LIGHT AND HEALTH. PART 2

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Свет и здоровье. Часть 2

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This article is the continuation of the article «Light and health», published in the Journal in 2018, №1. It deals with the influence of light on the hormones serotonin and melatonin. On the one hand, the importance of daylighting on serotonin production and our research work and results concerning this topic will be presented in this article. For the synchronisation of the inner clock daylight is essential. Our indoor society works and lives in spaces with a lack of natural daylight. The indoor (standard) illuminances may be enough for certain visual tasks but for the synchronisation of the circadian rhythm higher illuminances are needed. This can be achieved by light guiding systems as illustrated by application examples in this article. Light guiding lamella harvest the light and guide it to the reflective ceiling and therefore to the depth of the room. A conventional glazed façade is «repaired» by this light guiding systems. The more appropriate measure to improve daylight quality in buildings is another one: Daylight should be the decisive design parameter in the architectural designing process — new building typologies should be created. Additionally, in this process the knowledge about the avoidance of glare and the creation of visual comfort is crucial. On the other hand, the effect of light at night is discussed in this article. The melatonin secretion is suppressed by exposure to light which has a negative effect on our health. This topic concerns everybody, but especially people that are working during the night. Studies that aimed at preserving the melatonin production at night have provided insights into the necessary spectral distribution, the lighting system and the light and space atmosphere that is created. We have defined a melatonin-preserving spectrum for a laboratory research. The results of this research, which was carried out during the night and used high light with sufficient illuminance for the visual tasks was that with the melatonin light, production of melatonin was maintained to a significant degree. In further consequence we have implemented this melatonin sustaining light in our projects (e.g. Psychiatric Hospital Slagelse, Denmark). The melatonin light serves as «night light» for the patients and the stuff and should be applied to the whole building.

Keywords: serotonin, melatonin, night light, light guiding lamella

Данная статья является продолжением статьи «Свет и здоровье», опубликованной в этом журнале в 2018 г., №1. Он касается влияния света на гормоны серотонин и мелатонин. С одной стороны, важность дневного освещения для производства серотонина и нашей исследовательской работы обсуждаются в настоящей работе. Для синхронизации внутренних часов необходим дневной свет. Наше общество работает в помещениях и живет в местах с недостатком естественного дневного света. Внутренних (стандартных) освещений может быть достаточно для определенных визуальных задач, но для синхронизации циркадного ритма необходимы более высокие интенсивности освещения. Это может быть достигнуто с помощью световодных систем, как показано на примерах в этой статье. Светопроводящая пластина собирает свет и направляет его к отражающему потолку и, следовательно, к глубине комнаты. Обычный остекленный фасад «монтируется» с помощью этих световодных систем. Более подходящей мерой для улучшения качества дневного света в зданиях является другая: дневной свет должен быть решающим параметром в процессе архитектурного проектирования — должны быть созданы новые типологии зданий. Кроме того, в этом процессе крайне важны знания о предотвращении бликов и создании визуального комфорта. С другой стороны, в этой статье обсуждается роль света в ночнове время суток. Секреция мелатонина подавляется воздействием света, что негативно влияет на наше здоровье. Эта тема касается всех, но особенно тех, кто работает ночью. Исследования, направленные на сохранение производства мелатонина в ночное время, позволили получить представление о необходимом спектральном распределении, системе освещения и создаваемой световой и космической атмосфере. Мы определили спектр сохранения мелатонина для лабораторных исследований. Результаты исследования, которое проводилось в ночное время при высокой освещенности и достаточной освещенности для визуальных задач, заключалось в том, что при освещении соответствующего спектра продукция мелатонина поддерживалась в достаточной степени. В дальнейшем мы внедрили этот поддерживающий синтез мелатонина свет в наших проектах (например, в психиатрической больнице Слагельсе, Дания). «Мелатониновый» свет может служить ночником для пациентов и должен применяться для лечебных зданий такого типа.

Ключевые слова: серотнин, мелатонин, ночной светильник, светопроводящие пластины

Serotonin

Serotonin mainly works in the limbic system. This is the part of the brain that is responsible for our mood and emotional memory. Serotonin elevates feelings of well-being and has a stimulating effect, hence the name «happy hormone».

Serotonin is a neurotransmitter (biochemical substances that pass information from one nerve cell to another) that functions in the central nervous system, intestines, cardiovascular system and blood.

