

The impact of changing light on the well-being of people at work

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KEYWORDS

dynamic lighting, lighting control, human factors, direct-indirect lighting, alertness, shiftwork

ABSTRACT

Today it is well accepted that the subjective well-being and emotional condition of people working in an office are influenced by artificial light. Still, artificial lighting is mainly design as a static solution hopefully fulfilling basic ergonomical aspects. But learning from nature people expect changes in lighting over the day. So modern lighting design should be aware of the people's expectations for lighting conditions.

The various ways in which interior lighting can be changed should also communicate meaningfulness. In this context, it is worth remembering that the primordial human experience of sight is characterised by daylight. Although daylight is constantly changing, human beings are intuitively familiar with these changes and in tune with them. By contrast, changes in artificial lighting have been achieved with the assistance of modern technology. With the development of electronics and the spread of lighting management systems, it has only recently become possible to modify artificial lighting to suit almost any requirements. In the planning stages, a story board or lighting script, which records what happens in a room and how light interacts with these processes, can be a useful tool. Artificial lighting has now become a dynamic element within the design of a room. The term Active Light is used to describe meaningful changes in lighting.

By using the storyboard to communicate with the user the designer finds out simply what lighting situations have

to be prepared and how they should change. This is a new approach in interior lighting design, which gives more importance to the well-being of the user.

A CLOSER LOOK AT DAYLIGHT

Changes in daylight are intuitively accepted by every living creature. So far, nobody has ever complained about whether the quality of daylight or the changes in daylight are meaningful. The body of experience accumulated through evolution was determined by natural light, and for this reason, everyone regards the changes between day and night, the changes caused by the weather including surprising effects such as a rainbows, or thunder and lightning, as something quite "natural". Such events are almost expected.

- The course of the day can be predicted to the extent that the time of sunrise and sunset can be reliably calculated for every day in the year and for every position on the surface of the earth.
- However, the situation each day differs depending on weather conditions. In this connection, slow changes and even surprising effects can arise.
- The element of surprise in a day is always characterised by unpredictable events such as lightning or the unexpected occurrence of a rainbow.

These properties of natural light are also always linked with an experience to which human beings attribute emotional qualities.

ACTIVATION THROUGH DAYLIGHT

Human beings experience light as a process, not as a static situation. A sunrise is associated with the expectation that it will become lighter in the next few minutes and that life will begin to wake up. People become active and begin their daily work.

A sunset signifies the end of the day's work and leads into the evening, to relaxation, night-time and rest.

Photographs of the sun low in the sky cannot communicate whether it is morning or evening. A picture may capture a romantic moment, but it has no past and no future.

A similar thing happens in nature when thick clouds and mist create a monotony of directionless and uniform light. Boredom and lack of motivation are the consequence. By contrast, a walk in the woods, with light entering at varied angles and in constantly changing colours, triggers a very positive feeling because of the process of change.

THE EFFECT OF LIGHT ON THE BIOLOGICAL RHYTHMS OF THE BODY

Nature has been setting the rhythm for thousands of years through the change from day and night. The human body has adapted to this 24-hour rhythm with active phases during the day and rest phases in the night. Chronobiologists describe this as the circadian rhythm. Chronobiology is the science concerned with time-controlled functions of the body. Numerous experiments have shown that light is the timing element of the body's inner clock. Light has a decisive influence on the vegetative system [1] [2] [3].

When light enters the eye and falls onto the receptors in the retina, the optic nerves send signals to the brain. A cluster of cells called suprachiasmatic nucleus is located right at the junction of the optic nerves and connected to the pineal gland. In the night, when it is dark, the pineal gland produces the hormone melatonin, which controls tiredness and the need for sleep.

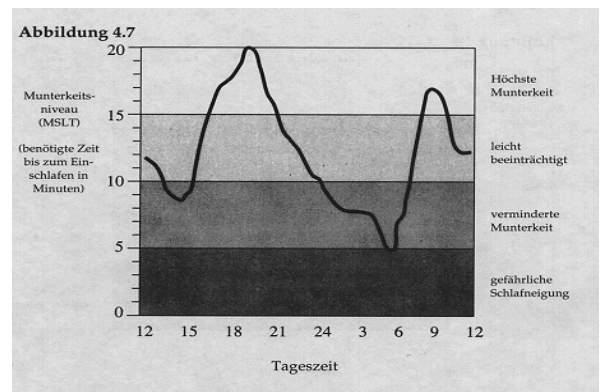
When the presence of brightness and light is signalled to the pineal gland via the optic nerve, the gland suppresses production of melatonin; when little or no light is available, full production of the hormone is resumed, and the result is a refreshing, healthy sleep.

We have made our nights bright with the invention of electrical light; we jet through time zones, work in shifts, and in the process, we disturb the natural rhythm of day and night. It has been shown that most accidents caused by human error occur between three and five o'clock in the morning. The reactor accident in Chernobyl, the Exxon Valdez tanker catastrophe off Alaska and the Bhopal toxic gas leak in India were dramatic examples. Many smaller accidents including road traffic accidents also occur at this time. The reason is that, as "daytime animals," people are at the lowest ebb of their biological performance at this time.

