

## HUMAN LIGHT RESPONSE VIA SKIN, EYE AND BRAIN

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### ABSTRACT

Ultraviolet light from sunlight unfolds a variety of different photophysical and photochemical activities in human skin, which are controlled and reacted upon by two photoendocrinologically active antagonistic organs in the brain, namely the pituitary and pineal gland, under the control of the eye.

There are also two organs for light reception, namely skin and eye. These systems have been attuned by the course of evolution under the frequent influence of sunlight. Human genes only know how to react upon bright light with the spectral composition of sunlight. Understanding this heliotropic logic behind the coordination processes between skin, visual and energetic portion of the retina and photoendocrine regulation in the brain is essential for creating a reliable concept of healthy artificial lighting.

Keywords: Photoendocrinology, pituitary and pineal gland antagonism, photochemical light reactions, stress.

### 1. INTRODUCTION

Bright light is, amongst other environmental stimuli, a major releasing factor for stress reactions (5, 6, 12). Darkness for humans is a stimulus for regeneration reactions and sleep. The circadian stress hormone concentrations and the melatonin curve show clear variations depending on light, acting as an antagonistic system controlled by pituitary and pineal gland. Without light entering the eye an involution of the pituitary gland can be observed after a while (7).

Ocular phototransduction under bright lighting conditions leads to systemic stress reactions (12) with increased production of CRH (Corticotropin Releasing Hormone), POMC (ProOpioMelanoCortin), ACTH (AdrenoCorticoTrophic Hormone) and other pituitary hormones like TSH (Thyroid Stimulating Hormone) and Gonadotropic Releasing Hormone (GnRH) through the

hypothalamic pituitary axis (HPA) (8). While the production of the pituitary hormones is increased, the production of melatonin in the pineal gland is suppressed and vice versa. The pituitary gland functions are mainly associated with day and summer tasks, the pineal gland rules over night and winter.

Dermal phototransduction leads to local stress reactions in the skin tissue under the mediation of the same hormonal components, except TSH and GnRH. The action spectrum for dermal light stress is well known since the groundbreaking research of Niels Ryberg Finsen, the father of modern phototherapy and winner of the Nobel prize for medicine in 1903 (3). It is associated with the photochemical potential of ultraviolet radiation in the UVA and UVB range and leads to a number of photochemical reactions. Most of these reactions are destructive photo-oxidations which concern nearly all pituitary hormones and other biomolecules with chromophoric groups, while only one reaction is a photosynthesis, namely the production of the hormone Calcitriol or so called Vitamin D (12).

Recent discoveries have unveiled the action spectrum of the optical radiation which seems to be most effective in inducing the endocrine reaction in the HPA which is located in the short wave segment of the visible spectrum with a sensitivity peak of around 460 nm. But not only the wavelength or color temperature of the visible radiation, but also the light intensity seems to be important for photoendocrine efficiency.

Even if science today discovers that different wavelengths in the visible range of the spectrum show different reactions in humans, under the evolutionary viewpoint this is not a new piece of information. Finsen, over 100 years ago, described a photodermatic reaction showing a spectral opponency in a number of simple organisms like salamanders or earthworms which always follow the same logic. Regarding the reactions after photic stimulation, blue and violet light is associated with bright light and red light is associated with darkness (3).

## 2. SUNLIGHT REACTIONS

Natural sunlight has a given spectral composition which is altered by environmental factors, seasons and local climate conditions. The spectral components in the UV range underlie the most significant variations depending on these altering factors and show also the highest photochemical potential and activity in the body. This particular range of radiation can only enter the skin but not the eye. The ocular lens provides filtering properties which make sure that the delicate retinal structures are protected from this aggressive part of the optical spectrum. Nevertheless the body needs orientation regarding the environmental UV concentration to coordinate dermal and systemic stress reactions and hormone production. The reason for this informational demand lies in the significance of the UV reactions in the skin: 20 minutes under sunlight can lead to a production of 25 000 international units of Vitamin D, but also, depending on individual conditions, to a severe erythema and inflammatory skin reaction. Vasoactive substances are liberated in the capillary layers of the skin which lead to a dermal pooling effect by widening the vessels.