We know that one of the factors that causes the production of serotonin in our bodies is light — sunlight

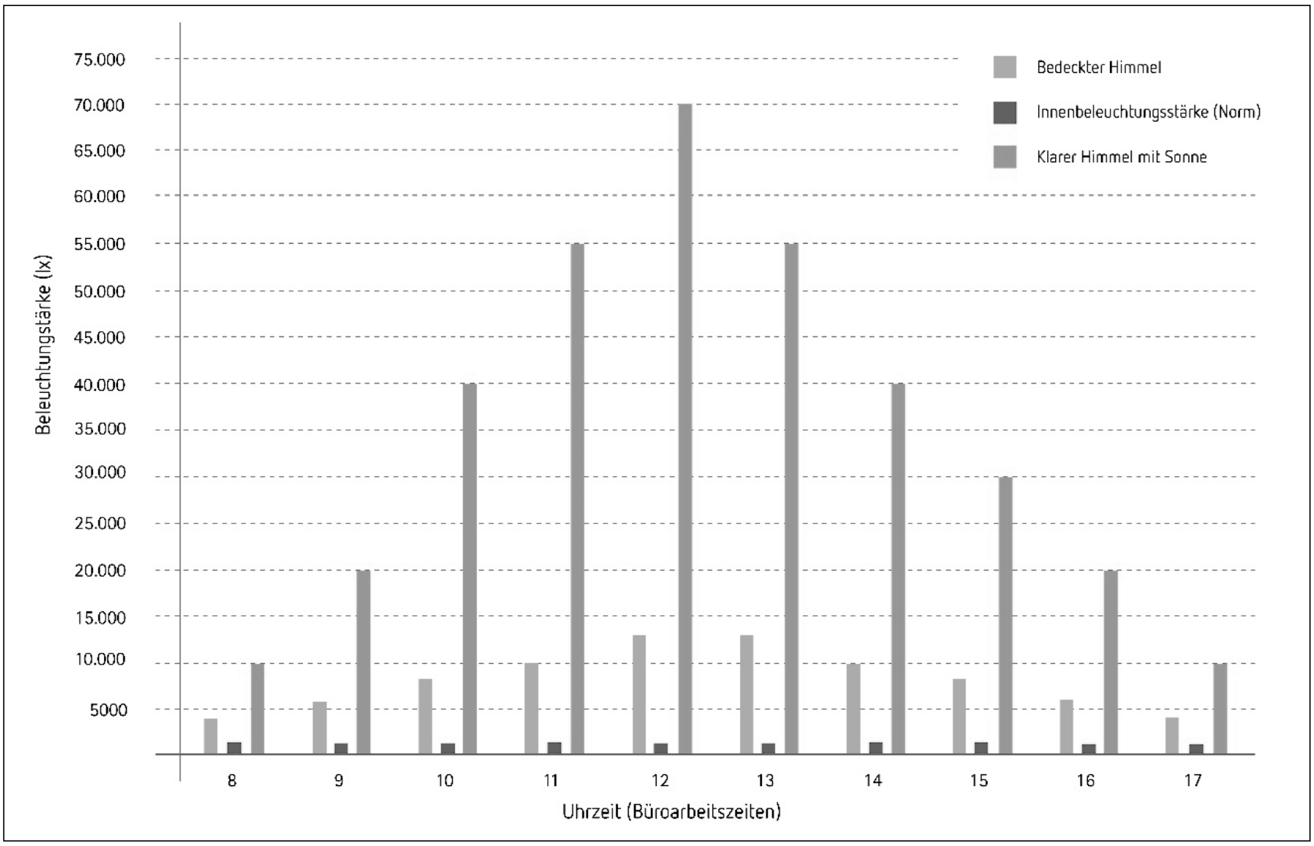

Fig. 1. Dynamic outdoor illuminance levels (lx) throughout the day: overcast sky illuminances (grey columns), clear sky illuminances (orange columns) compared to indoor light levels (red columns) according to the standards (Table from the book Melatonin by Russel J. Reiter, p. 229). Illustration of real daylight situations

and other forms of daylight. Even artificial light of a certain quantity and quality (spectrum) can achieve this effect. Because too little light leads to a deficiency of serotonin, depression can occur (an indisputable fact). This is also the reason why light therapy is used to improve light deficiency and successfully prevent any subsequent depression.

An American study carried out in sunny San Diego (Russell J. Reiter 1994) shows how little time we actually spend outdoors. On average, middle-aged adults spend about 4% of their time outside, and about half of this is in cars, so that most people spend 97 to 98% of their time indoors.

Because a daylight factor of DF = 2 to 3% is considered to be an adequate amount of daylight indoors (only visual performance is usually taken into account here), we usually find ourselves in a twilight-like atmosphere. Although this is enough for good vision, it does not satisfy the requirements of non-visual systems, as shown in Fig. 13.

Quantitative criteria developed for visual systems in real applications amount to approximately DF = 2% for office work during the day. If this level of brightness is not sufficient for the immediate activity, it is supplemented with artificial light. With regard to distribution, the term «daylight factor» is based on a standardised, diffuse overcast sky that varies with respect to brightness over the course of a day and year, and to the meteorological process.

People generally live in rooms that only have a fraction of the amount of light (2 to 4%) found outside. We create a kind of twilight that is usually sufficient for the necessary visual performance, but the rooms are not natural illuminated as rooms full of daylight would be.

