KESSEBÖHMER
ERGONOMICS

In cooperation with
Kesseböhmer Ergonomietechnik GmbH
Weilheim, Germany

Effects of Light

Workshop Effects of light on people

Oliver Stefani
Fraunhofer Institute for Industrial Engineering

Stuttgart, February 2017
Summary

Effects of light

Contents

WORKSHOP EFFECTS OF LIGHT ON PEOPLE
Summary

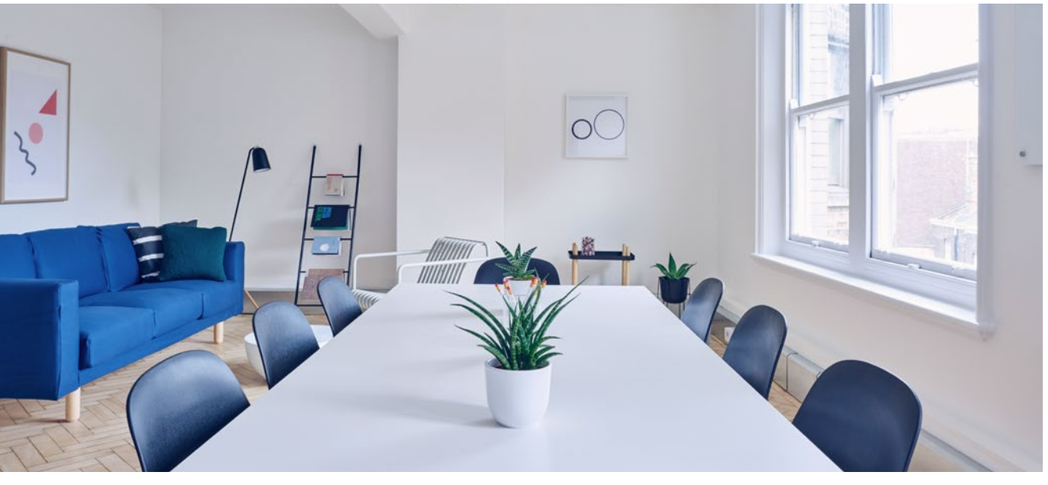
Oliver Stefani
Fraunhofer Institut für Arbeitswirtschaft und Organisation