Nowadays, alertness can be positively influenced by means of bright lighting, for example, during shift work, at the peripheral periods of daylight or in the night [4] [5].

Even during the day, the targeted use of lighting changes can positively support people's level of alertness.

Figure 1: Levels of alertness fluctuate throughout the 24 hours of the day. [6]



LEVEL OF ALERTNESS

Alertness or wakefulness fluctuates during the course of the day. The body seeks out its phases of activity and balances them against periods of rest. It is certainly not the case that we are wide awake at eight in the morning and remain so consistently until five in the afternoon when we go home and have a rest. Nevertheless, the lighting in offices often looks as if this were the case: on in the morning; off at night.

Chronobiologists therefore also recommend artificial sources of light, which are designed as attractive, low-glare, large-area luminaires [2].

Using the resources of lighting management, the lighting conditions in a room can be changed dynamically in order to create variety and stimulation. An increase in motivation is assured because acceptance of the working environment is increased.

The prerequisite for successful activation through dynamic lighting is good lighting design, discussed and agreed with the user. The central criterion here is the meaningfulness of the changes in order to achieve meaningful changes in lighting.

PLANNING OF LIGHTING SYSTEMS WITH MEANINGFUL CHANGES IN LIGHTING

Meaningful change is distinct from the merely playful, effect-seeking or arbitrary changes in lighting. Lighting design must always be preceded by an analysis of the uses of the rooms over time so that lighting design can be implemented on the basis of a storyboard. Lighting used in this way can activate, stimulate and set the scene. There should be a perfect interaction between electronic lighting control and the lighting technology applied in the luminaires. Good design can place the lighting "centre stage". The typical areas of application include shop lighting, lighting for window displays, foyers, leisure and wellness areas, and also lighting in places of work: meaningful lighting, to activate and stimulate the workforce.

With regard to changes over time, an approximation to the effects of daylight is an essential factor. This should, however, not be confused with the simulation of daylight with artificial lighting. It is important to include an im-

proved awareness of the dynamics of the day in the design of the artificial lighting system. Individual authors on this subject have stated that a lighting system which provides the effect of biological stimulation can act as a form of preventive medicine to preserve the health of people working in an office environment. [2] [3] [7] [8] [9].

CHANGES IN LIGHTING AND THE CONCEPTS OF LIGHTING TECHNOLOGY

Krueger has formulated an important physiological and cognitive rule for lighting design. It is essential **not** to perceive lighting as something **static**, as an installation positioned above a room and its adjacent areas in as uniform a manner as possible, but to conceive of lighting as a **dynamic feature of a visual interior climate** [10].

This approach provides the key to how the lighting for working areas in an office can respond more effectively to the needs of the workforce.

By preserving the quality features of lighting technology and at the same time introducing meaningful lighting changes, also including the use of daylight.

How can lighting changes be construed in terms which are already familiar in lighting technology?

- Change in level of brightness = illuminance
- Change in colour of light
- Change in distribution of light = distribution of brightness, shade, light direction

These properties represent concepts, which are already familiar, as classical quality features of lighting technology and which are mentioned in the lighting standards. Hitherto, these concepts have been perceived as static parameters, which have to be taken into account in lighting design and adhered to in a fixed manner afterwards.

MOTIVATING AND ACTIVATING OFFICE LIGHTING

Office work can be represented as a course of activities determined by the content of the work. Changes, which characterise the working day, occur between different tasks such as reading, discussing, telephoning or computer work. Orientation in time proceeds subconsciously but can be supported by information in the environment. In this context, lighting can motivate and orientate. The elements of progression, lighting situation and surprise are used as they occur in daylight situations. In the first example, the lighting system consists of four lighting components:

1. Indirect component from the suspended luminaire with fluorescent lamps, producing a light ceiling; coupled to a daylight sensor
2. Direct component from the suspended luminaire: directly controllable by the user as a working light
3. Strip lighting on the wall with halogen incandescent lamps in warm white colour; controlled by an automatic timer
4. Daylight, controlled via blinds

Figures 2-4

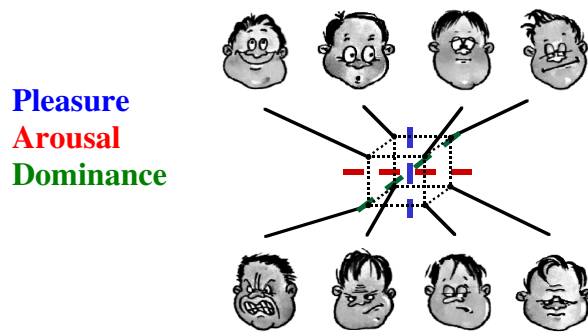


Figures 2-4: The progression of lighting via the indirect component, the individual adjustment of specific lighting situations such as the direct lighting for the workplace and the surprising effects of the strip light on the wall motivate employees in the office; the sequence of lighting changes is recorded in a story board.