The consequences of this are that light therapy is used if symptoms of depression occur. It is necessary, however, to design the light and atmosphere of rooms in a way that daylight allows to produce enough serotonin so that light therapy is not necessary in the first place.

The absolute brightness of daylight outdoors, it's temporal change, it's scenarios and the way it is transmitted to the interior rooms all have a great influence on the atmosphere of indoor spaces and thus on our well-being and health. As can be seen in the diagrams in Fig.1, there is certainly a sufficient amount of daylight in our world. It is available to us free of charge and we are biologically adapted to it. It is, however, urgently necessary to bring it into our rooms at the right time and in sufficient amounts.

Our concern as lighting designers should be that the level of daylight and artificial light inside buildings be

Fig. 2. Small area light therapy devices (standard market products)

of such quality that the interior environment harmonises with the production of serotonin, making any additional light therapy unnecessary.

That is the goal. This raises the question of which visual criteria we apply and how they have to be designed to meet the requirements.

Visual criteria for the support of serotonin production:

- Amount of light
- Exposure time
- Spectral composition
- Visual conditions for the optimisation process of visual performance and well-being

Research carried out by the Lichtlabor Bartenbach, the Competence Centre and the University of Innsbruck (psychiatry) professor Hinterhuber, have determined that the illuminances necessary for the production of serotonin are, for example

2500 lx over a period of 2 hours

5000 lx over a period of 1 hour

This corresponds to luminances of L= 3000 cd/m^2, which can be achieved by using small area light therapy devices, Fig. 2 (general recommendation)

If you want to distribute the lighting level over an entire room, the spatial angle (field of view) increases many times over (approx. $\omega = 1{,}26\pi$) and the brightness supporting the production of serotonin becomes considerably less but much more feasible. Such a visual space becomes therapy simply due to its «new brightness».

Planning processes require that all necessary luminance values be very precise, as they have a great influence on determining the amount of light and its distribution within a space, and thus significantly influence the location and geometry of openings that allow daylight in. This is one of the main requirements of designing a space.

The hypothetical assumption is that if brightness supports or enables serotonin production, while considering the spectrum and the effective duration of light, then this is also sufficient for maintaining the circadian rhythm.

Three studies were carried out. Common to all three were the ranges of luminance (Lu) to be tested:

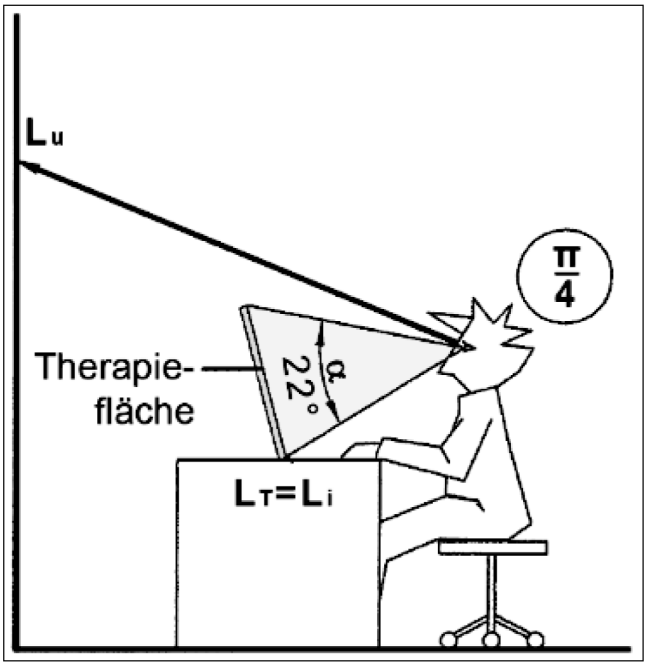

Fig. 3. Visual study of a therapy device. It is recommended to use 2500 lx for 2 hours

1st test series 80–1500 cd/m^2

2nd test series 33–130–1462 cd/m^2

3rd test series 11–274–770 cd/m^2

Description of the Procedure

Tryptophan depletion (TD), an established method of influencing the serotonergic system and mood, was carried out. The purpose of this study was to assess the effect of the TD under different light conditions using serotonin — associated plasma levels and a visual analogue scale (vAS), measured in healthy women. 215 female students were recruited by the Medical Faculty in Innsbruck (report reference). The results of these studies concerning an increase in serotonin are shown in Fig. 4.

