FEEL-GOOD FACTORS

Most studies on the visual effects of light in relation to alertness and mood take place in laboratory conditions. But is it possible to change the lighting conditions in a real workplace to improve the mood, alertness and sleep quality of the people working there? A research team set out to find the answer

By Roger Sexton and Professor Peter Raynham

A large body of evidence shows that, as well as the visual effects of light, there are direct and indirect non-visual effects that can boost alertness and mood and help to entrain the human circadian system.

These effects seem to follow the spectral sensitivity associated with melanopsin, which has a peak sensitivity, in energy terms, at about 490 nm, as shown in figure 1 below.

Details of the investigation of these effects are well documented, with the basic principles and main effects summarised and the spectra characterised [1].

However, the vast majority of the work on these non-visual effects is based on laboratory studies where people are exposed to light, often at high levels under strange conditions, such as being woken up in the middle of the night.

This leads to the question: would it be possible to change the lighting conditions in a real workplace to improve the mood, alertness and sleep quality of the people working there?

To deliver a meaningful increase in the lighting across a large workspace would require installing a lot more lighting and require significantly more energy. Thus, the logical solution is to use a localised lighting solution.

THE PROBLEM

To date there have, as far as the authors can tell, not been any experiments conducted to show if localised lighting can be used to boost general workplace lighting and provide the additional non-visual effects.

There is the issue of acceptability of localised lighting designed to provide significant illuminance at people's eyes as well as the issue of whether these increased light levels have any real impact on mood and sleep quality in everyday (rather than laboratory) conditions.

To add another complication, testing an intervention in the workplace is complex as, once people know they are part of a trial, they know someone is taking an interest in their working conditions and this in general is likely to make them feel happier and more engaged at work.

A further issue is that people's mood and sleep quality depend on a whole series of elements and not just the conditions of their workplace. Finally, there are also many factors, such as age, choronotype and work schedule that may influence the extent to which a change in the lit environment could impact a given individual.

In conjunction with the commercial partners, the researchers spent some time developing a light source, shown in figure 2 opposite, that was capable of delivering a biologically significant level of light to the user's eyes. For an example of what is meant by biological impact see figure 3.

That the authors felt comfortable in front of this led to the assumption that research participants would feel the same way. However, because of the aforementioned potentially confounding factors, it was expected that any experiment would only find limited changes to mood and sleep.

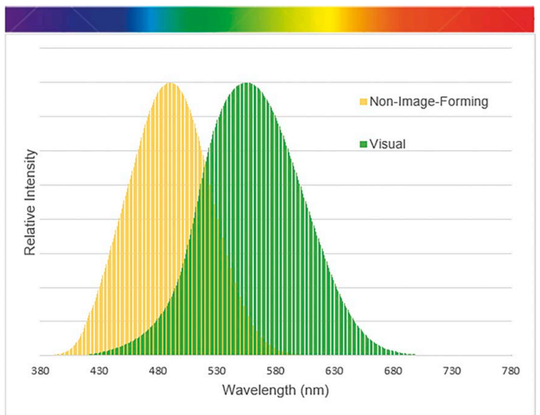


Figure 1. The relative melanopic and photopic response functions

THE EXPERIMENT

The critical part of the experiment was to ensure that the subjects were unaware of the light dose they were receiving on any given day, so that possible psychological responses to the light would be cancelled out in the experiment.

It was found it was possible to vary the luminance of the task light by a factor of two without the subject noticing, provided the change was made slowly.

The higher light level was taken from the Brown et al 250m-EDI lux vertical recommendation and the lower light level half of this, 125m-EDI lux, so the response would be as large as possible yet the subjects would not notice the level changes on different days [2]. The levels assumed a 0.5m distance subject to task light.

