LIGHT AND HEALTH

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СВЕТ И ЗДОРОВЬЕ

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This paper discusses how the effect of light is related to health, wellbeing and diseases, of both a mental and physical nature. This not only concerns the optimisation of vision and the visual performance range, but also the «creation of knowledge» as a harbinger of consciousness. Since most of the sensory stimuli that reach our brain are of a visual nature, this means that the processing of information inputs is mainly a visual activity. This processing and the associated visual behaviour is predominantly done in a neural way through the «visual system» and hormonally through the «non-visual system». These processes are explained and the associated research results, some of which have not yet been published, are presented. Results that predominantly concern the visual processes of perception also show the significance they would have if they were actually implemented. This also applies in particular to the «non-visual system», in which the hormonal components that are influenced by light, i.e. serotonin and melatonin, are considered in conjunction with the circadian rhythm with regard to the implementation of daylighting and artificial lighting systems.

Keywords: light, vision, health, visual processes

В работе обсуждается, как влияние света связано со здоровьем, благополучием и развитием заболеваний как психического, так и физического характера. Это касается не только оптимизации зрения и диапазона визуальных характеристик, но и «создания визуального знания» как предвестника сознания. Поскольку большинство сенсорных стимулов, которые достигают нашего мозга, носят визуальный характер, это означает, что обработка информационных входов — это в основном визуальная деятельность. Эта обработка и связанное с ней визуальное поведение преимущественно выполняются нейрональным образом через зрительную сенсорную систему и гормонально через «невизуальные» механизмы. Эти процессы объясняются и представлены соответствующие результаты исследований, некоторые из которых публикуются впервые. Результаты, которые преимущественно касаются визуальных процессов восприятия, также показывают значение, которое они имели бы, если бы они были фактически реализованы. Это также относится, в частности, к «невизуальной системе», в которой гормональные компоненты, которые находятся под влиянием света, в частности - серотонин и мелатонин, рассматриваются в сочетании с циркадными ритмами в отношении внедрения систем дневного освещения и искусственного освещения.

Ключевые слова: свет, зение, здоровье, зрительные процессы

Part 1

This paper deals with a discussion about the complex effects of light medium on humans' visual and non-visual systems.

This not only concerns good vision, but also the creation of knowledge, which is a prerequisite for raising awareness, and which in turn contributes to well-being and health.

Light influences the human body, influences our sense of well-being and maintains our health. The term «health» is defined by the World Health Organization (WHO) as the state of complete

— physical

— mental-emotional, and

— social well-being, and not only as the absence of illness and infirmity.

The brain's primary function concerns the «acquisition of knowledge» and it pursues this task through the «capacity to form concepts», writes neurobiologist Semir Zeki.

The essential foundation of this is the visual system as a source of sensory perception, as humans receive more information through eyesight, which is also part of our immediate visual field of activity. We are extremely dependent on our eyes and we live in a world that is largely adapted to being able to see. In fact, more than half of all sensory stimuli that reach our brain is of a visual nature, says Eric Kandel in his excellent book «The Age of Insight' [8].

It is my understanding that the brain, with its visual conceptions, and in particular that of daylight, it's course of time, the circadian rhythm that accompanies it, it's quantity and distribution as well as the spectral composition and changes as the day goes by, and thus the visual information associated with it in the surrounding environment, has a significant influence on our behaviour.

In my use of language and in my texts, «good light» means that high visual acuity and visual performance are essential criteria for our lighting technology. In addition, visual perception, i.e. recognition and the ability to pay attention and thus the expansion of what is conscious and unconscious, which in turn results from the processing of information in our brains, is a higher dimension and largely determines our behaviour.

«Good vision» is important, but is only an attendant component in the visual system. If vision is good, the processing of this «foveal field of vision» occurs via the neuronal nervous system and serves primarily to convey information. The neuronal processing occurs instantly. The visual system also adapts in order to meet varying visual conditions and copes with enormous differences in brightness during the day and at night, which range from EaSun ~100,000 lx in the direct sun to EaNight ~0.1 lx at night. Our visual organ is capable of adapting to these conditions and to continue seeing.