In summary, the results of all three studies showed that ambient light (average ambient or visual field lumi-

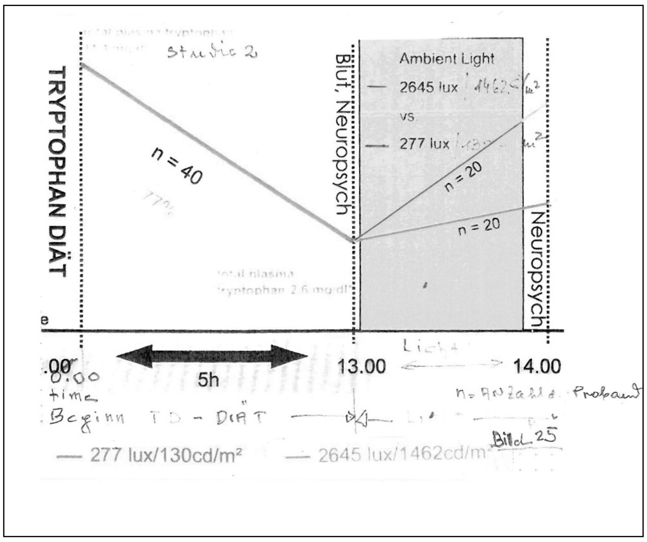

Fig. 4. The result after a five-hour tryptophan diet of the test subjects with subsequent exposure to light showed that the rise in serotonin already begins at L_u = 130 cd/m². Design of the 1st and 2nd test series

Fig. 5. Test situation. In such seating positions (arrangements) the field of vision has a spatial angel of $\omega = 1{,}26\pi$ and in the visual process of perception, visual field luminance (ambient luminance) has an average L_u value

nance in cd/m²) of L_u = 11–1500 cd/m² shows a significant influence on cerebral serotonergic systems. In addition, the results (Fig. 4) indicate that bright ambient light can have a positive effect on mood, even with lower brightness levels than those recommended in conventional light therapy (2500 lx/10,000 lx).

It was found that bright light is not only more effective than dimmed light (80 cd/m²) in improving dysthymia (circadian rhythm disorder) after a tryptophan diet but is also effective for other emotional and cognitive functions.

The results of Fig. 4 show that a serotonin increase occurs even at L_{um} ~ 130 cd/m². These investigations were carried out in a joint KPZ research project at the University of Innsbruck (psychiatry), headed both by professor Hinterhuber and Bartenbach.

Tendencies indicate that serotonin production occurs even at lower ambient luminance levels then are generally recommended for bright light. If we consider that the length of stay indoors is usually 3 to 4 hours and that our daily rhythms are caused by different intensities of brightness, distributions and appearances, it is often possible to achieve sufficient brightness at geographical locations at peak times of the day and year.

As can be seen from the results of another study, a significant increase in serotonin production even occurs at Lu ~ 270 cd/m²

These results are significant and allow us to conclude that brightness levels of Lu ~ 130–1.500 cd/m² over a two-hour period of time spent inside not only enable and support serotonin production, but are also a prerequisite for maintaining and facilitating circadian rhythms. They thus have an effect on the autonomic nervous system as well as on our mood, well-being and health.

When planning a daylight environment, it makes sense to ensure that the luminance ranges, which can change according to external brightness (circadian rhythm), are within the range of the theoretical luminance model, thus synchronising the visual and non-visual systems. As serotonin production begins in the morning, it is a good idea to consider this in the planning process and make it possible early in the day. Experience has shown that the level of serotonin will last an entire day and is also the prerequisite for subsequent melatonin production. Because the time required for serotonin production with higher average luminance should be approximately 1 to 2 hours, room environment scenarios can be limited to this period of time. Projects have already been carried out based on these findings.

The office illustrated in Fig. 6 has been optimised using a daylighting system — a 30° specular reflector lamella that provides sun protection and works at the same time as a light guiding system (two part-system).

Synchronisation of the inner clock is possible in this office room. On an overcast day in the depth of the room additional artificial light is required.

In this spatial environment (Fig. 6) visual performance is sufficient as the amount of daylight is more than DF = 3% and the distribution of daylight corresponds to the visual tasks. Artificial light is used when required, glare and distraction do not occur here. The amount of daylight is not enough to ensure serotonin production. The circadian rhythm is supported by a change in external brightness, especially in the room in Fig. 7. The amount of light can be partially increased through the use of the sun (Fig. 7), supporting both serotonin production and the circadian rhythm, whereby synchronisation is

Fig. 6. Daylighting systems, BMW Headquarters Munich

Fig. 7. Daylight design, Deutsche Bank Berlin

achieved during the period of possible sunshine duration (solar use).

In summary, it can be stated that in the case of buildings that have external light coming in from the facade, the goal of a synchronisation of the visual and the non-visual system can be achieved by using daylighting systems (that are guiding the sunlight into the room without causing glare).

Melatonin

Melatonin is a metabolic product of serotonin. It is known as a sleep hormone and is mainly produced in the pineal gland.