For the experiment we recruited 30 subjects who were selected with a preference to be:

- Regular desk workers in office hours (in other words, daytime)
- Work from one screen seated with face max 1m from the task light
- Healthy (no medication and no irregularities in terms of sleep or caffeine/alcohol intake)
- Range in age and sex
- The working area to receive a median daylight <200 m-EDI lux vertical and minimum CCT of electric lighting to be 4000K

After some issues, we received data from 28 subject whose details are given in table 1 below.

	60+	59-40	39-20
Male	1	7	5
Female	1	6	8

Table 1. This shows the breakdown of subject data

Each subject had a task light installed on their desk, which was set up to deliver the pre-sets to the subjects' eyes comfortably.

The source provided light with a colour appearance of 4000K and a colour rendering index of 97. The light was controlled remotely via a gateway so that it was possible to monitor when the light was turned on and off and to set the level of output on any given day.

Each day when the light was turned on it started at an intermediate level and adjusted to the assigned level for the day over a period of one minute. Each day, too, the subjects were sent two reminders to fill in some online questions. This followed a regular pattern that is summarised in table 2.

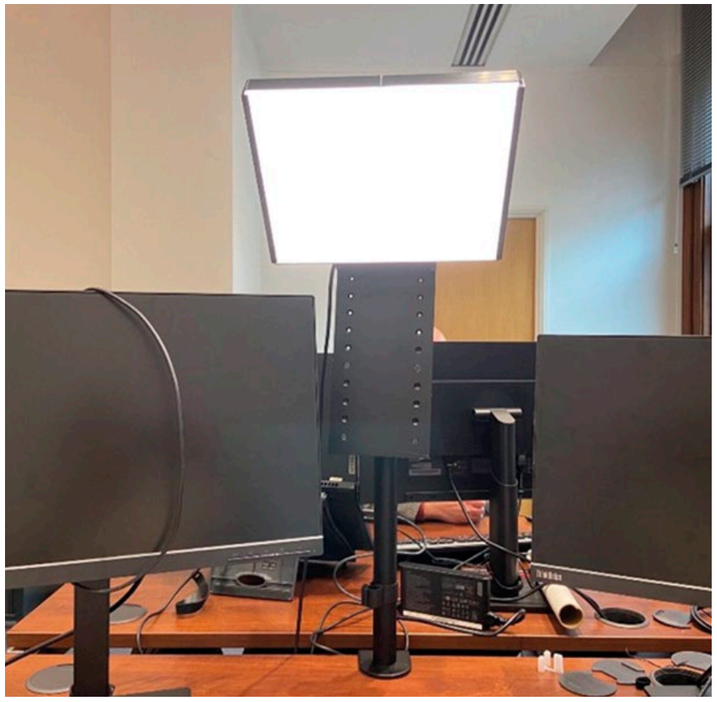


Figure 2. The experimental task light in a typical installation

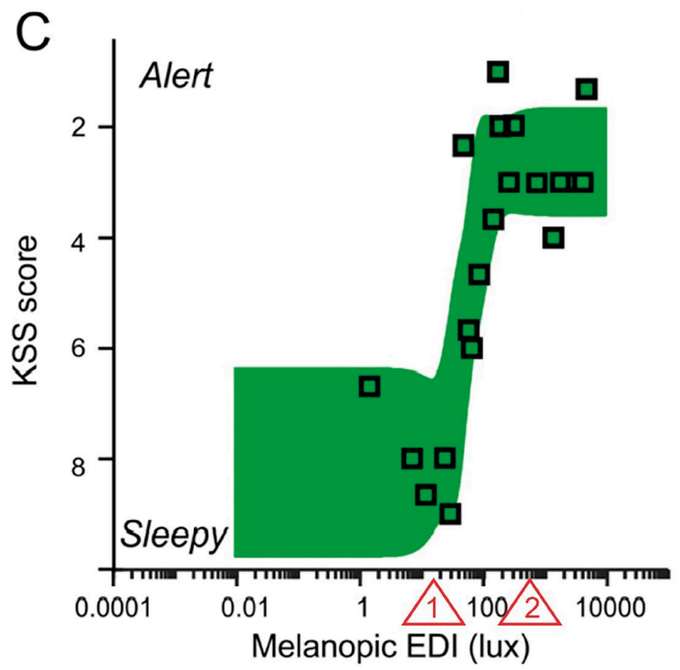


Figure 3. This shows a plot of the sleepiness score [KSS] against light received at the eye [m-EDI lux] taken from Brown et al with the two light levels used in the experiment marked

