Ultraviolet Radiation in Sunlight and Artificial Lighting Systems: Are They Alike?

Sandra Preto[1(✉)] and Cristina Caramelo Gomes[2]

[1] Faculdade de Arquitectura da Universidade de Lisboa, Lisbon, Portugal
sandrapreto@hotmail.com
[2] CITAD, Lusíada University of Lisbon, Lisbon, Portugal
cris_caramelo@netcabo.pt

Abstract. Nowadays, we are urged to avoid the sun to avoid the UVR (ultraviolet radiation) especially since the data indicate that the growing cases of melanoma and cataracts occur due to it. So, we stay out of the sun. Moreover, artificial light has UVR and, even though the amount of UVR under artificial light is much less than under sunlight, the truth is that the time that we spend indoor, with the lights on, is way too much. The light has a great impact on our visual and non-visual requests. These facts are responsible for many of our health complaints. Still, what are the differences between the natural UVR (sunlight) and the artificial UVR (artificial light)? The objective of this paper is, through literature review, examine the way we balance our needs and how we can promote our health and wellbeing.

Keywords: Artificial light · Visual and non-visual · Workplace · Ultraviolet radiation · Vitamin D

1 Introduction

In order to better understand how UVR affects our wellbeing, we start by defining vitamin D. Secondly, we summarise the ranges of UVR and their impacts on our skin, eyes and circadian system. After that, it is important to distinguish between UV production and UV destruction. Then information about UVR in artificial lighting systems is exemplified. However, there are filters for lamps and for windows. Lastly, we discuss about the UVR impact on indoor and outdoor workers.

2 Literature Review

2.1 Sunlight & Vitamin D

Since the beginning of life on Earth, sunlight has followed human evolution, and that is the main reason why we are adapted to the complete solar spectrum; it is an archetype of natural and healthy light [1, 2]. Sunlight has both protective and detrimental impact on human health, and when exposure is low it can cause seasonal affective disorder (SAD), rickets, and too much exposure can cause melanoma (skin cancer), cataract

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(opacity in the lens of the eye) and other eye diseases [3–5]. But, somewhere in the middle, there is the right amount of human exposure under sunlight. There are many benefits from sunlight, such as the production of Vitamin D, which only occurs when we are exposed to UV-B radiation (between 290 and 320 nm) [6, 7]. It is necessary that the exposure is not for too long so that we do not tan much [8]. In order to promote the production of vitamin D when in times of stress the amount of additional cholesterol increases [7], so it is essential to have cholesterol in our diet [8]. For instance, when in times of stress, the amount of additional cholesterol increases and we deplete our reserves to promote the production of vitamin D. The provitamin D7 is transformed into pre-vitamin in the outer skin, and in the liver and kidneys the bio-form D3 (Fig. 1) is formed [2]. This phenomenon was found by Adolf Otto Reinhold Windaus who received the Chemistry Nobel Prize in 1928 for his discovery of vitamin D3 [9]. In addition, the most food and supplements produce D2, which is a different type of Vitamin D. Therefore, the UVR is very important. Vitamin D (under UV-B) have a protective effect on health in diagnostics as depression, cancer, cardiovascular disease, influenza, diabetes, skin diseases (psoriasis, atopic dermatitis, vitiligo but it is also associated with a higher risk of such scourges as multiple sclerosis, tuberculosis and many forms of cancer, liver spots, actinic keratosis and solar elastosis [3–5, 10, 11]. Furthermore, it is essential for a healthy skeleton to consume calcium and phosphorus. UV-A is responsible for photo ageing, bone disorders, immune-suppression of the skin, immune system and potential enhancement of the negative effects of UV-B exposure [12, 13]. In order to produce 25.000 international units of Vitamin D the skin have to be exposed to sunlight for about 20 min. Even though, there are some conditions that can foster production of vitamin D, such as being young, not obese, for instance, have light skin, when it is summer, in the middle of the day, a greater percentage of skin exposed to the sun and not all parts of the body produce the same quantities of vitamin D (hands and face almost do not produce vitamin D, and chest is the body part that produces the most), when we are lying down (like at the beach), if we are without sunscreen and if we are near the Equator [8, 14]. However, sunscreen with factor 15, for instance, reduces solitrol (Vitamin D) production by 99.9% [20]. Women aged between 20 and 55 years living in a polluted area (urban) have a higher risk of developing vitamin D deficiency [15]. Those who are obese may require two to three times more production of vitamin D in order to satisfy the minimum requirements [9]. Also, as we age the skin loses production capacity of synthesize vitamin D [15]. Exposure to UV-B is very important for our health because there are very little food contains natural D3 and food that is fortified do not fulfil the vitamin D requirements [16, 9]. Moreover, in winter months (November to February), no production of vitamin D3 is found, at latitudes of 42°N, and the same happens at latitudes of 52°N from October to March. It is not easy to get the right quantity of vitamin D (Fig. 2) [5]. In nature bright blue light always comes with UVR. The hypothalamus has to coordinate different hormone concentrations and adapt them to the environmental conditions. There is one very important hormone that is not excreted by a gland but produced directly in the skin under the influence of ultraviolet radiation with wavelengths between 290 and 320 nm: the so-called Vitamin D.