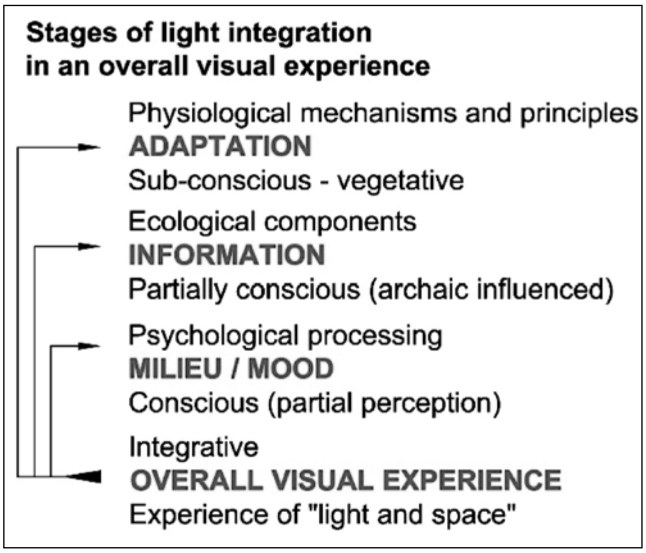

Fig. 1. Stages of light integration in an overall visual experience

The Visual System

The visual system refers to the visual processes that humans have. Its components are:

- Visual performance
- Visual perception
- Attention
- Information processing

When we refer to the visual system, we are concerned with optimising visual performance and the necessary prerequisites that lead to «good vision».

The key factors here are:

— The criteria of contrast sensitivity

— Adaptation processes

— The conditions of stable perception

Closely linked to this are:

— Luminance classification for the inner retinal and surrounding area in their visual field areas and their positioning

— The significance of textures and colour and their position in the visual space

Since about 80 per cent of the information processed by humans is a result of visual perception, the visual system's autonomous processes are crucial for the determination of good vision.

The mechanisms and processes of involuntary and divided attention are largely autonomous and unconscious. They are almost exclusively influenced by the vegetative nervous system. In order to gain or increase knowledge, however, focused attention and the creation of consciousness are necessary.

The range of visual information is so large that it cannot all be processed at the same time, as perception and processing would become diffuse. Selective attention reduces this range of information so that it can be processed.

The processes that lead to the optimisation of visual performance, i.e. «good vision», are adaptation processes, stable states of perception, contrast sensitivity and visual acuity, etc., as opposed to the visual physiological components. Flawless visual processes of optical perception as well as those of attention processes involving visual tasks and visual information are therefore prerequisites of well-being and health.

This includes the influence of the spatial visual environment, with its colours, textures, material surfaces and optical appearance. The resulting light and spatial environment has a significant influence on wellbeing.

These relationships are shown in the following diagram (Fig. 1).

Because the visual detection of an optical situation (space) is a complex mental process, it is necessary to approach the actual appearance of a space in several differentiated phases (Fig. 1). This process can be dealt with in the reverse fashion as well, as in many cases spatial concepts and appearances are determined by the owners of buildings and their architects.

In conceptualising lighting and spatial environments, it is important to realise that with visual perception and its processing operations, unconscious (autonomous) as well as conscious processes linked to awareness are involved.

Mental duress leads to fatigue and stress and can make a space uncomfortable. This can be caused by inappropriate lighting, textures or colours, and can lead to an inappropriate lighting and spatial environment. In addition there are disturbances caused by glare, which can be physiologically caused, but above all also by distraction and a reduction of attention, which then influence the state of consciousness.

One of the most important prerequisites is the balanced allocation of brightness for visual tasks. These con-

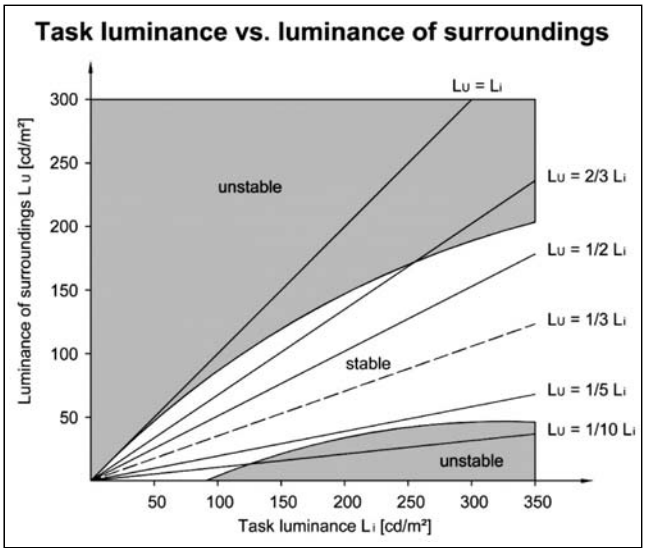

Fig. 2. Luminance ratios between task area and surroundings for stable visual conditions