Workplace lighting

QUESTIONS	
MORNING	**AFTERNOON**
How did you sleep (comments)	Karolinska Sleepiness question
Karolinska Sleepiness question	Mood Words
Mood Words	How was the day (comments)

Table 2. The daily test routine

Figure 4. The cartoon faces of the Karolinska sleepiness scale used for sleepiness evaluation

The sleepiness question used a cartoon version of the Karolinska sleepiness scale, as shown in figure 4.

Mood was evaluated by the subjects selecting multiple words from a list of adjectives that were chosen as indicators of mood in the standard circumplex model of mood. This permitted the assessment of mood in terms of arousal and valence in a standard way, as shown in figure 5.

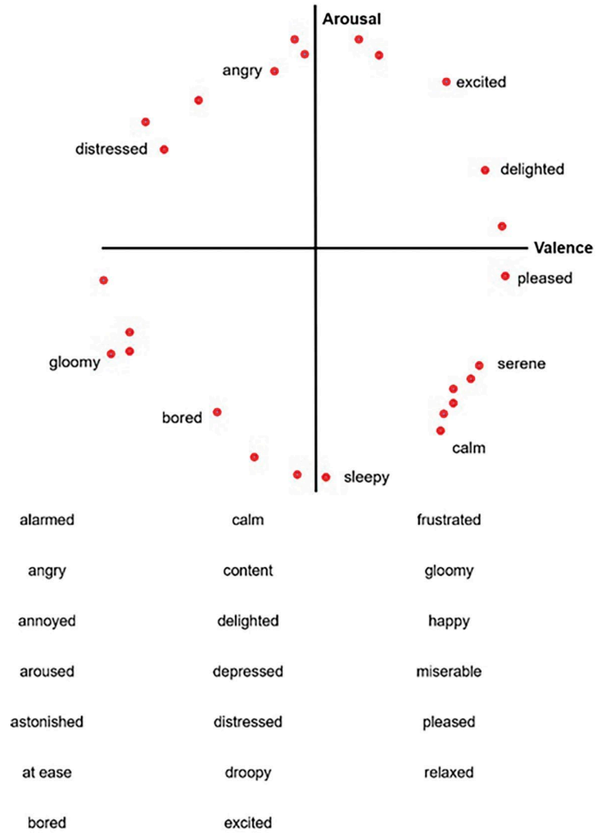
In addition to the daily routine of questions, at the end of the study the subjects were interviewed using a semi-structured technique whereby each subject was encouraged to talk about their experience during the study in as open a way as possible.

ANALYSIS

Rules were put in place to ensure that all data processed was valid and might contribute to the study.

One subject was excluded as it happened that there had been one light condition 18 times and the other only twice because of a disrupted working schedule. Another subject was excluded as they had used exactly the same words in nearly all of their mood surveys.

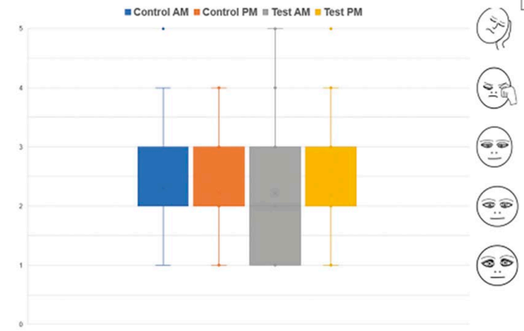
In addition, each daily set of responses was checked to see if the subject had been paying attention when filling in the mood words. This was done by looking for words with opposite meanings being selected, for example *happy* and *sad*.