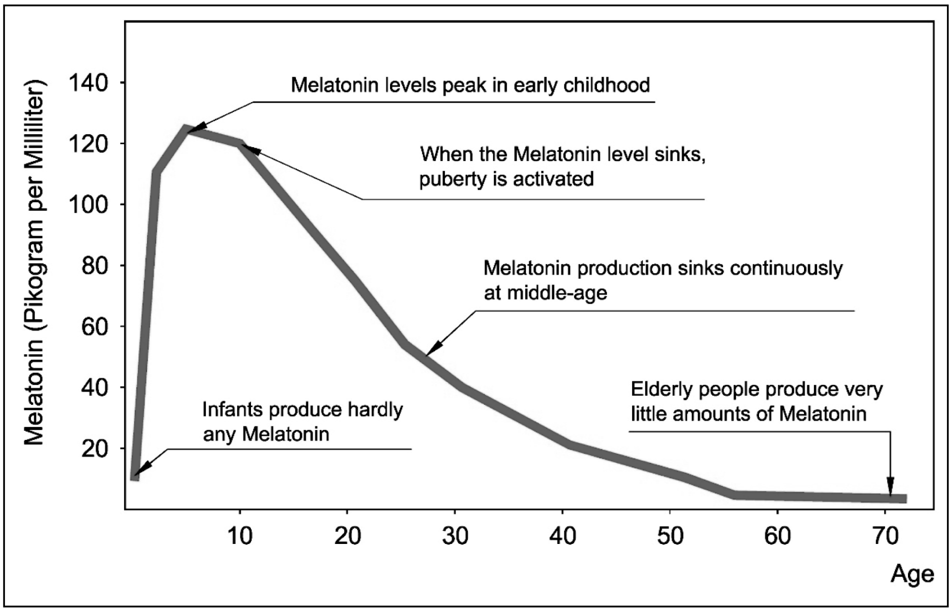

Fig. 8. Melatonin production depending on age (source: Russel J. Reiter, Melatonin, University of Texas, USA)

The production of melatonin is primarily influenced by the light that humans absorb through their eyes. As a metabolic product, melatonin is produced during the night and serves to help people fall asleep as well as regulate bodily functions during sleep. Bright, full spectrum light that hits the retina triggers a signal that inhibits the release of melatonin. Melatonin deficiency causes sleep disorders, weakens the immune system and reduces regeneration at night.

A major American study was made that investigated approximately 150,000 nurses who work the night shift under artificial light. It was found that the production of melatonin was reduced, and that colon and breast cancer increased by approximately 35%.

It is believed that during the night melatonin…

- protects against cancer (captures free radicals)
- protects against Alzheimer's
- prevents strokes and heart attacks (blood clots are prevented)
- activates the immune system
- inactivates the reproductive system
- promotes regeneration through sleep
- acts as an antioxidant

The maximum secretion of melatonin occurs between the ages of one and thirteen. Melatonin production in the pineal gland decreases by approximately 80% when adulthood is reached. Melatonin is sometimes referred to as a youth or growth hormone. Gerontological researchers assume that this hormone delays biological ageing and has a life-prolonging effect.

During the months when there is little light, the body does not break down excess melatonin sufficiently during the day. This leads to a disturbance of the sleep-wake cycle. At high levels of brightness, melatonin production is abruptly suppressed. This suppression during the day is, as mentioned above, important. According to research, this would otherwise lead to too much melatonin or melatonin that has been secreted for too long during the day, which would negatively influence winter depression and would also influence the stability of the circadian rhythm.

It also appears to be important that enough serotonin be available during the day, because, as already described, it is an essential component to produce melatonin. As mentioned, the circadian rhythm is one of the prerequisites for the functioning of the non-visual system.

The light-dark cycle's connection to the outside world is through the eyes, which are a source of sensory input to the nerve pathways, whose origin is in the retina and through the SNC to the pineal gland. This is also the most important producer of the hormone melatonin. It is the body's own signal for the night. White light, and especially that with a full spectrum, triggers signals that inhibit the release of melatonin.

The pineal gland is not only the producer, but also the mediator between the circadian rhythm and the endocrine functions that secrete hormones in our blood and organism. Almost all the body's cells are informed by the level of melatonin in the blood with regard to when the day ends, and when the next morning begins.

Melatonin primarily controls our biological clock and is one of the essential prerequisites of our circadian rhythm and our health. In order to integrate this general consideration of the handling and implementation of the non-visual system in the planning process, a number of questions must be answered, making research and development necessary.

Lighting Effect and Melatonin Production

The effect light has on the production of melatonin depends on its intensity, its distribution in an interior space and the vertical illuminance at eye level, as well as on the spectral composition of the light that reaches the eye and the course of time, as light intensities and spectra fluctuate according to the time of day and year.

Using the sensitivity curves of the photopic, scotopic and circadian processes, the melatonin retention function was worked out and shown in Fig. 11. It is also the case that the effective spectral distribution on which the colour location is based, is generated in a room through the spectrum of the light source, the types of reflections (indicatrix) of surfaces of the walls and the of multiple reflections in the room.