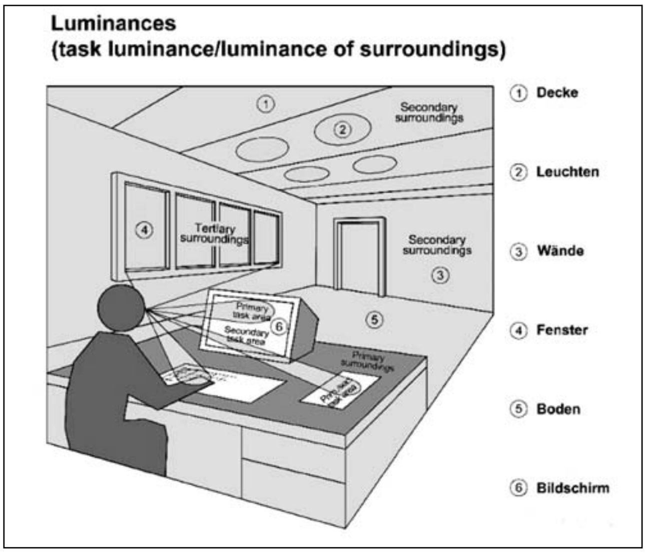

Fig. 3. Ergonomically relevant structure of the visual field in its spatial sub-components using the example of a computer workstation

siderations are part of the visual system. In addition, there is a change in the hormonal balance, which is part of the non-visual system.

As can be seen by looking at standards, the qualitative assessment of lighting is still based primarily on quantitative criteria. Although physiological components of vision are taken into account, they are not sufficient for us to have a true understanding of the complex process of visual perception.

This is necessary, however, in order to obtain objective findings on the basis of which the lighting qualities of rooms can be assessed with regard to various requirements (use, activity, visual tasks). An essential aspect is therefore to incorporate the findings of visual perception into planning processes, especially in the design and creation of the lighting environment.

For this reason, the focus in the design and creation of lighting environments should be on the aspect of visual perception. The individual components of the perception process can thus be used to extend the assessments of spatial appearance. The importance of design-related constraints such as colours, textures, materials and furnishings, etc. can be duly incorporated in order to be able to plan a holistic, integrative appearance on a visual basis.

Through the neurophysiological mechanism of adaptation, the eye autonomously (for the most part unconsciously) adjusts its sensitivity to brightness in response to constantly changing light conditions in its field of vision. Thus, fluctuations in brightness are seen as a largely invariant quantity. This is the primary prerequisite for a constant, i.e. relatively continuous, perception of space.

The condition that brightness (L) becomes an invariant is the «constancy of brightness through adaptation». This range is considered to be achieved when the adaptation process has reached its final state under the given luminance conditions.

In order to optimise the basic sensations of vision, and due to the changes that accompany active behaviour, it is necessary to stabilise the visual field of perception. The task area is surrounded by the spatial environment, which is visually included and defined by the field of vision. These relationships are shown in Figs. 2 and 3. The theoretical luminance model (Fig. 2) makes it possible to define an objective relationship between Li (task luminance) and Lum (surroundings that need to be determined for the conception and implementation of the planning process).

Interrelationships such as the ones shown above are frequently used in planning processes on actual projects, especially concerning office lighting (computer workstations). Tests carried out with many test persons (up to 40 people) have led to the recommended luminance ranges shown above and have also been described in a number of articles.

These results are shown in the series of images here, and the test methods used are shown in the table and Fig. 4. These results clearly show that if the luminance distribution in a space is not within the stable range of perception, effects on a person's health can be expected, which will particularly impair people's well-being.

The following models of optical perception and information processing were used as a basis for our research activities.

Test Room

Quantitative recording of psycho-physiological stress exposure under variable luminous ratios between task area and surroundings (Fig. 4, 5).

Fig. 4. Test room

Fig. 5. Test room

More than 30 lighting variations based on performance and fatigue variables were compared and a total of approx. 1400 persons (random sampling) were tested.

Some of the results (Fig. 6—7).

