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Do color and light affect physiology and psychology in proportional ways?

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Abstract

The application of the studies on light and color for the wellness of human beings is relatively recent. For decades, the design field's primary concern has been to ensure an optimal level of illuminance for workers, passers-by, or tourists, paying attention, where possible, to energy saving. This fact is even odder when we consider that light and color have been studied since the fifth century AD. Even if the emotional impact of light and color on emotions has never been a mystery, the studies on their interaction with the human circadian rhythms found no relevant, productive application since the early 90s. This is another reason to emphasize the differences between physiology and psychology when humans interact with light and color. The relationship between these stimuli and human physiology has been carefully investigated. As a result, many discoveries have been made, like the existence of specific structures in the retina called ipRGCs (Intrinsecaly Photoreceptive Retinal Ganglion Cells) have been identified, containing a photosensitive protein called melanopsin, capable of carrying out the phenomenon of phototransduction (such as the other photoreceptors, cones and rods). The difference is that the electrical impulse created by these cells follows a different path from that of vision and is conveyed through the retina-hypothalamus tract, where it will affect the pineal gland by suppressing melatonin. This hormone is essential in the regulation of the human circadian cycle. These notions highlight a fundamental aspect: the influence of light and color on human physiology does not follow the exact mechanisms of the one of vision. Instead, and as far as we know, the emotional reaction results from the brain elaboration after a lighting stimulus is conveyed through the visual system channels. This difference is also evident in human sensitivity to the different wavelengths of light (various colors). For example, in the spectral sensitivity curve (which colors we see better), the maximum response coincides with 555 nm (yellow-green). In contrast, in the sensitivity curve concerning the circadian cycle, i.e. which wavelength affects the most, the maximum sensitivity corresponds to 460 nm (blue). In a nutshell, the differences between these two mechanisms are reflected in human beings' perception of color. For example, it is not uncommon for an individual to associate the term "activating" with warm and bright colors such as yellow and red, while, physiologically speaking, activating colors are at the opposite end of the spectrum (blue). The doubt arising from these observations is that a complex system like the one of human perception does not possess some form of convergence between these two mechanisms. In this paper, we will discuss the early stages of research that aims to understand if it's possible to find a proportion between the emotions and moods aroused by colors and their influence on our physiology.

Keywords: Light, Color, Physiology, Psychology, Design, Behavior.

Introduction

Much is known about the perception of light and how it is transformed through a physiological pathway into a mental representation of color. To date, all knowledge of this perceptual process has been investigated, as is often the case in neuroscience, through studies on patients with a pathology related to this specific aspect. A recent work comprehensively analyzes and reviews everything we know today about this process (Bosten, 2022), showing not only the differences related to patients with some color perception deficit but also possible differences between healthy individuals. The description of an elaborate scene or object will most likely be different from that of another person who is describing exactly the same scenario, varying not only in physical characteristics related to shape and color but possibly also in emotional responses and feelings triggered by it. Specifically, variability at all levels of the color vision process creates diversity in color perception, from discrimination to color matching and subjective experience, so each individual lives in a unique perceptual world (Helm and Tucker, 1962). Biology might suggest that healthy humans with the same anatomy react in a relatable way to certain stimuli. Still, the complexity of the interactions between psychological and physiological aspects of perception shows that this is not always true.

Theoretical background

The role of light and color is critically important when thinking about the design of indoor and outdoor spaces in a society such as ours that is constantly evolving, where productivity and sustainability are the basis for innovation. To achieve this goal, it is possible to bring an impact on human perception to modulate behavior; in fact, in the field of environmental psychology color plays a key role in this process. In the past, many studies on the perception of color and light in application mainly investigated the productivity of workers or students during their working hours, investigating which among various light sources or color could improve their performances (Phipps-Nelson et al., 2003). The attention of researchers also focused on applications of light and color for the physiological and psychological well-being of humans or a combination of them (Chen et al., 2022). Studies proved how light and color affects both people's physiological and psychological health through modulating parameters such as circadian rhythm, attention levels, and mood (Küller et al., 2006; Kakitsuba, 2020; Wang et al., 2020; Papinutto et al., 2020; Zhu et al., 2019). These studies are of fundamental importance for their application in people living and working environments. Still, it is necessary to set stakes and begin to make distinctions between some of the processes described. Undoubtedly, color is a very controversial stimulus, and its study is far from easy (Bortolotti et al., 2022).

Controversies.

In general, it is possible to state that color has three main physical characteristics of hue, lightness and saturation, each of which can affect our autonomic nervous system in some way and in return, create physiological and psychological responses (Al-Ayash et al., 2016; Wilms e Oberfeld, 2018). One of the controversies this article emphasizes is the difference between physiological (physical) and psychological (emotional) modulation of the perceptual process of light and color. These physiological and psychological processes are often, superficially, united as if they were a single process, when in fact, they are two distinct processes capable of influencing each other (Cacioppo et al., 1993). A first distinction that can be made is that psychological type processes that can be

influenced by color can be: memory, attention, and perception (to name a few), while the physiological type processes are: breathing, sweating, heart rate, body temperature, wake/sleep cycle and others. As mentioned, they can influence each other, and emotions also play an important role (Valdez & Mehrabian, 1994). Therefore, comparing psychological effects to more or less conscious perception and physiological effects to occurrences (not conscious or not at all) is possible. These two processes might have different perceptual processing at the brain level, which we will call the "dual pathway" in this paper. These processes compose the perception of objects, scenes, and communication through color.