The general prerequisites and level of knowledge about melatonin as a basis were developed in detail in a research project (KPZ 35) carried out by Bartenbach Lichtlabor's Austrian Competence Center together with the UMIT in Hall, professors Schobersberger and Hoffmann. The objective was to define the spectral progressions with sufficient brightness at night and at the same time to enable visual performance using a lighting system or light source whose spectral distribution on the eye maintains the production of melatonin. The multiple reflections in the room, their reflection values and reflectance properties as influenced by a steady state were all taken into account regarding how they determine the eye's colour location.

With these requirements in mind, two test rooms were set up, whereby Test Room 1 (V1) was illuminated with melatonin light, while Test Room 2 (V2) was illuminated with white light. With the exception of the differentiated spectra, both rooms had the same lighting indicators and technology, and the same visual activities (Fig. 9).

The spectra that are appropriate for use are shown in Fig. 24 as an example.

Day and night work study

Test Room 1

spectrum melatonin light (Fig. 12)

$T_f \sim 2500$ K

LED light sources «test light»

The spectral distribution of the light with $T_f = 2500$K is shown in Fig 12.

Test Room 2

white light, spectrum —

fluorescent light $T_f \sim 6300$K

normal light

The results of this extensive research, which was carried out during the night and used high light intensity (EV = 800 lx and $L_u = 310$ cd/m^2) was that in Test Room 1 with the melatonin light, production of melatonin was maintained to a significant degree. In Test Room 2 with the fluorescent lights and a colour temperature of 6300 K, the production of melatonin was greatly reduced (Fig. 11).

Performance tests (visual system) were carried out during a simulated night shift. With neither the visual perceptual performance nor the processing of cognitive information and motor response organisation was there any significant difference between the test lights and full-spectrum normal lights. As described above, the production of melatonin in Test Room 2 was reduced.

The spectral distribution of a light source that corresponds to melatonin light can be determined from the so-called melatonin suppression/maintenance curve (Fig. 13).

Fig. 9. Test room 1

Fig.10. Test room 2

It should be noted, however, that...

— it is objectively possible to maintain melatonin production in the intensity range of L_i = 80—300 cd/m^2 and L_f = 15—75 cd/m^2

— the spectral transitions that lead to night or rather melatonin light brought about by daylight, daylight supplementary lighting and the transition to artificial light need to be objectively determined

— the visual forms of behaviour in question need to be objectively analysed

— luminance ratios (with their accompanying technical lighting codes) and the spectral progressions that occur in the circadian rhythm over the course of time and with transitions need to be determined and the melatonin light associated with this process is to be tested comprehensively with regards to its feasibility of production

— the acceptance of such light in room environments needs to be subjectively investigated, as melatonin light produces unfamiliar light and room environments due to its low blue content and low colour location. Temporal and spectral transitions for behavioural aspects of acceptance (appearance) are therefore dominant.

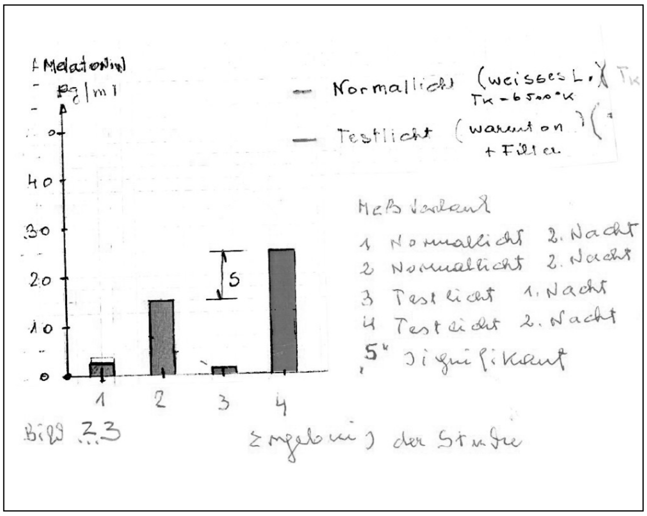

Fig. 11. Measurement process:
1. Normal light 2nd night 10pm
2. Normal light 2nd night 6am (morning)
3. Test light 1ST night 10pm
4. Test light 2nd night 6am (morning)
5. Significant

The Determination of Melatonin-Maintaining Spectra

Method:

The melatonin suppression curve serves as the theoretical starting point, and acts as a base for designing a melatonin maintenance curve (Fig. 13).

There is a relatively wide range below 2500 K to 1500 K, and especially below 2000 K, where no reduction in melatonin is indicated. The spectra used in Test Room 1 have already shown that melatonin production is present even at high intensities of EV = 800 lx und L_u = 310 cd/m^2.

If the stipulation to maintain melatonin production is met, melatonin light will exclusively or consistently become night light, meaning that the basic principles of good lighting design, as already mentioned above, must be observed.