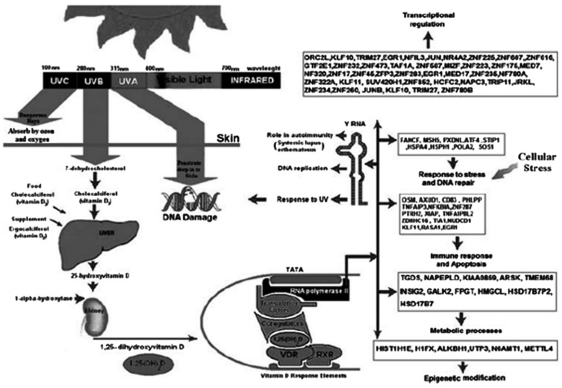

Fig. 1. Biological functions for genes whose expression levels were altered after 2 months of vitamin D3 supplementation. After receiving vitamin D3 supplementation were identified 291 genes whose expression was significantly decreased or increased. Some of these genes influence several pathways that are involved in response to stress and DNA repair, DNA replication, immune regulation, epigenetic modification, transcriptional regulation and other biological functions. In addition, vitamin D3 supplementation influenced the expression of Y RNA and CETN3 that are involved on DNA repair in response to UVR exposure [9].

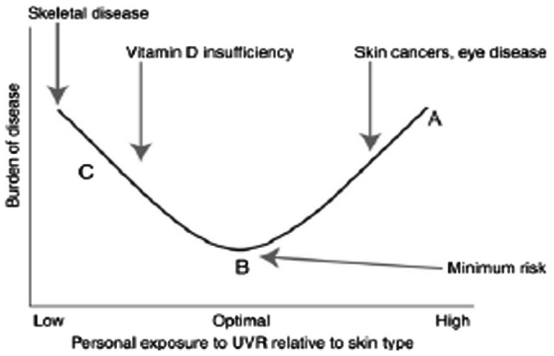

Fig. 2. Schematic diagram of the relation between UVR exposure and the burden of disease. Points A and C represent inappropriate UVR exposure. Fair-skinned populations in Australia with high outdoor UVR exposure typify point A. Point C represents people with insufficient UVR exposure, whose dietary vitamin D intake will also be important in determining their vitamin D status. Point B represents optimal UVR exposure: a person with correct UVR dose for skin type [5].

In order to enlighten the several impacts on our body and mind, let us begin with the definition and distinction of different wavelengths.

2.2 Ultraviolet Radiation

The solar radiation (SR) is composed of ultraviolet radiation (UVR), visible radiation (light) and infrared radiation (IR). UVR (Fig. 3) is often divided into 3 wavelengths:

UV-A (315–400 nm) - the weakest, UV-B (280–315 nm) and UV-C (100–280 nm) - the strongest, like proposed by the Second International Congress on Light in 1932 [2, 5, 10, 11] However, dermatological and environmental photo biologists use values slightly different. Visible radiation (380–780 nm) and Infrared includes IR-A (780–1400 nm), IR-B (1400–3000 nm) and IR-C (3 μm–1 mm) [2].