Dependence of visual performance on the colour locations. The results of these tests show (Fig. 8) that with objective methods of measurement, higher colour locations at computer workstations lead to significantly higher visual performance (objective test). The subjective test methods (surveys — semantic differential) allow us to make no significant statement, as shown in Fig. 9.

This assessment shows that, despite the high absolute TQ due to the high luminance of the window's surface (outside world), the clear window has similar values to the shaded window, which receives low task area values but also indicates a low self-luminance of the system. The window with the deflection system shows sufficient task area brightness of TQ ~3 per cent, which is lower than the values of the clear window but still has a luminance of 200 to 300 cd/m^2 of the window — which corresponds to the range of stable perception (the system was developed for this purpose) and thus shows the highest mental performance and least amount of fatigue.

Summary of Visual Performance, the Visual System

Visual performance is largely networked with the «autonomous processes» that control our visual processes. Through the focused area, the task area, the directed attention processes and awareness is stimulated.

As far as the processes of «conscious-unconscious» can be generally separated, and whether the emergence of states of consciousness occurs abruptly, i.e. is a threshold phenomenon or whether there is a smooth transition between unconscious and conscious states, is unclear (the neurologist Gerhard Roth says he thinks the latter is probable).

One can assign criteria of stable perceptual processes to the autonomous visual process. They form the basis for optimising the visual performance and are also the basis for creating a lighting and room environment that is appropriate to the task and supports well-being and health.

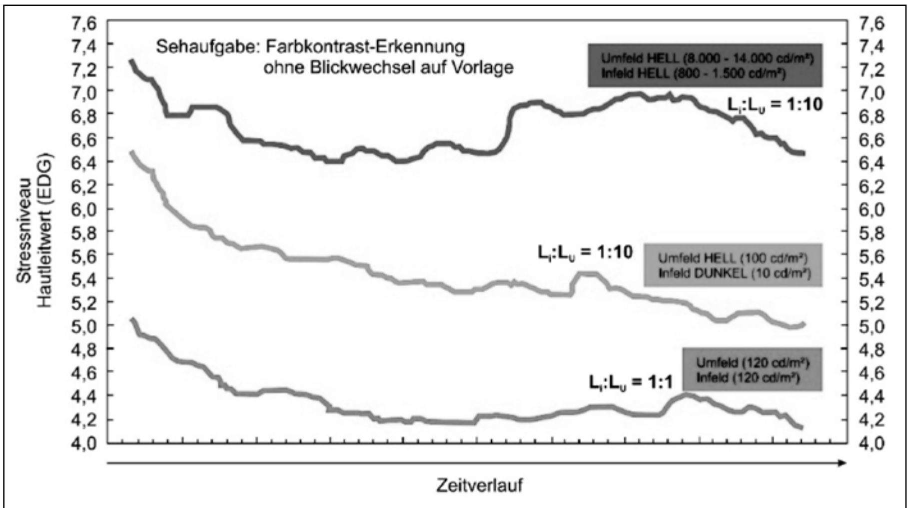

Fig. 6. Ratio of L_i to L_u, based on skin conductance (stress level) over time

The Non-Visual System

The non-visual system (timing system) has another purpose. It measures the slow fluctuations in luminance during the day and at night and reacts to the retina's «photosensitive ganglion cells», which are able to absorb light as an independent type of receptor. They are distributed