This means that so-called «night light», during which the various activities at night occur, must also ensure high visual performance, while making relaxation and well-being possible as well. According to the biological process that takes place in the circadian rhythm, humans should sleep at night and regenerate themselves in the process. In our society, however, this is no longer possible to this extent, as night has literally been turned into day. Artificial light is now used for all night-time activities. Up to the 19th century, fire provided light, but today there is a wide variety of light sources.

We have to be aware of the fact that night light is human-made artificiality. It is similar to a tool that has been changed or improved over time. Fire, the oldest and longest-used light source, has accompanying phenomena such as warmth, comfort, closeness, and well-being.

This type of night light does not inhibit melatonin production. It would thus make sense to determine the appearance of the different spectra at such low colour temperatures and the associated notions of appearance, especially as visual performance and diverse lighting and room environments are also determined by such requirements.

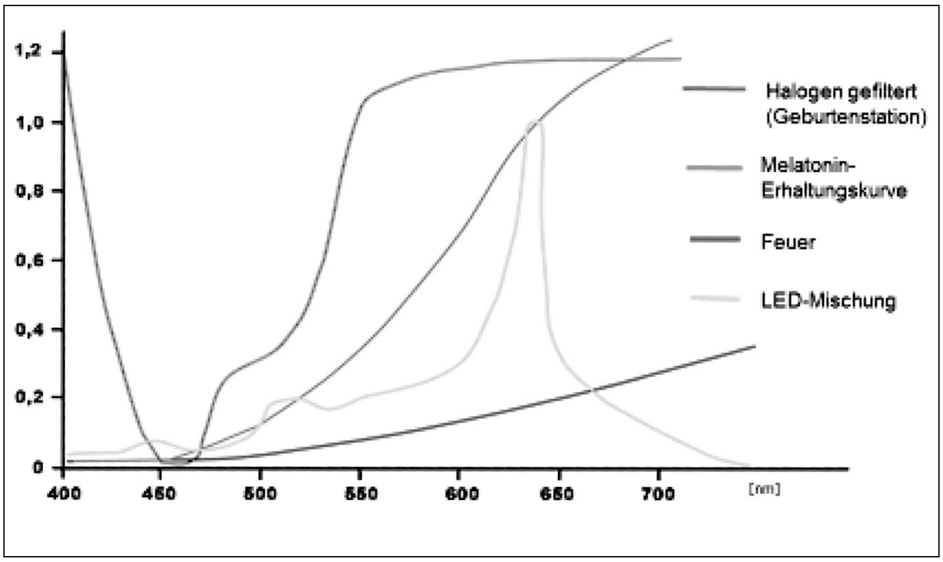

Fig. 12. Possible spectral range for the melatonin maintenance function

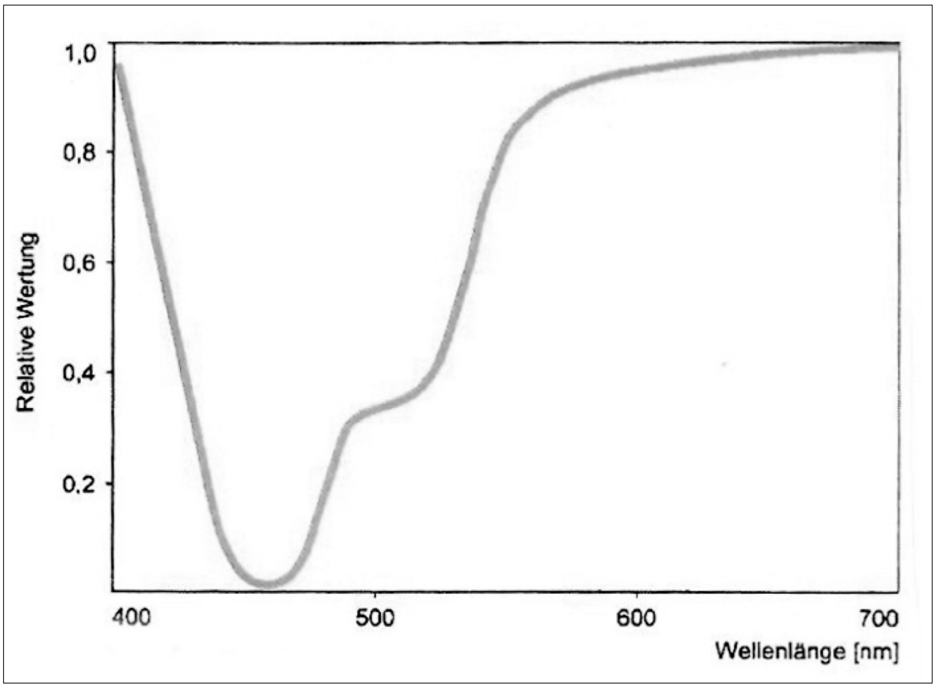

Fig. 13. Melatonin maintenance function, light spectra that can be used to maintain melatonin production can be derived from this

This shows that it is possible to determine a spectral range that is suitable for the corresponding intensities of light (visual performance) while also maintaining melatonin levels. When designing a melatonin-preserving light milieu, the following criteria must be taken to into account:

— L_i/L_u intensity / distribution / visual performance — objective

— state of mind / well-being / HRV

— adjustment processes.

