About the influence of color perceived lightness on psychological functions

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ABSTRACT

As human beings, we are continuously exposed to stimuli that modulate our psychological functioning and behavior, presumably through the influence exerted on our emotions. In literature, among others, the feature of color, mainly as related to the three attributes of hue, chroma, and lightness, represents one of the most explored topics. By the way, the multidisciplinary lens through which it has been investigated and the partial lack of methodological rigor make it difficult, thus far, to unify the research evidence while being able to disambiguate the single contribution of each color's attribute. The current review aims to provide an overview of the most recent literature, focusing on evidence that highlights the role of the perceived lightness of color, in its function as well as aesthetic properties, in influencing psychological functions and behavior. Practical implications and future directions in this research area are outlined.

KEYWORDS Color, Lightness, Psychology, Context

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1. Introduction

Our world is full of stimuli that constantly bombard us, and we tend to give meaning to these stimuli. The stimulus that we perceive, most of all, and that involuntarily modifies our behavior is color. Throughout history, different disciplines, with different research methodologies, have dealt with the study of color. Through a series of theoretical and empirical works, they have created a general framework on the subject, as shown in other review works (Elliot, 2015). The scientific literature presents several works on various aspects of color as a stimulus, such as the physics of color (fundamental properties of color), the physiology of color (processing color information), and the language of color (naming a certain color in different countries); these works have given an idea of how to study color in all its characteristics. However, even today, defining the term color, giving a definition that can be accepted by all the disciplines that study it, is a very difficult challenge. Throughout history, color has been defined in a myriad of ways, and it is fair to say that a universal and definitive definition has yet to emerge (Kuehni, 2005). In a psychological perspective, to fully define or understand the term color, it is important to distinguish two main characteristics that comprise it, the first being the physical nature of the stimulus as such, and the second being the response of the individual who encounters the color (Hunt, 1978). In this case, color can be described as that perceptual phenomenon present in everyday life, capable of influencing our mood and our behavior according to the emotions it arouses. Since the 2000s, there has been a boom in the scientific literature on the subject of color and psychology, with research in this field generally dealing with the relationship between color and human cognition in a broad sense. Unfortunately, as other authors have pointed out, (Elliot and Maier, 2014) research in this field does not all have good methodological rigor. By methodological rigour we mean various aspects including, Failure to control the physical characteristics of colour leads to a confusing design and results that are essentially impossible to interpret (Valdez & Mehrabian 1994). For example, if more than one colour attribute varies at the same time, it is not possible to determine whether a result obtained is due to the colour attribute of central interest or to one or more of the other colour attributes.

In this review, the main aim is to shed light on the previous literature on colour and emotion, and in particular we will focus on the emotions that modulate cognitive performance through lightness. We will analyze recent theories and research regarding the possible relationship between emotions and the perceived lightness of color. Given the vast number of theories on color, starting from Aristotle, Newton, and Goethe, and also given the exponential growth of publications on the subject, we will focus only on the most recent and influential theories concerning the influence of color on emotion, utilizing the most objective works that have methodological rigor. Up to this point, it is best to be patient and humbly acknowledge that the psychology of color is an extraordinarily complex area of inquiry (Kuehni 2012) that is only beginning to manifest itself. The results of color research can be misleading, and because of the great interest of the various areas of research, it can be tempting to conclude before the scientific research is fully in place. There is considerable progress in research on color and psychological functioning, but much more theoretical and empirical work needs to be done before the full scope of this proposal can be identified and hopefully realized, perhaps yielding universal conclusions. So far, a limitation of previous research, which we will try to show in this literature review, is that most of the research conducted in this area, and related theories, has focused heavily on a single colour characteristic, hue. The purpose of this work is to show the importance of other colour characteristics, one of which is lightness.