Stuttgart, Februar 2017

In Kooperation mit
Kesseböhmer Ergonomics GmbH, Weilheim

CHAPTER 1

Effects of light on people
Introduction

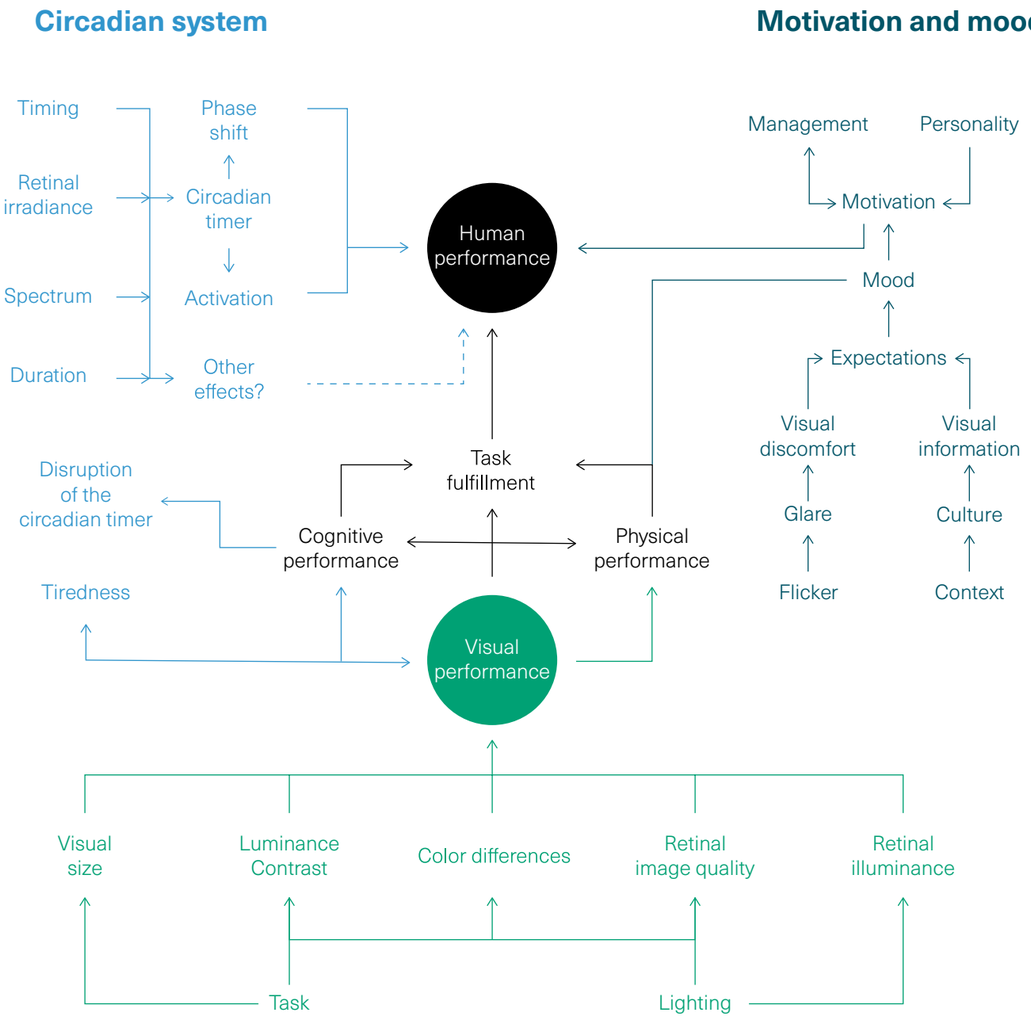


Light generally has three types of effect:

Nonvisual
In other words, the influence on people's bodily functions and cognitive processes

Visual
sensitivity, color vision, visual size perception, image quality, illuminance

Emotional
Motivation, mood, expectation



Visual System

CHAPTER 2

Effects of light on people **Nonvisual**

Light affects cognitive brain functions, even in blind people. After only seconds of exposure to blue light, regions of the brain are activated that are responsible for attention and cognition.

Bodily functions influenced by light

- Sleep-wake cycle: Everyone is subject to what is known as the circadian rhythm. This is regulated by our hormone balance and differs from person to person
- Release of hormones
- Heart rate/blood pressure
- Body temperature
- Pupil movement
- Cell division and regeneration

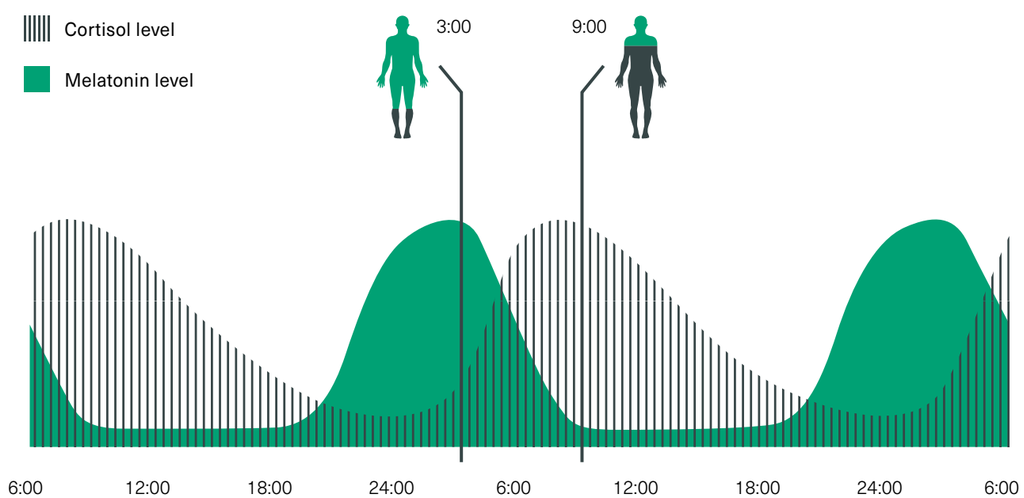
Cognitive functions influenced by light

- Memory
- Attention

Hormonal changes influenced by light

Melatonin

- Messenger substance and antioxidant
- The sleep hormone plays a key role in entraining the 24-hour circadian rhythm, which regulates hormones, body temperature, and metabolism, depending on the time of day.
- It influences healthy sleep, tumor suppression, immune system regulation, the metabolism, as well as defending against free radicals.
- On average, it should be possible for melatonin levels to increase from 6 p.m. onward to ensure adequate production for healthy sleep.