alarmed	calm	frustrated	sad
angry	content	gloomy	satisfied
annoyed	delighted	happy	serene
aroused	depressed	miserable	sleepy
astonished	distressed	pleased	tense
at ease	droopy	relaxed	tired
bored	excited		

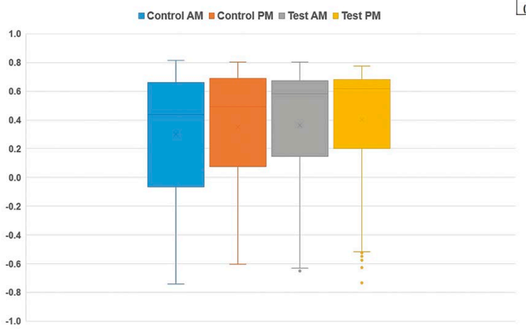
Figure 5. This shows the mood adjectives used together with the mood diagram

Workplace lighting



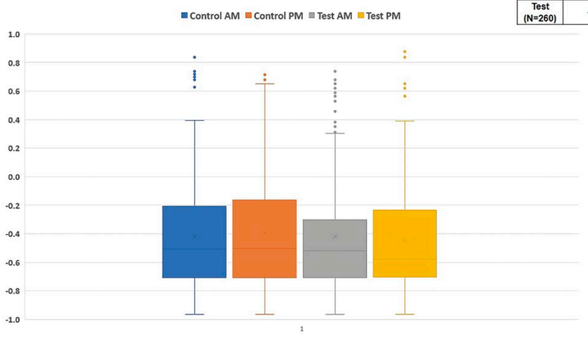
	AM Sleepiness	PM Sleepiness
Control (N=231)	2.29	2.225
Test (N=260)	2.212	2.177

Figure 6. This shows a box and whisker plot of the sleepiness scores



	AM Valence	PM Valence
Control (N=231)	0.30	0.35
Test (N=260)	0.36	0.41

Figure 7. Box and whisker plot of valence scores



	AM Arousal	PM Arousal
Control (N=231)	-0.42	-0.39
Test (N=260)	-0.42	-0.45

Figure 8. Box and whisker plot of arousal scores

Where this was found, the results for that day were excluded. After this data cleaning we were left with 491 daily records from 28 subjects.

In the analysis of results, the higher level of light is referred to the *'test'* condition and the lower level as the *'control'* condition.

ALERTNESS

Alertness (or sleepiness, its inverse) was plotted using the scores (1 = fully alert; 5 = struggling to stay awake) under the headings 'control' and 'test' for AM and PM.

The lower the score, the more alert the participant was. The outcome showed little difference in the 'lower' alertness scores between control and test conditions but a notable difference with a higher alertness of some subjects during the morning in the test condition. Figure 6 opposite gives the results for sleepiness.

MOOD

Mood was analysed as valence and arousal by averaging the scores associated with each word selected by the subjects. Figure 7 shows the valance or happiness scores. It can be seen that on, average, the subjects are happier in the test condition compared with the control condition; this change seems to be because of fewer people being unhappy.

The alertness scores are plotted in figure 8. In general, there is very little difference between the test and control conditions; there is only a very marginal trend for subjects in the test group to have a lower arousal in the afternoon.

SLEEP

In the records on how participants slept during the previous night five-word options were used: 'bad', 'patchy', 'fair', 'good' and 'exceptional'. An analysis was made of the five-word recordings comparing these outcomes with the lighting (control or test) that the participant worked with on the previous day.

Note that because of discontinuities in diary entries (weekends, hybrid working and so on) the dataset was smaller: 202 records.

The outcomes (see figure 9) clearly show a trend to 'bad' or 'patchy' nights following the control condition and 'good' or 'exceptional' nights following the test condition.