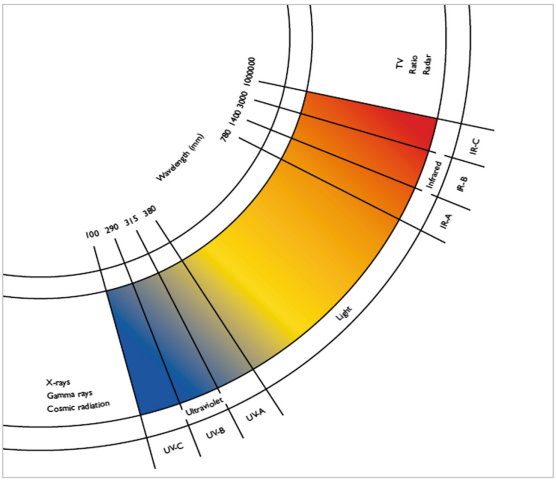

Fig. 3. Spectrum of the Sun [2].

Only 60% of the UVR are responsible for driving life on Earth, the remaining 40% is reflected back into space. Ultraviolet (UV) radiation (R) is produced mainly by the sun, and almost (95%) of the UVR that reaches the Earth is in the UV-A range, and a smaller amount (5%) is UV-B [11, 17]. There are many factors that UVR depends on, such as the time of day (a third of the daily UVR is produced from 11 a.m. to 1 p.m. and the other three-quarters between 9 a.m. and 5 p.m.) [15, 17], season of the year (UV rays are weaker in winter time) [17] (Fig. 4, on the right), distance from Equator (latitude 0°, as we get further away from the Equator the weaker the UVR is) [9], altitude (UVR increases with altitude, by 6–8% per 1000 m) [14, 5, 17]. In fact, in the summer at noon, the UV is more intense due to a shorter distance between the Sun and the Earth´s surface, and the UV-B is more intense (two-three times more) in Equator, when compared with northern Europe (Fig. 4, on the left). In addition, direct and scattered (diffuse) are the components of the solar radiation, where direct is characterized by the rays from the sun that passes through the atmosphere and the scattered is diffuse by air molecules and depends on the wavelength [17]. Another factor that contributes for this effect is the weather conditions, such as a cloudy day (a clear sky have higher UVR, although at certain conditions clouds could enhance UVR) [10, 14, 17], whereas on days with scattered clouds we have to spend more 10% of time exposure, on broken clouds we need to stay more 27% of the time and, finally, beneath overcast it is advisable to spend more 68% of time [8]. In addition, we have to count with reflections from surfaces, such

as grass, soil, water (less than 10%) snow (80%), and sand (25%) [10, 17]. Also, we must realise that the ozone layer filters completely the UV-C radiation [8] and absorb UV-B which it is the reason for the annual variation, compared with the UV-A, conversely the ozone depletion lead to a UV-B radiation increase [10, 11, 14]. Pollution, also, filters out UVR [11, 15]. In addition, the different UVR ranges have different impacts on humans, the UV-A, for instance, can alter the structure of collagen and elastin fibres, cause skin-ageing (wrinkles) and can cause indirect damage on DNA. UV-B, are the main responsible for direct damage to the DNA, can cause sunburn and thought to cause most skin cancers. UV-C, is filtered by the ozone layer, but it can be present in some man-made artificial light, such as arc welding torches, mercury lamps, and used to be present in the sunbeds [10, 11].

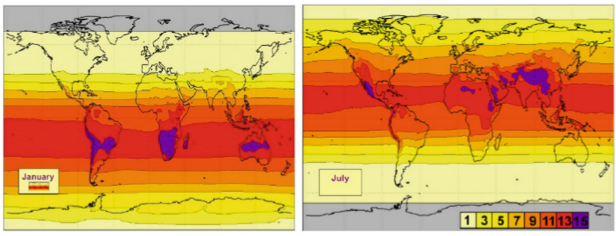

Fig. 4. Estimation of global geographical distribution of the UV Index in the winter (January) and summer (July) months at noon, for clear day [11].