2. Background on color and emotions

Color exists only in the mind; that is, it is a highly subjective experience that creates strong individual differences (Helm and Tucker, 1962). This can be described as a perceptive, highly subjective response to light entering the eye directly from self-luminous light sources or, indirectly, from light reflected by illuminated objects. Without going into too much detail, our visual system perceives the colours present in the colour spectrum thanks to the presence of three types of cones with different spectral sensitivity, they can be divided into three types, S cones (short), M cones (medium) and L cones (long). At this point, the definition of color that may be considered the most popular at present is the most recent offering provided by the CIE (International Commission on Illumination): “color (perceived): Characteristic of a visual perception that can be described by attributes of hue, lightness, and chroma”, and each of these attributes can influence psychological functioning (Suk and Irtel, 2010). In order to better understand this review work it is necessary to point out a distinction between lightness and brightness, which are often confused in the scientific literature. Brightness is the attribute of a visual perception according to which an area appears to emit, or reflect, more or less light, while, lightness is the brightness of an area judged relative to the brightness of a similarly illuminated area that appears

to be white or highly transmitting. In summary, color perception provides us with a representation of the physical objects and lights in our three-dimensional environment (Brindley, 1970; Geisler, 1989). This process allows us a complete understanding of the space around us through different processes. the global process of "color perception" gives us a description of the physical properties of these objects and lights; a description of how information about these physical properties is transported by light to the eyes and stored by optics to form the retinal image; a description of how retinal photoreceptors respond to the retinal image; a description of how photoreceptor responses are transformed by visual processing into the way we see the world; and finally the emotional connection generated by the color-object interaction". Each physical characteristic of the color taken individually has little value, but studying them individually allows you to better control the chosen variable, giving it the right importance. One of the characteristics of color that has been little considered up to now is the perceived lightness (which we will discuss in detail later). Lightness is important as it allows us to optimally perceive an object; in this regard, it is right to introduce a neurological disorder (still unclear), in which sometimes it is the only component present. This pathology is known as "achromatopsia", literally means "not seeing colors", or severely reduced ability to discriminate between different colors shades (Heywood and Kentridge, 2003) but which allows, in different cases, to still perceive lightness (Cole et al., 2003) "Monochromatism" means "seeing shades of one color" (seeing the world in shades of grey). In this pathological condition, the fundamental importance of perceived lightness is highlighted and an in-depth study in this field will allow us to identify differences related to the “lightness” variable alone compared to the other physical components of the color.

Color has fascinated scholars for millennia (Patricia, 1991; John, 1993). As a starting point for psychological theories associated with color, one could point to when the theory of color and psychological functioning has been present since Goethe in 1810 wrote his “Theory of Colors” (Johann Wolfgang Von Goethe 1982), in which he linked color categories to emotional response (e.g., warmth, arousal). Historical research on the topic has created at least general conceptual statements about color and psychological functioning, particularly with the general associations people have with colors and their corresponding influence on emotions, cognition, and behavior (Frank and Gilovich, 1988). As mentioned, color can have psychological and behavioral effects (Elliot and Maier, 2014), and it can also have purely aesthetic properties (Schloss and Palmer 2015). Other studies have investigated the relationship between color and other more specific psychological variables, such as sexual attractiveness (Pazda, Elliot and Greitemeyer, 2014), intellectual performance (Shi, Zhang and Jiang, 2015), and food consumption (Genschow, Reutner and Wänke, 2012; Bruno et al., 2013). It is known that emotions can influence our cognitive functions, and these in turn are influenced by colour. In the last twenty years have seen an increase in research in the field of color on different cognitive functions, in fact, if we search in Google Scholar 'colour and cognitive functions', we get around 2 million scientific articles. One of the most investigated cognitive functions is the attentional process influenced by color. On selective attention, for example, it has been shown how red stimuli receive an attentional advantage (Elliot and Maier, 2007). Research on color and alertness has shown that blue light increases subjective alertness and performance on attention-based tasks (Chellappa et al., 2011). Other cognitive functions have been investigated as studies on color and athletic performance have linked the use of red to improved performance and perceived performance in competitions and sporting activities (Elliot and Maier, 2012). Empirical work on color and avoidance motivation has linked viewing red in performance contexts to increased caution and avoidance (Elliot and Maier, 2014). Other studies, on the other hand, have investigated the relationship between memory-emotion modulated by color and how it affects performance in older adults (Mammarella et al., 2016).