The influence of daylight on the human body

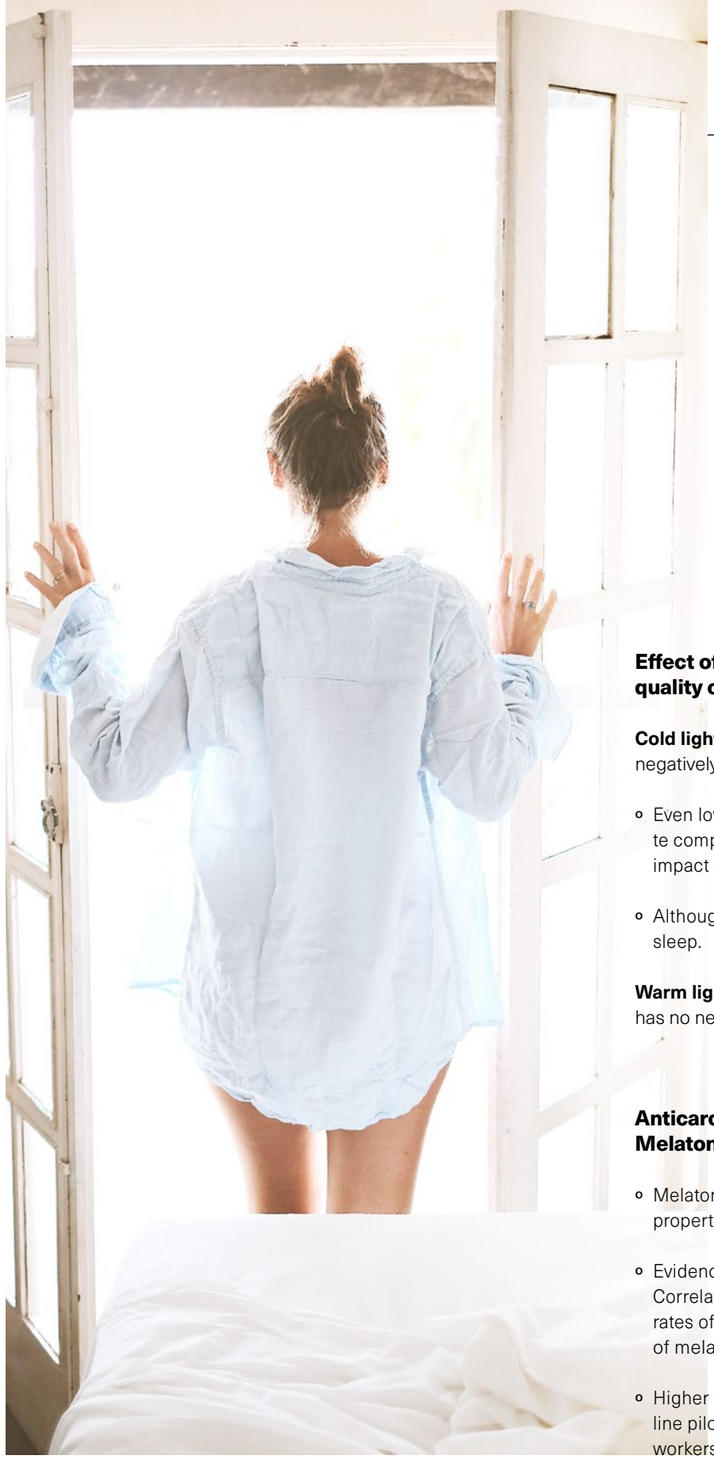
Cortisol

- Messenger substance (stress hormone)
- Cortisol is essential for our many metabolic processes such as fat, protein, and carbohydrate metabolism.
- Cortisol is mainly produced in the second half of the night to ensure ideal preparation for the demands of the day. Over the course of the day, the cortisol should be broken down to a minimum.