Possible Applications

Night light, whose spectral range should be within the melatonin maintenance curve shown in Fig. 13, will be a continuous spectrum and have a colour temperature of 2000K±3000K (hypothesis).

From the results of the studies, as mentioned above, it could be concluded that using such colour temperatures and suitable spectral progressions, a light and room environment could be created that will be both objectively (sustainably) and subjectively accepted.

The change from daylight to night light is, if not made abruptly, unproblematic. Room surfaces using the reference colour white objectively show no significant HRV differences at colour temperatures of 3000/4000/6500K. Subjectively, more pleasant properties were assigned to the test rooms using 3000K. This also emerges from an interview of the test subjects with melatonin light.

Similar results can be found in the studies of night shift work. This study of night shift work is also based on findings that light environments with low colour temperatures were broadly accepted and were in this case also desirable. For the application in general, it becomes clear that the respective activities and usage processes can be attributed to the correspondingly necessary optimised visual services. It is therefore essential when conceptualising night light that the spectrally critical range is designed using wavelengths between 450—550 nm, so that even at intensities of L_{max} = 250 cd/m^2 melatonin production is maintained.

In addition, the areas of activity, that determine the task area Li are not only adapted in intensity, but also partially zoned and thus differentiated accordingly. The task area is a maximum of 20° of the visual field of the fovea, which is about 2 to 3% of the entire visual field. Of great importance for the formation of a sensitivity to differences and for focused attention is, however, the medium environmental impact, which covers a majority of the visual field, and which is thus decisive for one's state of mind when designing a lighting and room environment.

The relationship between ambient luminance, colour temperature, texture, colour, form and the features of the light sources or the light system must be understood.

As a guideline for system development, it is certainly necessary to take the spectral possibilities of this system into account in such a way that they correspond, for example, to the spectrum illustrated in Fig. 13.

While with such concepts, visual performance (UE) and directed attention should be maintained if possible while using night light, the entire appearance of the room is changed.

In time, using chromatic adaptation (especially with white room surfaces), familiarisation and acceptance will grow. As such adaptation processes must be optimised and allow for many possibilities, as shown in figure 13, it is necessary to determine this spectral range through psychological experiments on both an objective (HRV) and subjective basis (semantic differential).

System conception for separate functions is:

— direct lighting systems with 2×30° (LED) with system luminances (L_{max} = 80 cd/m^2) that occur outside the distribution cone, reflective with adjustable optics

— equipped with a basic spectrum for the maintenance of melatonin

— wallwasher LED
with direct wallwash
in zonal areas
with additive overlay
determinable (different size spaces)
adjustable intensities
self-illuminance outside of distribution cone (L_u = 40—80 cd/m^2)
basic spectrum for the maintenance of melatonin
variation of blue proportion
spectral adaptation to the surface of materials
control

In summary, it can be said that light inhibits nocturnal melatonin production. The main objective is to develop a light spectrum that does not impair melatonin production and that satisfactorily meets the visual requirements such as:

— visual performance (UE = directed attention)
— well-being and health aspects (HRV)
— acceptance of the resulting spatial environment for the visual area of work and living.

If one considers the general trend and thus also the importance of the melatonin hormone, it can then be assumed that in future melatonin production should be maintained during the night.

This means that artificial light at night will be used in an integrated way as melatonin-maintaining light. Since human activities at night are many-faceted, the optimisation of visual performance and maintenance of directed attention is important.

And therefore, the range of task area luminance with L_i = 80—300 cd/m^2 and ambient luminance with L_u = 15—80 cd/m^2 was adopted from the research results. The spectral distribution of the spectrum that falls on the eye and, above all, the environment (L_u) that surrounds the visual field has a significant influence on mood; within the space these are the room-defining reflective room surfaces.

This realisation is based on the results of research work but is at this time not sufficient for the development of a sound planning framework or products.

It is therefore a goal to create melatonin light whose spectral distribution maintains melatonin production at night (night light), while permitting the necessary luminance ranges (L_i = 80—300 cd/m^2, L_u = 15—80 cd/m^2).

This makes it possible to design light and room environments that have optimal visual conditions of perception and directed attention.

As far as sensitivity is concerned, it is important to set the colour temperature at the eyes, which is mainly caused by steady state equilibrium and the modulation of light on the surfaces of the immediate environment, as this increases the objective criterion of HRV and supports parasympathetic processes.

The effect of the sensitivity of the mean ambient luminance Lu, which is a result of the entire surrounding visual field, can be evaluated using the HRV criterion. This mainly influences mood and thus well-being. The luminance ranges are dominated by Lum.

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