3, the index of emotional status was higher throughout the year for those who had the most colourful work environment. The interaction between season and decoration was not significant.

5. Discussion

It was felt that the varied locations of the testing sites and the care taken in sampling and data collection, together with the low dropout rate, provided a satisfactory testing ground for the hypotheses. Apart from minor differences, males and females responded in a similar way and so did the younger and older personnel. Replicating a study in countries with different cultures and languages makes comparisons in absolute figures difficult. This was considered in the experimental design by repeating the measurements on five occasions covering a total period of 1 year.

All the results clearly point to the existence of an interaction between season and country, which could be ascribed to variations in day length. In the countries situated far north of the equator there was a strong and highly significant variation in psychological mood over the year that did not occur in the countries closer to the equator. These mood

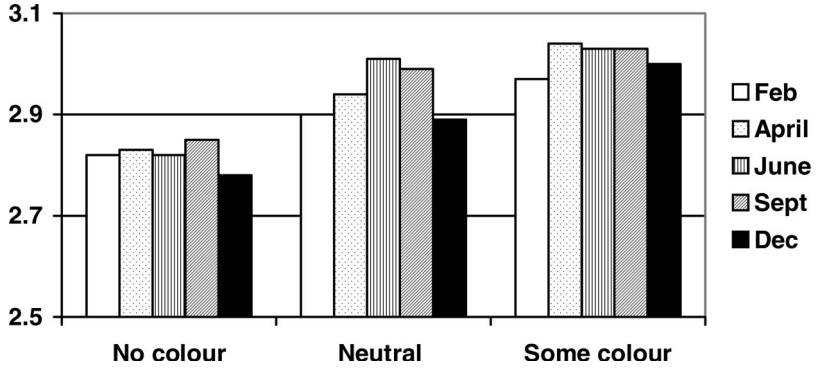

Figure 3. The mood was better throughout the year for those who had the most colourful work environment.

swings of personnel working indoors may partly be related to the amount of daylight through the windows. They may also reflect more basic seasonal variations of sub-SAD (Küller and Küller 2001, Veitch *et al.* 2004).

Theories of emotion are as old as psychology itself, or even older, and many different attempts at conceptualizing and measuring emotions have been made. Environmental psychology has generally taken a dimensional approach to the study of emotions (the HEI-model; Küller 1991). In the present study mood was assessed in terms of one total index of emotional status. Analysed one by one, the different mood scales generally behaved in a consistent way, which means that light and colour influenced a wide range of emotions in a similar way, making people feel, for instance, more alert, interested, friendly and confident. The only exception was the scales related to arousal, which declined more than the other emotional qualities when the days were at their shortest. As an example, tiredness increased more than sadness.

Among the more striking findings in the study is the considerable variation of the indoor illuminance, ranging from below 30 lux to well above 2000 lux. In all four countries, a large proportion of the observed values fell below the recommendations given in contemporary lighting manuals (Rea 2000). In view of this, it may seem remarkable that the vast majority of the studied subjects perceived the lighting conditions at their workplace as 'just right'. The lighting was thought to be 'much too dark' in only 2% of all responses. The difficulties in establishing objective criteria for good lighting are further illustrated by the rather low correlations between the different lighting measures. Most lighting engineers nowadays are aware of the complexity inherent in any lighting situation and the necessity to also consider its qualitative aspects.

When all four countries were considered together, it became evident that the light and colour of the workplace itself had an influence on the mood of persons working there. Perhaps somewhat amazing, the illuminance as measured in objective terms showed no significant impact on mood at any time of the year. Horizontal illuminance values had been obtained at each workplace under realistic, still standardized, conditions. In spite of large variations in absolute lux values there were no corresponding effects on mood. This is contrary to the results of some earlier studies, where such effects were found (e.g. Daurat *et al.* 1993, McCloughan *et al.* 1999). However, most of these studies were made in the laboratory and not in real environments. In addition to illuminance it might be useful to include various measures of luminance.

On the other hand, the distance to the nearest window had a significant impact on mood in February (August in Argentina) and there were similar tendencies on three of the other four occasions. This distribution was bimodal with one peak when the distance was 0–2 m and another when the window was far away (>10 m), actually so far that the workplace in practice was windowless. This latter peak might represent an adjustment to windowless environments, and, as such explain at least in part, the conflicting results in some of the earlier studies (Küller and Wetterberg 1996). It must be emphasized that the view function of windows is very different from the daylight delivery function. It has been suggested that, to satisfy most workers, windows should cover at least 20% of the window wall area (Rea 2000). In addition, tinted glass and the use of various shading devices might also have a slight emotional impact (Bülow-Hübe 1995).

Another non-linear relationship concerned subjective lighting. The psychological mood was at its lowest when the lighting was experienced as much too dark. The mood then improved and reached its highest level when the lighting was experienced as just right, but when it became too bright the mood declined again. This result is hardly astonishing. However, it indicates the usefulness of subjective lighting assessments in field studies of the present kind, where objective lighting measurements might be complex and time-consuming or not available. In this context it may be tempting to quote an old study by Flynn (1977), where he lists four characteristics of lighting of importance for subjective impressions: overhead/peripheral; bright/dim; uniform/non-uniform; visually warm/cool.

Finally, the colour of the workspace stands out as rather important. The index of emotional status was higher throughout the year for those who had the most colourful work environment. Thus, it may seem that the brighter the colour, the better it is for those who work there. However, this should be seen in the light of the fact that the majority of the environments were subdued or neutral. Only 5% were experienced as very colourful. In some laboratory studies of colour and mood, very strong colours were applied with results that seemed undesirable (e.g. Küller and Mikellides 1993, Kwallek *et al*. 1996). To apply highly saturated colours in real environments, thus, might not be a good solution. Still, it is suggested that a moderate increase in the use of good colour design will serve to improve the overall mood of the working staff.

In conclusion, human emotions are influenced by a number of factors and only part of them might be related to the conditions at work. In this perspective the impact of light and colour found in this study certainly seems large enough to warrant increased attention. For the practitioner it will be important to consider both the seasonal impact and the access and distance to windows. Physical measurements should be supplemented by qualitative assessments by those directly concerned. There is also need for continued research on a longitudinal basis. A better understanding will demand the setting up of long-term quasi-experimental field studies that will allow a more detailed analysis of several different lighting parameters. Furthermore, light and colour should be treated as part of a more complex system making up the totality of a healthy building.

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