Influence on hormone balance via the ganglion cells

Ganglion cells

- Intrinsically photosensitive retinal ganglion cells (ipRGC) and their connection with melatonin production or suppression have been known about for only a relatively short time.
- The cells respond in particular to light with a high blue component. They are distributed across the retina in such a way as to respond to light from above, such as natural daylight.
- The maximum sensitivity of the cells is approximately 480nm. This is where the greatest suppression of melatonin occurs.
    - This means that lighting with a high blue component, as is normally emitted by office lighting and computer monitors, results in suppression of melatonin formation.
    - This has a direct negative effect on the circadian rhythm, our sleep patterns and on cell regeneration.



Effect of light on quality of sleep

Cold light (6500 K) in the evening negatively affects our non-REM sleep.

- Even low brightness levels of chalky white compact fluorescent light negatively impact sleep onset.
- Although we are tired, we are unable to sleep.

Warm light (2500 K and 3000 K) has no negative effect.

Anticarcinogenic effect of Melatonin

- Melatonin also has anticarcinogenic properties.
- Evidence shows the following: Correlation between increased rates of breast cancer and suppression of melatonin by light at night
- Higher incidence of cancers among airline pilots and flight crew, and nightshift workers

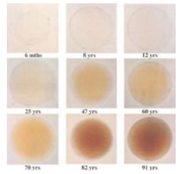
Factors influencing our circadianen rhythm that lighting must take into account

Personal preferences

- Every person has their own genetically determined rhythm.
- Well-known chronotypes include:
  - **The »lark«**
    Early birds whose internal clock runs faster
  - **Normal types**
    Majority of the population
  - **The »Owl«**
    Late types, whose internal clock runs slower

Age

- Our chronotype depends largely on changes in our eyes as we age.
- Three phases are generally distinguished:
  - **Child/youth**
    Generally late chronotype
  - **Working life**
    Characterized by rising early, frequent sleep deficit
  - **Old age**
    Loss of biorhythm, greatly reduced sleep quality

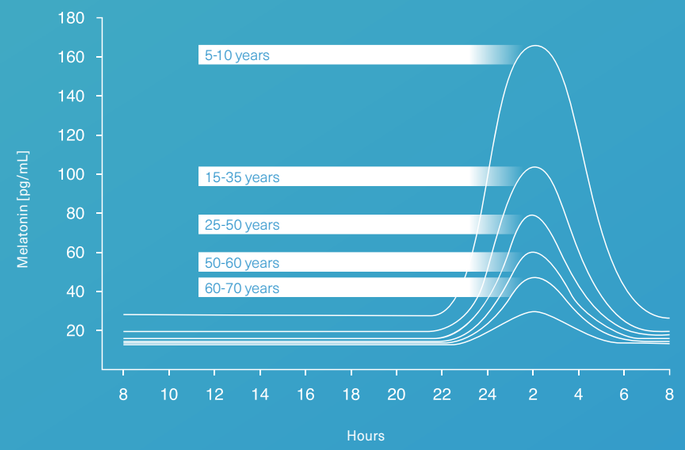


Well-known age effects:
- Ocular opacity
- Yellowing of the lenses
- Decreased function of the iris