With the luminaires used here, the direct and indirect components were separated from one another. In this example, neutral white light colours were chosen. Different colours of light for the indirect and direct component (warm white and daylight white) have an impact on stimulation and are currently under investigation [12] [13].

In combination, the four lighting components disclose their full potential. The programs are developed into a "story board" which is written during the planning stage for the lighting system. This storyboard describes how the **progression** of indirect lighting interacts with daylight. A personal **lighting situation** can be selected individually by each user and adapted to her or his work by means of the

Figure 5: Characterisation of human emotions according to PAD



direct component. **Surprise**, in the sense of a sub-conscious stimulation rather than a shock, is provided by strip lights on the wall which create a warm, friendly glow of light, especially in the evening or in winter.

This changing lighting environment is associated with increased acceptance and therefore also with enhanced motivation. People who worked with this pilot lighting system stated in their response to a survey that they felt they had been positively influenced by the lighting.

PREFERENCE OF LIGHT DISTRIBUTIONS AND LIGHT COLOURS

The effects on well-being and motivation as well as on stimulation by different light distributions and the change between them and by different light colours was investigated by Dr Susanne Fleischer [11] [12]. She used field and laboratory trials.

The lighting consisted of luminaries with direct and indirect distribution of light. The ratio between direct and indirect lighting was changed either by the time of the day or by the weather conditions.

A number of responses were given where the most important effects are:

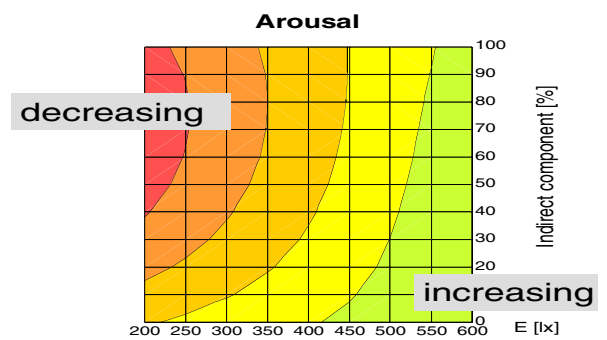
- Pleasure rises with the illuminance and a large indirect component
- Arousal rises also with the illuminance, with an increase of the direct component and with daylight colours
- Dominance shows a minor influence as for example “inferior” for low illuminances and larger direct components

In the following figure the relationship between illuminances and the percentage of indirect lighting regarding arousal is shown.

The major significant result was that arousal rises with higher illuminances and is increased by direct lighting and/or daylight coloured light.

These results state an activating influence on people. But there should be a change because in long term use of one lighting situation the effect for example of activation may lead to a reduced sense of well-being.

Figure 6: The factor of arousal depending on illuminance E and indirect component ID



ENERGY CONSIDERATIONS

On the first view it looks as if the installed load of a dynamic lighting solution would automatically result in a higher consumption of electrical energy. The following consideration will show that energy consumption measured in kWh per year is not higher than in a standard lighting installation, which is operated all day long.

Room: 100m² with windows and blinds, reflexion 70/50/20

Operation hours: 2.500 hrs per year (10 hours, Monday – Friday, excl. holidays)

1. Direct-indirect pendent luminaire, 58W single lamp, electronic ballast,

500 lx all the time, no switching

24 luminaires, installed load: 1.320 W, 3.300 kWh/year

2. Direct-indirect pendent, direct: 1/35W workplace lighting, indirect 2/35 W daylight controlled: workplace min. 300 lx, max. 650 lx (without daylight)

18 luminaires, installed load: 702W + 1.404W = 2.106 W

Low voltage downlights: 50 W

10 luminaires, installed load: 500 W

Control:

indirect: 50% (controlled by daylight, morning and evening low level, off on midday break) direct: 50% (personally controlled, only when workplace occupied)

wall lighting with low voltage: 25% (occasionally during daytime, evening)

∓ 351W + 702W + 125W: 2.945 kWh/year

This very simplified calculation proves that by intelligent control of artificial lighting the consumption over a year is in the range of a standard installation without any control. The installed load is not a measure for energy consumption.

Summarised:

	Exp 1	Exp 2
Total load:	13,2 W/m ²	26 W/m ²
Energy use	3.300 kWh/year	2.945 kWh/year

The use of meaningful changes of light is positive to the well-being of people: motivation increases and the acceptance of the lighting is very high. On the other hand it is not less energy efficient as there are savings in energy consumption just by controlling the lighting with intelligence.

CONCLUSION

Energy efficiency and well-being of people at work is not a contradiction. There should be a meaningful change of light according to a storyboard, which tells what the people are doing in the room. In a combination of an automatic change and a direct control by the people motivation and stimulation can rise and people can accept their workplace much more than in a conventional design.

A pure daylight control does not lead to the same positive results.

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