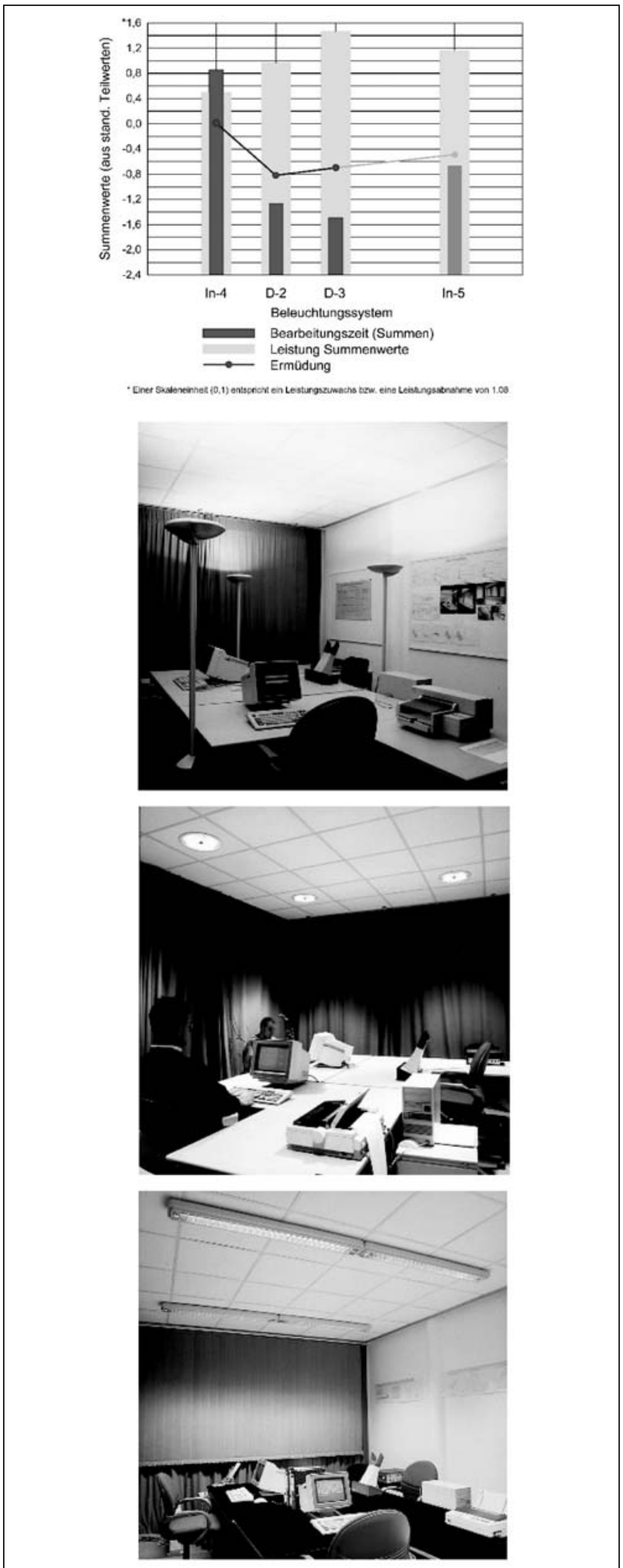

Fig. 7. Visual performance subject to visual performance, fatigue and processing time, using the criterion of lighting systems. The indirect system is to high ambient luminance unfavourable.

In-4 Floor lamps, indirect distribution; D-2 Round ceiling lamps, direct distribution; D-3 Specular louvre lights, direct distribution.

Fig. 8. Dependence of visual performance on the colour locations.

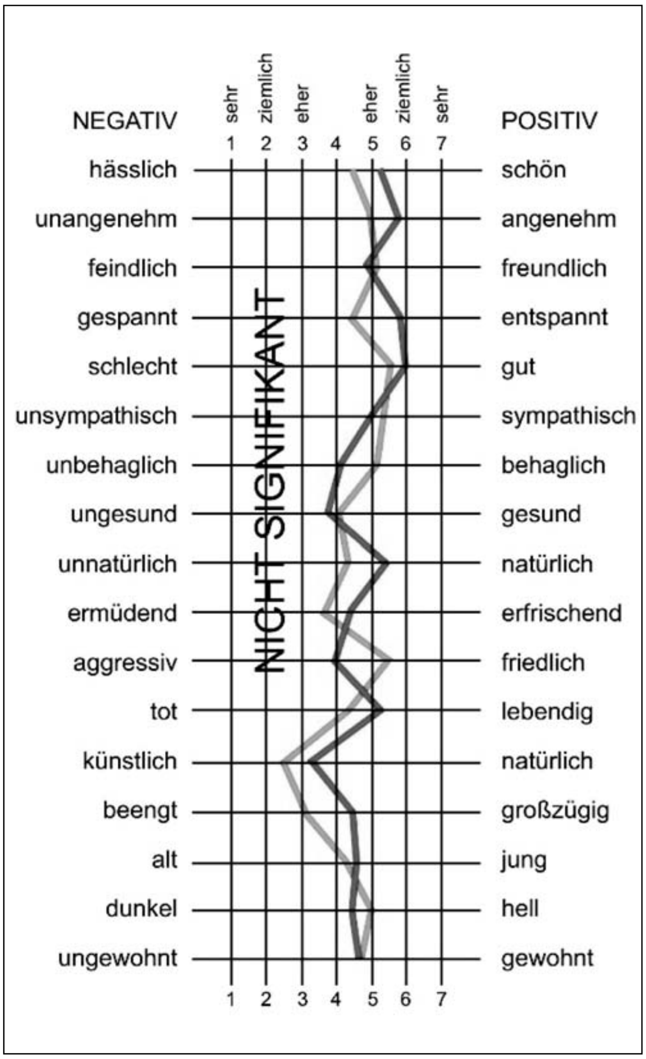

Fig. 9. The subjective test methods (surveys — semantic differential) allow us to make no significant statement