Lerman 1980

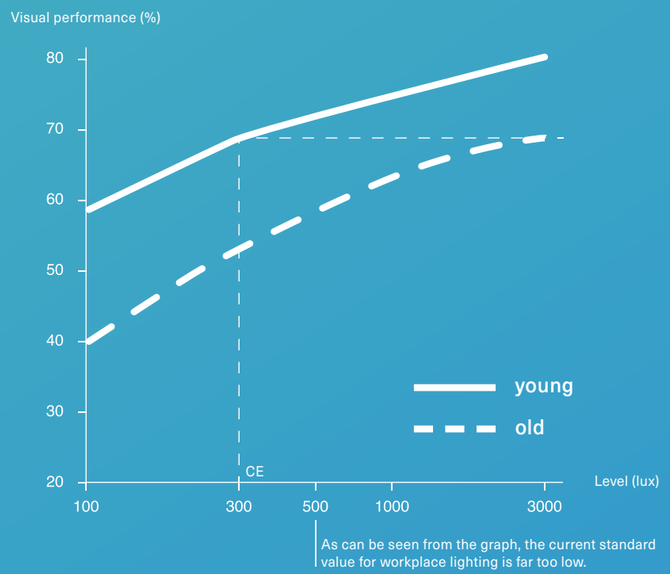
Age-related changes in the eye

- As we grow older, our eyes become increasingly opaque.
- This reduces their transparency, particularly with regard to the blue part of the spectrum.
- In addition, pupil size decreases continually in age.
- Melatonin production decreases.



Age-related changes in the eye

- Artificial lighting must take into consideration the increased demands that come with age.
- The curve shows an example of the correlation between: brightness (x axis), performance (y axis) and age (curve).



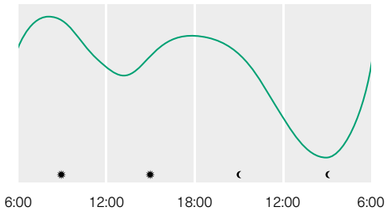
Factors influencing our circadianen rhythm that lighting must take into account

Sex

- **Women** tend on average to be earlier chronotypes; warmer light colors are experienced as pleasant.
- **Men** often change their chronotype when they reach retirement age, becoming early risers. Colder light colors are preferred.

Time of year and day

- People's performance varies over the course of the day and throughout the year.
- In winter, we tend to be less fit, have poorer concentration, and body weight and blood sugar increase.



Willingness of the people

Source: licht.wissen »Wirkung des Lichts auf den Menschen«

It is generally assumed that the more natural the light, the healthier it is for people

Studies have shown:

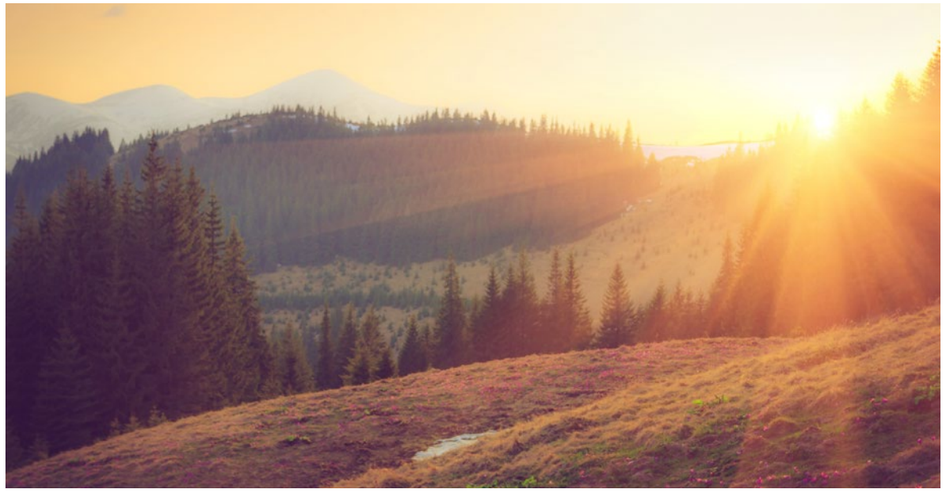
Natural daylight

- Less stress for office workers
- Greater productivity and better health
- Better test results for students

Lighting based on natural light (17,000 K with high blue component during the day / 1700 K blue reduced during night shift) in the workplace had the following results:

- **Day shift:** Higher subjective alertness, good mood, significantly higher productivity and concentration, better sleep quality, and longer sleep during the night.
- **Night shift:** Melatonin suppression significantly lower, no negative effects on cognitive performance and well-being.