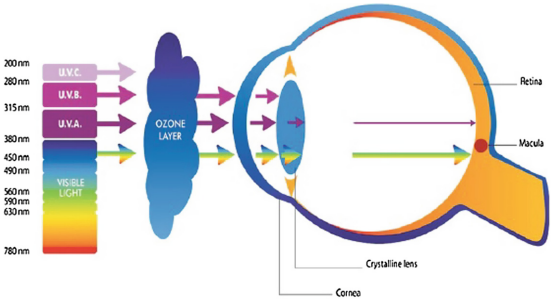

Fig. 5. Absorption and transmission of solar radiation in the eye. The cornea and crystalline lens filter out UV-B and most UV-A, so that the most energetic light reaching the retina is short wavelength blue-violet light [19].

Nevertheless, there is more into it, the light has great impact on human health, which can be divided into three ways: the radiation exposure can damage the eye and the skin, on photochemical and thermal systems, and the visual and the circadian systems [4, 12]. The eyes and the skin are the organs more exposed to UV rays [11]. At the eyes it can cause many conditions, such as the formation of cataracts (opacity of the lens), photo keratitis (snow blindness) photo retinitis (also called blue-light hazard) [4] and pterygium (tissue growth on the surface of the eye) which can lead to impair vision [10, 11, 16]. UV-C exposure of the eyes, for instance, can cause DNA damage, lead to

cataract formation and retinal damage [18]. Fortunately, the eye has some mechanisms of defence (Fig. 5). Some of the damages can be repaired although the repair mechanisms become less effective with age [4]; moreover, damages can be accumulated over lifetime. Sunglasses with UV-A and UV-B filters are very important for children [11] under 9 years of age, when their retinas are less protected.

Besides the impact at the eyes, there is, also, the impact on the skin. However, we must keep in mind that UVR is also dependent on the sensibility of the individual [11]. As a matter of fact, a skin type I, produces six-times more vitamin D than a skin VI [14]. Even though, the skin has protective mechanisms such as the production of melanin (tan) [11]. The darker the skin, the less will be affected by radiation [2]. The skin is the largest organ of human body, and it is, constituted by the dermis, which contains the collagen fibres, gives the skin its elasticity where the skin-aging is a result of elasticity decrease (Fig. 6). The UV-A reaches the epidermis [6], but UV-A only reaches the dermis, the capillary layers and the blood vessels [6]. Some of the biological effects of UV-A to skin are: it generates free radicals and causes indirect DNA [2, 9, 18] damage (malignant melanoma), due to the fact that UV-A penetrates deeper which contribute for the damage of the collagen fibres, destroys vitamin A [2, 18], reduces skin and blood antioxidants [16]. Whereas skin exposure to UV-B causes erythema (sunburns), malignant melanoma, although it has positive effects, also, such as the moderate doses induce the production of vitamins D and K [18]. Melanin, is a natural protection of the skin that is produced in response to UV-B exposure, and acts as an antioxidant and reduce the damage on the cells by free radicals [21]. Cloths such as hats and sunscreens are a protective measure of the UV negative effects [5, 14] as well as Mediterranean diet [2, 15, 16]. Also, monosaturated fats in our diet, such as almonds, will help to increase bio-availability of vitamin D from the UV-B radiation [8]. Another protective factor is the Omega-3 characterised by fatty acids [16] and Vitamin D may also reduce damage in the skin induced by UVR [16], even though UV-B exposure showed no significantly increase in the risk of skin cancer [2].

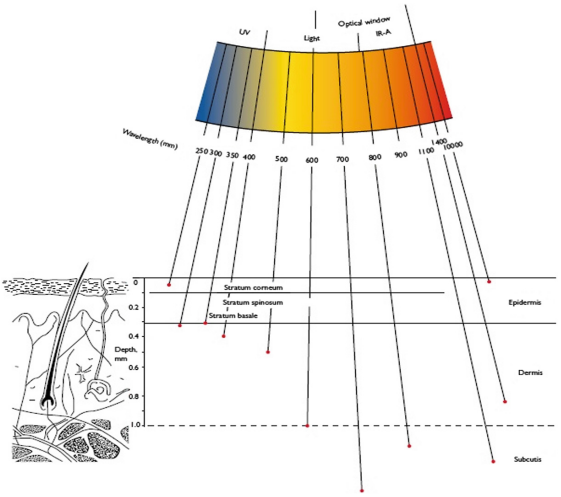

Fig. 6. Skin penetration depth of optical radiation [2]