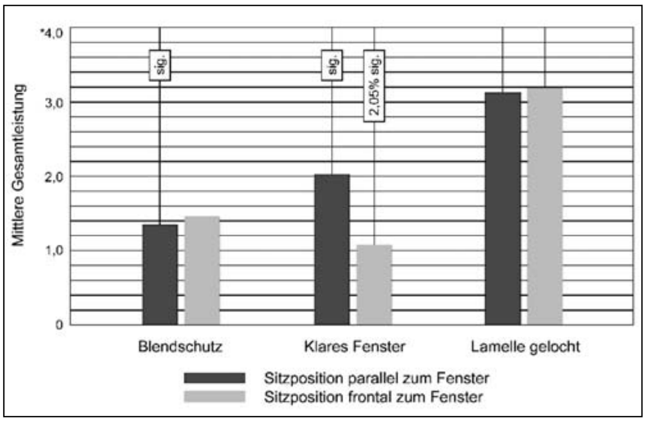

Fig. 10. 1 — Glare protection: Side window with screen (principle of shading); 2 — Clear window; 3 — Deflection vein: Mirror reflector elements and sun protection with ambient luminance (principle of light deflection)

over the entire retina and have the largest receptive fields in the retina, enabling them to efficiently collect light that provides information about light and darkness. They also receive input from the cones and rods and are thus part of the «visual system», and contain the light absorbing pigment melanopsin.

The photosensitive ganglion cells, which were first discovered in the last decade, act as a third type of photoreceptor alongside the cones and rods. They react in a less sensitive way and are much slower to light stimuli than the cones and rods' visual system, making them unsuitable for image processing.

They are, however, able to continuously respond to constant exposure, but only that with high intensity (daylight). This distinguishes the photosensitive ganglion cells, the third type of receptor, from the cells of the visual system (cones and rods) and they process and act differently as well, making them part of a non-visual system. These photosensitive ganglion cells are connected to the SNC (nucleus suprachiasmaticus, i.e. the inner clock), which monitors the circadian rhythm of the body as a central timer (Fig. 11).

It has been determined, that circadian rhythms such as...

sleeping — waking
rest — activity
influence on hormone control
such as melatonin,
serotonin, cortisone
digestion-detoxification
ultradian rhythm such as,
e.g. breathing,
heart, brain activity
infradian rhythm, such as
weeks, months, years, daily

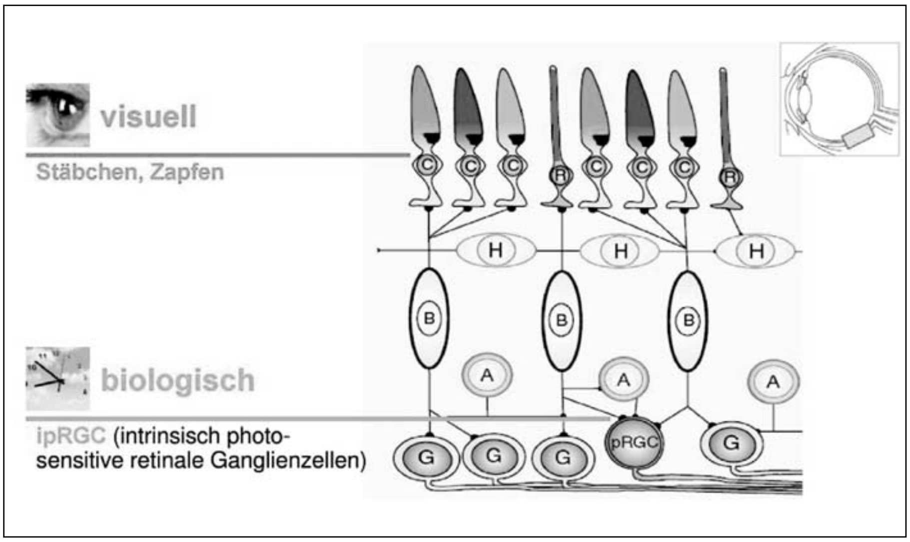

Fig. 11. Visual and non-visual effects are based on different receptors (Source: Osram).