Source: Hoffman G. et al.: Effects of Light with Reduced Short Wavelength Components on Parameters of Circadian Rhythm and Performance in an Experimental Night Shift Model



Characteristics of natutal light

Healthy artificial light should have as many of these characteristics as possible:

- The color and the intensity of natural light changes constantly (with the time of day, weather, season, geographical latitude, etc.). Studies show that dynamic variations in light have a positive effect on people's well-being.
- The solar spectrum is continuous and contains virtually no gaps. During the day, it contains a high blue component, which is biologically stimulating and suppresses melatonin production.
    - Full-spectrum fluorescent lamps, known as True-Light lamps, demonstrably improve health and well-being (originally developed for astronauts).
- Natural light varies considerably in brightness; sunshine during the day emits up to 100,000 lux compared with 0.002 lux in the darkness of the night. Even the applicable lighting standards recommend only 500 lux. Light that does not change in brightness destabilizes our circadian system.
- Natural light is diffused widely from above. Because the ganglion cells containing melanopsin in the eye are distributed across a large-area of the retina, it is assumed that the biological effect of light is greatest if the light comes from a source with a large area

CHAPTER 3

Effects of light on people **Visual**

- The spectral light distribution influences processing of emotional stimuli in the brain.
- Blue light increases our response to emotional stimuli.
- The color temperature and illuminance that are experienced as pleasant are on the one hand interdependent and on the other subject to cultural differences.
- Color temperature and ambient temperature mutually influence each other:
  Low ambient temperature = low color temperature (pleasant),
  high ambient temperature = high color temperature (pleasant)
- In natural light, there is:
  - Color contrast, blue and green cool (associated with cool places): red and orange warm (associated with warm places)
  - Quantity contrast, colors seldom occur in the same quantities in our natural surroundings.
- Above all, light should reproduce the colors in the room correctly; the color rendering index for this purpose is measured in Ra. 100 corresponds to natural color rendering.

CHAPTER 4

Effects of light on people **Emotional**

- Light creates an atmosphere in rooms, and this is primarily perceived emotionally.
- People's well-being increases in proportion to the lighting situation and how well they can see in the workplace.
- In a darker working environment, employees tend to be more creative and cooperative but less honest.
- In a brighter working environment, employees are more analytical and morally upright.
- Orange-colored and pulsating light support recuperation.
- Red has a positive effect on concentration.
- Blue enhances creativity.

CHAPTER 5

Effects of light on people
Summary

The potential of lighting is untapped

What good lighting can achieve:

- Lower the risk of heart disease
- Make the workplace more attractive
- Enhance attention and cognition
- Improve well-being
- Reduce sleep disorders and reset the inner clock
- Increase sales figures
- Act as an antidepressant
- Minimize cancer risk for shift workers
- Reduce errors

Recommendations from SSLerate – Lighting for people

- Morning: Artificial dawn helps people wake up faster and results in better well-being and cognitive performance during the day.
- During the day: High-intensity with large blue component to improve alertness, performance, and mood
- Adequate daylight supports nocturnal sleep; the same applies for adequate darkness during the night.
- Patients and elderly people require a more and better quality of light. Good light acts as an antidepressant. It adapts the circadian rhythm of the body clock to the natural day/night cycle.
- Both during the day and the night, intense blue-enriched light can improve alertness and vitality.
- Bright blue light during the last two hours before going to sleep negatively affects sleep onset and sleep. Low intensity and warm light (red and orange) disrupt sleep less.
- Bright and blue-rich light in the evening can cause a phase shift in the circadian rhythm. In contrast, the same type of light in the early morning can accelerate the circadian clock, causing people to feel tired earlier the following evening.
- In the night: Light reduces natural secretion of melatonin. Longer wavelengths and lower brightness help reduce the influence of nocturnal light on sleep.
- Exposure to bright blue-enriched light during the day helps make the circadian system less sensitive to nocturnal light. A greater contrast between day (high brightness levels) and night (darkness) helps stabilize the circadian system.

More information
available
in PDF format

Find out more about healthy lighting **Kesseböhmer Ergonomics**

Your contact partner for further information

Sibylle Pöhler
Product Manager

Phone +49 7023 108-3119
Mobile +49 175 2682626

s.poehler@kesseboehmer.de