As far as the impact of light on the circadian system [4] is concerned, the light received by the eyes is transmitted through the optic nerve and reaches the pineal gland, which is connected to the hypothalamus. The synchronization of circadian rhythms is related to the hormonal system, and the result is perceived by the alertness fatigue, and emotional levels (Seasonal Affective Disorder, SAD) [13]. As stated above, sunlight regulate various body functions, and it is a great disappointment that western society gives more attention to the negative effects of UV [2]. Even if with an UVR exposure equal to zero some of the diseases still occur, without vitamin D this situation gets worse. For instance, the pituitary gland and pineal are antagonistic organs in the brain, which regulates the endocrine and the circadian systems, respectively, and at the same time react to light through the eye and skin. The pituitary is of extreme importance since it induces the stress hormones production (like cortisol) and the pineal gland is responsible for melatonin production. In addition, it is important to juxtapose what could be the results of UV and how it impacts in our physiological system.

2.3 UV Production vs UV Destruction

In spite of that, vitamins are by definition substances which the body cannot produce independently, Solitrol (Vitamin D) is antagonistic to melatonin, whereas melatonin concentration is higher the risk of cancer is lower. Furthermore, while UV builds up Solitrol (Vitamin D) in the capillary layers of the skin, other hormones like steroids are destroyed under the influence of this radiation. This endocrine reduction is compensated by the activation of retinohypothalamic tract, which promotes the new hormone production [6]. One of the main reasons of this paper construction, is to point out that the UV contained in the man-made artificial light do not have the same behaviour. The artificial light, especially with high colour temperature tells to the brain through the eye the amount of UV outside that it is time to build stress hormones, but Solitrol does not come, and the stress and sex hormones are not destroyed (Fig. 7). This happens because there is no UV-B, or not enough, in the light and, in addition the skin is

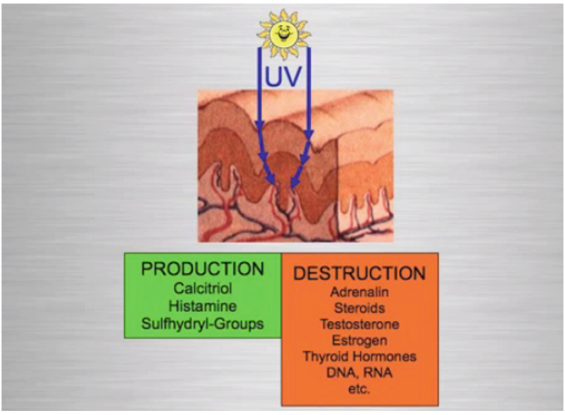

Fig. 7. Dermal photo transduction: photochemical skin reactions [20].

covered by clothes, which when in long term conditions can lead to cardiovasculatory diseases and hormone-dependent cancers, such as breast cancer [6]. So, it is important to understand the UVR presence in the artificial light.

2.4 Artificial Light

UVR and infrared are present in artificial light, which means that some lamps produce significant infrared and ultraviolet radiation. A side effect is that we are exposed to UVR at indoor environments - such as workplace - without knowing [4, 12]. Fortunately, the infrared radiation repair the oxidative damage caused by blue light and UVR (Fig. 8) [1] but incandescent lamps, which are mainly red light, are no longer produced or available for consumption. UVR is produced mainly by gas discharge lamps (low pressure mercury), fluorescent lamps (and compact fluorescent lamps - CFL) and light-emitting-diodes (LEDs) [11].

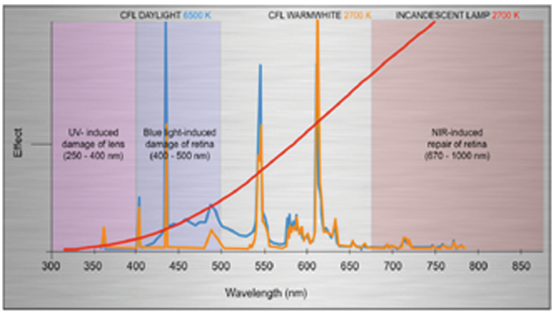

Fig. 8. Spectral ranges responsible for retinal damage and repair correlated with spectral energy distribution of different lamp types [1].