Dermal pooling is a shift of blood and liquid from inside the body into the vascularised and outer layers of the skin. Under extreme conditions, the skin can take more than 60% of the whole blood contingent of the body (1). If a normal individual has about 5 liters of blood, this equates to an amount of more than 3 liters. This seems to be a very high amount, but can be better understood if one knows, that the skin is one of the largest organs "in" the body with a mass of about 12 kg (without subcutaneous fat layers). Massive dermal pooling can lead to a lethal condition of circulatory shock reaction if not sufficiently counteracted, even the loss of 1 liter of blood can be rather harmful. This dermal pooling effect has been used therapeutically since the 1920s to treat high blood pressure.

The systemic stress reaction is capable of counteracting excessive dermal pooling effects, because the catecholamines constrict the vessels, raise the blood pressure and increase the heart activity. In addition, a hormone of the posterior lobe of the pituitary gland, ADH (AntiDiuretic Hormone) is directly released into the blood

stream and induces water retention in the kidneys. For the control of the inflammatory skin reactions, the cortisol is liberated together with the adrenaline. These controlling mechanisms seem to be so essential that the liberation of the stress hormones is not only provided by the HPA, but there are also accessory stress hormone releasing systems located in the hair follicles in the skin as well, which have been recently discovered (13).

A second reason for compensatory stimulation of pituitary secretion activity under bright light conditions is the circumstance that there is a hormonal drain or loss caused by the UV radiation which enters the skin. All of these hormonal substances are photosensitive (2) because they carry chromophoric groups in their molecular structure which lead to an absorption of photon energy in the UV range. The photon energy destroys or deactivates these molecules as a consequence of absorption. As the hormone levels are controlled by feedback loops, the destruction of certain amounts of these hormones in the skin leads to an increased production in the endocrine organs.

These light reactions described above have been essential for survival under the different climatic and lighting conditions on earth. Under the pressure of evolution it has finally turned out that survival has been easier for those organisms which could somehow foresee the content of UV in the environment and thereby anticipate the adequate pituitary activity needed for hormonal balance. In natural sunlight a high amount of UV is always accompanied by high levels of brightness and, what's even more significant, a high content of blue radiation. While UV is invisible, blue can be detected by the eye and thus can be used as a parameter for indirect extrapolative measurement of ultraviolet radiation.

This system seems to be ingenious, but it only works under natural sunlight conditions. As soon as there is artificial fluorescent light involved, the system begins to malfunction: the bright artificial light with high color temperature triggers adaptive endocrine stress reactions against high environmental UV radiation which does not exist. This induces a hormonal imbalance which can be detrimental for health, especially under long term conditions.

### 3. ARTIFICIAL LIGHT AND HEALTH

Reviewing the recent publications concerning healthy light, a focus upon circadian effectiveness and melatonin can be noticed. It mostly appears as if this circadian or chronobiological effectiveness is used as a quality label for healthy lighting. The equation circadian effective = healthy has to be thoroughly examined. This kind of artificial light can be used for therapeutical purposes in treating SAD and other circadian disorders. It can also be used in helping shift workers to cope with their unhealthy working conditions. But these examples give no proof that this light is healthy, it only shows a certain therapeutic potential. For the largest part of a population it might be healthier to use chronobiologically and endocrinologically neutral light sources in order not to interfere with their individual endocrine regulation systems.