...are controlled by this central internal clock (SNC). Since each cell has an internal clock and we consist of trillions of cells that have corresponding rhythms according to their functionally determined area, they are controlled and synchronised by the central clock (SNC). Just as a conductor leads his orchestra and acts as the timer, light via the SNC acts as a timer for our inner clock.

Bright light is one of the strongest timers. Especially daylight, with its rhythm, its distribution and its changes. The light that enters the eye is decisive, i.e. the vertical illuminance at the eye (EVA), which is the criterion for the light flux that enters the eye.

The question arises as to what is connected to the term «bright light» that is necessary to activate and bring to bear the third photoreceptors (photoreceptive ganglion cells), which serve as the basis of the non-visual system and the circadian rhythm? This is extremely important for the planning process, as knowledge about quantity and type of light used to achieve the desired effect is necessary and can be defined to a large extent.

Since it seems to be essential, as shown by research results and other chronobiological activities, that «light with sufficient brightness and a suitable spectrum» is available, according to daylight and its changes throughout the day, the circadian rhythm that occurs in our buildings — is stabilised by our inner clock and the timers. Daylight is the strongest and most important timer, but there are other strong timers inside buildings, other people and structures during the daily routine, such as a regular daily routine with fixed times for...

work — social contact — leisure activities — meals, etc.

These structures of time information keep our «inner clock» stable, in a 24-hour time rhythm. Regarding the internal clock (SNC), chrono biologists also see the central control of a higher-level pacesetter, whose primary task is to...

- repeatedly coordinate the complex human organism and the inner clock it has for its cell structure
- synchronise the inner clock with the outside world, e.g. every morning this pacesetter receives time signals (like a radio-controlled clock) via the timers in order to synchronise, e.g. switching to active during the day and less active during the night
- prevent disruptions: in the case of long-lasting disruptions, it once again begins to coordinate things with the external world

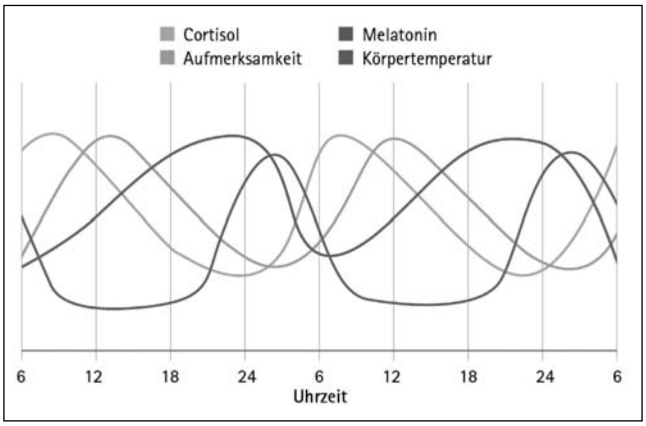

Fig. 12. Circadian rhythms of cortisol, melatonin, attention and body temperature

- prepare for upcoming events, e.g. during sleep to prepare for the «waking state» in the morning.

And thus, the foundation for the optimisation of the non-visual system and therefore for well-being and health has been laid. It can also be said that health will be influenced if internal or external harmony and order are inhibited by physical, mental or social processes.

In real terms, this means a corresponding expansion of the design of daylighting and artificial lighting, and the resulting requirement with regards to the type of daylighting openings (e.g. skylights) there should be with daylighting systems and the necessary building structure that «lighting design» requires.

The SCN (suprachiasmatic nucleus) is the anatomical domicile of the biological clock. It checks and coordinates, together with a semi-autonomous system with inner organ clocks, numerous daily rhythms, «vegetative functions» and the hormonal blood level using a hierarchically structured system.

The rhythms shown in Fig. 12 modify sensations and states of mind, and thus form the basis for daily rhythmic patterns of behaviour [2]. Synchronising factors in the environment are called timers, and as already mentioned, the decisive human timer is daylight and the rhythm inherent in it.

The second part of the paper will be published in the next issue of the journal.

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