The incandescent lamp produces clean light without modulation frequencies and flicker [6]. Incandescent light sources avoid unwanted hormonal malfunction [1]. However incandescent lamps are no longer available since they have been discontinued. Tungsten halogen lamps are used at home and at workplaces, and when unfiltered they can cause injury at short distance, as for example, task lights [4, 12, 16]. The problem is that they have been recently discontinued also. So, there are only two lighting systems left: Fluorescent and LED. Fluorescent lamps are commonly used at workplaces. Although these lamps emit small amounts of UV the exposure to it accumulates over the day, which could cause some risk to skin and at the eyes. Besides, UVR emission, fluorescent lamps contain mercury vapour [6]. And, this is an issue that it is worthy to clarify, since mercury is a toxic substance which is very difficult to eliminate and the body deposits it in tissues with a low metabolic activity so we can find it in the neuronal myelin sheaths of the brain [6], Myelin wraps axons then are responsible for the communication between neurons, i.e. synapses. Another fact is that in the past the human was attuned to sunlight, but nowadays man is attuned to mercury,

so this is a real problem and most of us do not realise it. In addition, the discharge on the mercury atmosphere produces UVR [13]. This being stated, let us get back to UVR presence in fluorescent lamps. So, in the UV-B range there are TL/01 and TL/12 lamps, which are mainly used in phototherapy and, in the UV-A region there are TL/09 and TL/10 used in photochemotherapy and phototherapy [2]. Moreover, UVR is used for cosmetic treatment of the skin [11]. So, all fluorescent lamps emit some UV. Typical fluorescent lamps, including CFLs (compact fluorescent lamps), emit very low levels of UV. Depending on the mercury vapour pressure we can have: low-, medium- and high-pressure mercury lamps [2]. Whereas low-pressure mercury (254 nm, UV-C range) is used for sterilization, disinfection (water and waste, for example) [2], the medium-pressure mercury lamps emit the same UV power but can be made more compact [11]. And, high-pressure mercury lamps emit more radiation below 215 nm (UV-C range) [11]. Like traditional tube-style fluorescent lamps, CFLs contain a small amount of mercury as already stated. Typical household CFLs contain less than 5 mg of mercury (size of the tip of a pen). Though CFLs do not emit mercury as they operate, only when the outer glass tubing that contains the mercury breaks [21]. LEDs spectrum is above 400 nm, which is not within the UV light wavelength but, instead is in the blue light range. The output of a UV LED, is in the 368-nm range [11], so relatively pure blue light from the LED has almost no UV [21]. However, exposure for long periods of time will have some impact. At outdoor environments, we can find sodium vapour lamps which are used essentially in street lights. The sodium-vapour bulb is extremely efficient, producing large amounts of yellow light with little electricity and it contains virtually no UV [21]. Furthermore, we must have in mind, that there is a large and increasing number of fluorescent light sources in our environment which produce high amounts of photooxidative potent light, such as mercury vapour lamps with high colour temperature, like for instance the backlight of TFT computer screens and TV sets [1]. So, it is important to understand how, and if there is that possibility, we can avoid the downside of UV-A and, maybe, increase UV-B exposure, when indoors.

2.5 Filters

As for filters, there are some ways to avoid UVR. Let us begin with the luminaire and afterwards we will discuss about windows filters that can be used. For instance, UVR from tungsten halogen lamps can be reduced by using a glass cover [4]. CFLs should not be allowed for more than 60 min at distances less a 0.30 m [4]. Dyes can absorb UVR. HID (High intensity discharge) lamps emit significant amount of UVR and like tungsten halogen can be minimized with a UV filter [12]. The glass used in CFLs already provides a UV filtering effect. In addition, any additional glass, or plastic, or fabric used in lighting fixtures that is between the individual and the CFL will act as additional UV filters and by increasing the distance between individual and any radiation source, will also reduce the small level to a lower level [21]. On the other hand, there are also window filters such as UV-filtering window films which are flexible films that adhere to glass and block UV and visible light. Films that filter mainly UV light are clear (usually with a slight yellowish cast when viewed on edge), while to filter visible light the film must be tinted or coated. The majority of films available now nearly