The emotional impact of light and colors on emotions has never been a mystery (Bortolotti et al., 2021; Elliot, 2015), although the study of color and brightness still has many controversies, such as the correct description of the concept of lightness (Bortolotti et al., 2022). Studies on their interaction with human circadian rhythms have not found relevant and productive applications since the early 1990s. Still, with the advance of LED and control technologies, lighting design is going in this direction (Rossi, 2019). According to the above, it is fair to distinguish between these two different types of color and light perception.

Dual pathway

A child asked to tell where the color will probably answer that color is part of the object. The same answer will probably come from many adults. However, color as a concept is "visible" only in people internal subjective world; it is humans subjective processing of the different wavelengths of light (Helm and Tucker, 1962). Color vision for humans can be described as "trichromatic" because it is based on photoreceptors called "cones" that are sensitive to long wavelengths (L), medium wavelengths (M), and short wavelengths (S). However, this distinction may not be sufficient to fully explain the perceptual process related to light and the mental creation of color. This arises from the fact that this type of processing is very complex and, in some cases, "emotional" processing does not occur simultaneously in terms of temporal processing of the stimulus (Gao, and Xin 2006).

Cones (but also rods) are not the only specialized cells that are considered photoreceptors in the retina; in fact, it has been shown that light affects a distinct photoreceptor in the eye, a specialized type of proteic photopigments that are today known as Intrinsically Photosensitive Retinal Ganglion Cells containing melanopsin (ipRGCs) (Hattar et al., 2002), which are most sensitive to wavelengths of about 480 nm (Hankins et al., 2008). The discovery of ipRGCs and their spectrum of action has focused the industry attention on adding short-wavelength radiation to the light source spectrum, even during the daytime. Many discoveries have been made, such as the existence of specific structures in the retina called ipRGCs containing a photosensitive protein called Melanopsin (Provencio et al., 2000), which can carry out the phototransduction phenomenon (like the other photoreceptors, cones and rods). The difference is that the electrical impulse created by these cells follows a different pathway from that of vision and is channelled through the retina-hypothalamus tract, which will affect the pineal gland by suppressing melatonin. This hormone is responsible for the insurgence of drowsiness and is essential and the regulation of the human circadian cycle. These notions highlight a fundamental point: the influence of light and color on human physiology does not exactly follow the mechanisms of vision. This topic is a knot to unravel today as little has been done in this regard, especially regarding the overlapping or simultaneous execution of these two processes, which, although distinct, may not be mutually exclusive.

In this perspective, the literature on color psychology is full of articles where colors are often associated with characteristics such as hot, cold, etc. (Elliot, 2015). It is not uncommon for an individual to associate the term "activating" with warm, bright colors such as yellow and red, whereas, physiologically, activating colors are at the opposite end of the spectrum (blue). Furthermore, it is not uncommon for such colors to physiologically activate our heartbeat (Cajochen et al., 2005, Thompson et al., 2008), increase body temperature and affect the activity of the cerebral cortex (Badia et al., 1991). The doubt arises from these observations that a system as complex as human perception does not possess some form of convergence between these two mechanisms.

Discussion

The world is full of light stimuli that are often taken as objective and universal an emotional or physiological response humans feel related to any stimulus, whether it may be an object, a room, the scene of a movie, and so on; however, this is a highly deviant concept that stems from the way individuals see things and end up in underestimating them, a kind of bias. Studies on perceptual dysfunction in patients with perceptual disorders lead researchers to think that this process is not as objective as commonly believed but rather subjective, and studies on healthy individuals also support this. Therefore, it appears to be of fundamental importance to understand why people react to a light stimulus and how it triggers both an emotional and physiological response.

The idea of this research is to verify if there is a proportion in these two mechanisms: in the first moment, through an extensive analysis of the available bibliography and in the second moment, through tests on subjects. Going through the articles that describe what has been studied up to the present day, it is already clear that the common approaches of these two disciplines (physiology and psychology) have different analysis methods. As an example, while physiology generally measures the impact of the stimuli on the organism by the concentration of melatonin in the bloodstream or saliva or through ECG and EEG, the branch of psychology relies much more on visual tests done on subjects, with oral surveys (also eye movement, pupil size); two different approaches that need to be cross-referenced in some way, to avoid misinterpretation of the results.

It will be necessary to find a test approach that allows one to evaluate the two processes coherently, minimizing the visual bias that can emerge in the context of the psychological evaluation. To be able to obtain results that can be applied in the field of design, it will be desirable to resort to the use of mockups of real scenes rather than simple visual stimulation through displays or visors, precisely to avoid creating the abstract percept of a color sensation, which may not correspond to its application in a real context.

Conclusions

In this article we have discussed the early stages of research that aims to understand whether it is possible to find a proportion between the emotions and moods elicited by colors and their influence on our physiology.

To date, lighting devices that populate homes (smart bulbs or LED strips, perhaps controlled via apps) have chromatic routines that intend to influence the emotional state. However, the approach of these systems is to mimic the real world, attributing arbitrary definitions that can be more or less accepted by users (polar breeze, tropical sunset, winter bonfire, etc.).

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Other lighting products aimed at achieving the so-called methodologies aimed at implementing the principles of human-centric lighting are mostly focused on achieving the well-being of individuals by intervening in the physiology (circadian rhythms) and optimizing the photometric performance as much as possible (distribution of luminous intensities, glare control), relegating the sphere of color once again to a mere aesthetic expedient.

The possibility that the two perceptual processes are correlated, and the way this happens or, on the contrary, that the two paths are mutually exclusive without having any direct interaction leaves room for exciting research that can lead to direct feedback in the design of products for the lighting that contribute to the well-being of individuals in an even more complete way than existing products.

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