Previous Day	Number	bad	patchy	fair	good	exceptional
Control	95	7.4%	16.8%	25.3%	48.4%	2.1%
Test	107	6.5%	10.3%	26.2%	50.5%	6.5%

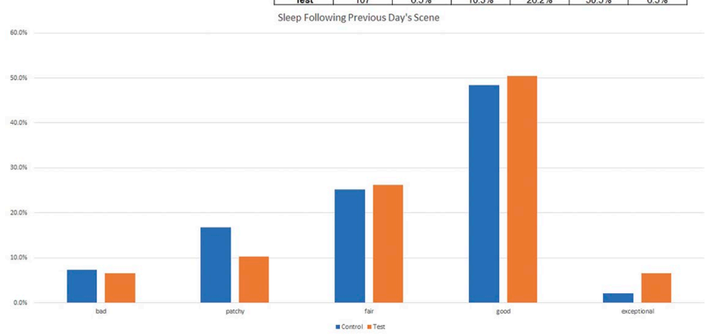


Figure 9. This shows the results for reported sleep following a day with a given light condition

END OF STUDY SEMI-STRUCTURED INTERVIEWS

The end-of-study semi-structured interviews typically lasted five minutes and covered the following topics:

1. How has the experience been over the last month? Has the task light been in any way intrusive or on the contrary a welcome addition?
2. How have you been generally? Feeling OK? Finding work OK?
3. Any other points you'd like to air?

From the interviews, some major themes emerged. These have been grouped into general areas, and some typical comments are shown:

- The light – 30 positive comments from 23 subjects
  - 'Most useful on gloomy days'
  - Time-related comments: 'good in the morning and at end of day'
  - Acclimatisation: 'the light became invisible after a while'
  - Effect on work: 'a boost like a walk outside'
  - Spatial distribution: 'I liked the vertical nature of the light'
- The Light – nine negative comments from nine subjects
  - 'Sometimes the level was too bright'
- Alertness – 24 positive comments from 22 subjects
  - 'I just think I felt like a bit more alert'
  - 'Some days I thought that I should be more tired than I was, particularly towards the end of the day, and I still felt peppy'
- There were no negative comments on alertness
- Sleep was mentioned in 20 interviews
  - Sleep improved: 10 subjects
  - Sleep made worse: 0 subjects
  - No noticeable impact: 10 subjects

CONCLUSIONS

The experiment by its nature was quite complex and most of the recorded data is comparing the impact of relatively small differences in light level at the subject's eyes.

Nevertheless, it does appear that the higher level of light reduces sleepiness (improves alertness) and also leads to an improved valence (happiness) with the subjects.

It also indicates that there is some improvement in sleep quality following a day working with the brighter light.

There are so many factors at play, however, that these findings do not demonstrate high levels of significance. Nevertheless they are indicative.

The results from the end of study interviews show that the task light was well accepted by the subjects and, if the light was controllable by the user, there would not be any negative comments about it. Over a third of the subjects reported improved sleep during the trial.

Thus, it can be concluded that, if a task light similar to the one tested was used in practice, there would be benefits for the users of the light. This is both because of the physiological impact of the light but also the psychological impact of being able to control their own lit environment.

ACKNOWLEDGEMENTS

- The experimental task lights were designed and manufactured by Stoane Lighting
- EldoLED provided the control gear and BLE dongles.
- Atrium provided the Casambi gateways and communication know-how.
- Llama Digital developed the experiment microsite.

Roger Sexton FSLL is business development lead at Stoane Lighting and **Professor Peter Raynham** is emeritus professor of the lit environment at the Bartlett at UCL as well as the ILP's Vice President – Membership, Qualifications and Registrations

NEED TO KNOW

- Research has been carried out to consider whether it is possible to change the lighting conditions in a real workplace to improve the mood, alertness and sleep quality of the people working there.
- Mood, sleepiness, alertness and valence (happiness) were all considered, with 30 participants taking part in the study.
- The research concluded that, while there are variables and more research is needed, a higher level of light can reduce sleepiness and improve alertness and also lead to an improved valence or happiness.

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