eliminate UVR, elimination of UV light is typically stated as 95–99% or better in the range of 200 to 380 nm. Window films are usually laminated polyester film layers modified with material that absorbs, scatters, or reflects UV and visible light. Most often films are impregnated with dyes or carbon particles or coated with a layer of magnetic sputter vapor deposited metal to accomplish the desired results. Metallic coatings, usually aluminium, will reflect incident light, thereby reducing the transmission of UV and visible light and can also create a reflective mirror-like surface from the exterior. There are non-reflective/metallic options that can also reduce glare on the interior. The UV absorbers can be built into the film base, coated on the film, or applied in the adhesive. They can be applied to interior windows, storm glass, or used as roller blinds. Often window films are applied to the interior window surface. Films made for exterior application are more expensive and guaranteed for about half the amount of time, because they are prone to peeling due to exposure to the elements. Interior films are generally guaranteed for 10–15 years. Films can be removed with solvents, such as paint strippers, ammoniated solutions, or odourless thinners. Besides, window film can, in summer, cuts down heat within the home, reducing air conditioning expenses, and in winter, some films reflect interior heat back into the house, reducing heating costs and it helps keep sunshine from fading upholstery and home furnishings [22, 23]. Filters can be very important since chronic exposure to UV-A rays through windows may accelerate skin aging by 5 to 7 years. More than 90 percent of skin cancers and the visible signs of skin aging, are caused by the sun [23]. So, what is better for us, to stay indoors or to go out?

2.6 UV Indoor versus UV Outdoor

There is some contradiction when we compare workers working in indoor and outdoor environment. Although, outdoor workers are exposed more time to UVR than indoor ones, there are an increased incidence of malignant melanoma for indoor workers. UV-A radiation passes through windows, which can break down vitamin D3 formed after outdoor exposure. So, production of the provitamin D3 only happens under sunlight. Vitamin D3 can be converted to its most hormonally active form, calcitriol, which kills melanoma cells in vitro and reduces tumour growth in vivo. Therefore, indoor workers may be at a higher risk of malignant melanoma. Besides, UVA window exposures can cause negative biological effects such as photo-aging among others. In addition, indoor workers are exposed to minor amounts of UV-A and UV-B from fluorescent lights [24].

3 Discussion

Presently, many dermatologists and physicians strongly recommend us to avoid sunlight as a countermeasure to melanoma formation. The melanoma, particularly the malignant cases are increasing worldwide, as the other immune diseases. So, they are suggesting that we spend, more time indoors, especially between 11 a.m. and 16 p.m., which is when the UV-B radiation is at its peak. The simple fact that the present society

spend 90% of their lifetime indoors, where the mainly light available is artificial and the only way that we receive UVR is from the windows and from artificial light sources itself, although this last fact is unknown for the most the indoor workers, it isn´t the best answer. Because of the fear of skin cancer people continually avoid sunlight, and what is worse is that they think that before and after this UVR time, there is no risk of melanoma, but, it is the opposite that is true. Our windows glass and lamps could help us to decrease UV-A and to increase UV-B but as already stated the impact on our endocrine system can never be ignored. So, how can we balance our needs? Well, it seems that the best solution is have an access to outdoor environment of some kind. If we think in our workplace it can be hard to fulfil our needs, on the other hand if we change our way of conceiving spaces we might achieve the equilibrium. If we start to think of indoors environments with a place where we can be outdoor for pauses for instance, then we begin to have some answers to our needs. Spaces like patios, indoor gardens, where we simply can get some sun we will have a more balanced vitamin D production, we will not endanger our endocrine system, not so much at least, we will promote our health which will improve our wellbeing and help us to achieve a better performance at work. So, what are we waiting for? Let begin to change our way of thinking and of conceiving spaces for a "sustainable self" and not be concerned merely with energy costs.