As seen from the extensive reference literature, all effects of color undoubtedly depend on certain psychological conditions (or variables) that are independent of the stimulus but vary from individual to individual. These variables have been greatly underestimated until a few years ago (Schloss, Hawthorne-Madell and Palmer, 2015), variables such as the culture of belonging, sex, age, the emotional state of the individual, and the type of task (in the experimental case). These variables make the color-emotion interaction a process that cannot be underestimated and it is not universal. The awareness and realization that understanding these conditions will be an important marker of maturity for future work in this area (Schwarz and Singer, 2013; Tracy and Beall, 2014). These variables, hitherto underestimated, have created several methodological errors, creating results based on false expectations. It is therefore necessary to take individual variables more seriously, and give them their due importance. Starting from the idea that color exists only in our minds, it is important to describe individual differences in color perception. In this regard, a recent psychological theory, the "color in context" theory (Meier et al., 2012) is based on social learning and biology. This

new strand of research, with a more fully comprehensive view, for this theory all three of color properties may be important, at both the main effect and interaction levels, with regard to links between color and affect, cognition, and behavior, In addition, this theory places at the center a new variable that can influence psychological functioning, the context. Some responses to color stimuli are presumed to be due solely to the repeated matching of colors to concepts, triggering particular experiences. Others, however, are presumed to represent a biologically ingrained predisposition that is reinforced and shaped by social learning, as in a mechanism of natural selection (Humphrey, 1976). The theory introduced, through this social learning process, color associations can be extended beyond natural bodily processes (e.g., blood flow modulations) to objects close to the body (e.g., clothing, accessories), making the theory applicable to various contexts, taking into account the variables listed above. As the name of the theory implies, it is believed that the physical and psychological context in which the color is perceived influences its meaning and, consequently the responses related to it.

3. Color controversy

A constant feature of this work points to important methodological problems that precluded rigorous testing and clear interpretation (O'Connor, 2011). One such problem has been the inability to pay attention to scientific procedures including investigator blindness to the condition, identification and exclusion of color-deficient participants, and standardization of the duration of color presentation or exposure. One of the most common mistakes is the inability to specify and control color on a spectral level in manipulations. Without this specification, it is impossible to know what precise combination of color properties has been studied and without such control it is inevitable to confuse focal and non-focal color properties (Valdez and Mehrabian, 1994). Another problem is perhaps due to an optimistic view of one's research, as the effects of variables are inflated and given for universals (Elliot and Maier, 2014), color stimuli can also vary in terms of perceived typicality (the degree to which a color resembles a commonly seen representation of that color category). Thus, more rigorous experimental work addresses both the multidimensionality and perceived typicality of color stimuli in manipulations; most research has not addressed either simultaneously. All of these methodological problems have greatly hindered (rigorous) scientific progress in this area. Color control is typically improperly performed at the device level (rather than the spectral level), is impossible to implement (e.g., in web-based platform studies), or is ignored altogether. Color control is certainly difficult, as it requires technical equipment to evaluate and present color, as well as the experience to use it. However, careful color control is essential if systematic scientific work in this area is to be conducted. The results of uncontrolled research can be informative in initial explorations of color hypotheses, but such work is inherently fraught with interpretive ambiguity that must be subsequently addressed. The process of color perception is not only a function of hue (is "color's name", which represents a particular wavelength of visible light), lightness (represents the degree of reflected light), and chroma (refers to the intensity and purity of a hue), but also of factors such as viewing distance and angle, the amount and type of ambient light, and the presence of other colors in the immediate background and general surroundings (Fairchild, 2015). In basic scientific research on color, these factors are carefully specified and controlled to establish standardized viewing conditions for participants. These factors have been largely ignored and have allowed for variation in research on color and psychological functioning, with unknown consequences.

To date, most theories have focused on hue, one in particular, red, which is understandable given its importance in nature, body, and society (Changizi, 2009). However, other hues also carry important associations that undoubtedly have effects on psychological functions such as green and blue (Akers et al., 2012; Labrecque and Milne, 2012; Mammarella et al., 2016). But lightness and chroma also undoubtedly have implications for psychological functioning (Lee et al., 2013; Kareklas, Brunel and Coulter, 2014); lightness has received some attention within conceptual metaphor theory (Prado-León and Rosales-Cinco, 2011), but chroma has been almost entirely neglected, as has the problem of combinations of hue, lightness, and chroma. Finally, it is also likely that many situational (Bubl et al., 2010) and intrapersonal (Fetterman, Liu and Robinson, 2015) factors influence color perception such as the concept of color preference (Palmer and Schloss, 2010). The complexity of color as a stimulus capable of creating psychological effects needs more attention and further scientific research in this regard, for while much has been done just as much remains unexplored.