For photometrical purposes and simplified reflections on the functions of the circadian system it might be practical to look only at the suppression of the hormone of darkness (melatonin) in terms of a marker substance for endocrine reactivity, but this approach only touches the surface of a highly complex system: human endocrinology. From the medical viewpoint, it seems to be more important to look at the increased secretion of pituitary hormones. The Proopiomelanocortin (POMC) is a very interesting candidate for further investigation, because it is a multi – purpose peptide which shows the link between light influence and systemic stress, even on the molecular and genetic level. It is the precursor molecule for ACTH (which controls the secretion of catecholamines and cortisol),  $\alpha$ -MSH and  $\beta$ -Endorphin. If the body needs ACTH, this always comes along with  $\alpha$ -MSH and  $\beta$ -Endorphin. In the central nervous system  $\beta$ -Endorphin reduces pain, in the periphery it acts as an immune modulator.  $\alpha$ -MSH is the melanocyte stimulating hormone which stimulates pigmentation (sic!), but it also increases the heart rate, the concentration of lipoproteins in the blood and stimulates the activity of the thyroid gland. All these hormones are deeply involved in the development of civilization's diseases. In industrialized societies about 50% of the population die from cardio-vascular diseases (CVD) which are the consequence of high blood pressure and a disturbance in the

lipoprotein and cholesterol metabolism. Another 30% develop deadly forms of cancer, which are mostly hormone dependent/sensitive and also the result of a malfunctioning immune system. Catecholamines, gonadotropic hormones, steroids and hormones of the thyroid gland are the major influences in this field and they are all hormones under pituitary control (4). The development of these diseases is certainly the result of multiple factors, so it will be difficult to prove the role of artificial lighting for this outcome, but the findings in photoendocrinology indicate at least a promoting effect of circadian effective light sources.

### 4. CIRCADIAN LIGHTING AND VISION

The human eye has two pathways for the processing of light signals. The optical part is responsible for vision processes while the energetic pathway controls the HPA via the retino-hypothalamic tract. For vision purposes it is better if the surrounding light does not contain high amounts of blue and violet wavelengths. The higher refraction for short wavelengths which occurs in optical media appears also in the eye. This causes a chromatic aberration effect with negative consequences for sharp vision. The different wavelengths focus on different planes in and around the focus plane of the retina. Due to photooxidative effects (9, 11), the blue and violet radiation also promotes chemical reactions in the optical media of the eye and in the fovea centralis. We find a number of mechanisms in the eye which provide better vision on one hand and less photooxidative stress and damage on the other, in order to reduce the negative effects of blue light on vision. First the number of blue receptors is up to 20 times less compared to the number of red cones in the fovea centralis (10). Secondly there is a concentration of lutein, a yellow pigment which filters out excessive portions of blue and shows also antioxidative properties. The concentration of this protection substance is reduced in the eyes of elderly people. Ophthalmologists have discovered that there is some evidence that the age related reduction of lutein is functionally compensated by the increased blur in the lens, which is also promoted by blue and ultraviolet light. As a consequence they replace the lens in cataract surgery by a colored one, which filters out the blue portions in order to protect the macula from

further degeneration. This shows that even the structures of the eye wear out, depending on age and the amount of light which has to be processed during a person's lifetime. The question is, is it only the sunlight which is responsible for the increasing incidence of age related macular degeneration, which is found in 30% of the population over 70 years of age in industrialized nations? These people stay 90% of their time inside buildings while under the influence of artificial light, which has to be taken into account as well. We indeed find that there is a large number of light sources in our environment which produce high amounts of photooxidative potent light, such as mercury vapor lamps with high color temperature and TFT computer screens.

## 5. CONCLUSION

Epidemiologic data show that the incidence for civilization related health problems like cardio-vascular diseases, cancer, immune deficiency, osteoporosis and age related macular degeneration is rising. All these disorders are photochemically and endocrinologically related to the influence of light (12). Artificial light has become the major photonic influence in modern societies. The tendency in artificial lighting is the ubiquitous use of mercury vapor light sources with high color temperature. This parameter indicates high portions of photochemically and chronobiologically active radiation in the spectrum, which is also hindering sharp vision. From the medical viewpoint the question arises as to whether the use of mercury vapor light has a promoting effect on a number of these diseases of civilization. In terms of prevention of hormonal disorder and improvement of vision in healthy individuals, it may be better to use artificial light sources with a low content of blue and low color temperature and go for alternatives to the mercury vapor light sources.

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