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References

1. Wunsch, A.: Artificial light and health—a plea for the incandescent lamp. https://www.google.pt/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjAw-7tgqDUAhXGuhQKHVjxBJUQFgg1MAA&url=https%3A%2F%2Fwww.vitamindwiki.com%2Ftiki-download_wiki_attachment.php%3FattId%3D6285%26download%3Dy&usg=AFQjCNHRqS_8PogGqARA24NmM6i0Fju2kw
2. Koninklijke Philips Electronics: Light sources for phototherapy. https://www.interlight.biz/Catalogs/Philips/Philips%20Phototherapy%20Lamps.pdf
3. Beute, F., Kort, Y.A.W.: Salutogenic effects of the environment: review of health protective effects of nature and daylight. Appl. Psychol. Health Well-Being **6**(1), 67–95 (2014)
4. Boyce, P.: The impact of light in buildings on human health. In: SHB2009—2nd International Conference on Sustainable Healthy Buildings, Seoul (2009)
5. Lucas, R., McMichael, T., Smith, W., Armstrong, B.: Solar ultraviolet radiation global burden of disease from solar UVR. In: WHO Public Health and the Environment, Geneva (2006)
6. Wunsch, A.: Artificial lighting and health. J. Optometr. Photother. 2 (2006)
7. Carbone, L.D. et al.: 25-Hydroxyvitamin D, cholesterol, and ultraviolet irradiation metabolism clinical and experimental. Metab. Clin. Exp. **57**, 741–748 (2008)
8. Vitamindwiki: Optimize vitamin D from the sun. http://vitamindwiki.com/tiki-index.php?page_id=1051
9. Holick, M.F.: Biological effects of sunlight, ultraviolet radiation, visible light, infrared radiation and vitamin D for health. Anticancer Res. **36**, 1345–1356 (2016)

10. American Cancer Society: Ultraviolet (UV) radiation. What is UV radiation? http://www.cancer.org/cancer/cancercauses/sunanduvexposure/skincancerpreventionandearlydetection/skin-cancer-prevention-and-early-detection-what-is-u-v-radiation
11. Heering, W.: UV sources – basics,properties and applications. IUVA News **6**(4), 7–13 (2004)
12. Hse.gov.uk: Lighting at work. http://www.qub.ac.uk/safety-reps/sr_webpages/safety_downloads/HSG38Lightingatwork.pdf, www.hse.gov.uk
13. Boyce, P.: Is full-spectrum lighting special. http://www.iar.unicamp.br/lab/luz/ld/Sa%FAde/Is%20Full-Spectrum%20Lighting%20Special.pdf
14. Engelsen, O.: The relationship between ultraviolet radiation exposure and vitamin D. Status Nutr. **2**, 482–495 (2010)
15. Hosseinpanah, F. et al.: The effects of air pollution on vitamin D status in healthy women: a cross sectional study. BMC Public Health **10**, 519 (2010)
16. Coroneo, M.: UVR and the anterior eye. Eye Contact Lens **37**(4), 214–224 (2011)
17. Vanicek, K., Frei, T., Litynska, Z., Schmalwieser, A.: UV-index for the public: a guide for publication and interpretation of solar UV. COST-713 Action, Brussels (1999)
18. Case Western Reserve University: Ultra violet radiation safety—environmental health and safety. https://www.case.edu/ehs/media/caseedu/ehs/documents/UVsafety.pdf
19. Essilor Inc.: Blue light hazard: new knowledge, new approaches to maintaining ocular health. http://www.crizalusa.com/SiteCollectionDocuments/Crizal-Literture/Blue%20Light%20Roundtable_White%20Paper.pdf
20. Wunsch, A.: Indoor lighting and health. In: KAM Conference, Norway (2006). https://vimeo.com/99538838
21. Irfan, U.: Can compact fluorescent lightbulbs damage skin? http://www.scientificamerican.com/article/can-compact-fluorescent-lightbulbs-damageskin/
22. Springer, S.: UV and visible light filtering window films. WAAC **30**(2), 2 (2008)
23. SkinCancer.Org: Window Film: The Best Sun Shield for Car, Home and Office. Skin Cancer Foundation, New York (2013)
24. Godar, D.E., Landry, R.J., Lucas, A.D.: Increased UVA exposures and decreased cutaneous vitamin D3 levels may be responsible for the increasing incidence of melanoma. Med. Hypotheses **72**, 434–443 (2009)