4. The lightness effect

The aim of this paper is to show the few studies on the subject of lightness, and to show how it may be of interest for future studies. On a physiological level, lightness of color influences the production and release

of hormones. Color perception stimulates the neural portion of the optic pathway in the hypothalamic brain region and the pineal and pituitary glands, which control the entire endocrine system (Mahnke, 1996). Empirical work demonstrates the physiological effects of color in both animals and humans (Bellizzi, Crowley and Hasty, 1983), with physiological effects such as heart rate, respiratory rate, blood pressure, muscle activation, blinking, palmar conductance, and brain waves. In this paragraph we will focus on the importance of one of the fundamental dimensions of color, lightness, which is just as important, if not more so, than hue (Gorn et al., 1997; Labrecque and Milne, 2012). It has been known for many years that light directly influences physiology and increases arousal, but the effects of light can be non-visible and influence behaviour by modifying the biological state of the individual (Cajochen, 2007).

In the field of neuropsychology, cognitive performance refers to the ability of the human mind to acquire, store and process information, to solve problems of any kind, from the simplest ones, such as the needs of daily life, to others decidedly more complex to study, such as the level of subjective vigilance and the level of alertness that involve the brain, and in particular the attentional process. In this regard, color lightness can influence all these factors by modulating the cognitive performance of individuals (Rossi, 2019). There are non-visual effects of lightness that affect the human body through mechanisms other than melatonin regulation, through direct action on the human nervous system and with consequences that affect alertness level (or attentional process) (Cajochen, 2007) mood (or emotion) (Legates, Fernandez and Hattar, 2014) behavior (Chellappa et al., 2011), and other human physiological parameters such as heart rate and body temperature. All this effects can affect the cognitive performance in every behavioural choice. In general, light and lightness, represent the core of the process of visual perception, through transduction, the process by which the energy (light) of environmental stimuli is converted into neural activity. Leaving aside the difference between natural and artificial light, which have important differences between them (Jazizadeh and Wang, 2016), we will focus on the concept of lightness in general, without making this distinction. The effects of light on psychological components can be divided into several categories encompassing all human cognitive functions.

4.1. *The lightness effect on Emotion*

The human being is guided in his behavior by emotions and they are regulated by the context and experience (Mesquita, 2007). The emotions triggered by the external environment change the internal state of the individual going to affect the regulation of body temperature, mainly due to endogenous phenomena such as sweating and vasodilation. The ability to perform this regulation depends on the body surface involved and on the temperature difference with the external environment. In this regard, a study has analysed research that relates the amount of light to thermoregulation and the subjective feeling of thermal comfort. In some cases, light with color shades that turn toward red induces a feeling of greater environmental warmth than light that turns toward blue (Te Kulve et al., 2016, 2017). However, the results of the latter type of research are sometimes contradictory because the context, mode of experimentation, and detection of results differ. In this perspective, psychological factors may also come into play, leading to different results in different social and cultural contexts. A non-pathological condition, winter depression or seasonal affective disorder (SAD) is a disorder that affects people during the winter who are normally healthy during other seasons of the year (Targum and Rosenthal, 2008). The symptoms are those types of depression, such as lack of energy, tendency to sleep a lot, but also obesity, asthenia, insomnia, and difficulty in concentrating. It has also been observed that the same subjects in summer can show symptoms of intensified anxiety. For this reason, today this disease is no longer considered as an exclusive winter mood disorder, but as a disorder that can recur at different times of the year with different symptoms. Studies have shown that the likelihood of contracting this disease is greater with increasing latitude and particularly in Nordic countries, especially when exposed to solar radiation is lower (Rosenthal et al., 1988). How color lightness relates to emotions is the subject of much psychological research, but the results are difficult to assess for practical use, the reasons for this are both technical and conceptual. On the technical side, color-emotion data have been collected using experimental methods that vary widely in precision and scope, as described below.

To our knowledge, many of the studies on color and the relationship between color and emotion, to date have not used an objective method for studying color, not applying a correct description of color, without restrictions to specify the color (with a correct description of its characteristics) that best corresponds to a given emotional stimulus. These methodological problems make it very difficult to correctly study the physical characteristics of color such as lightness, which is a less studied characteristic than hue. If we wanted to list all the studies on the subject of colour associated with psychological characteristics, a review would not be sufficient, given the extensive literature on the subject. Our aim, in fact, is to analyse the psychological functions

influenced by colour lightness. In this respect, it is important to emphasise the role of emotions in this interaction, as they are a ubiquitous aspect of human beings and which in turn influence the various human cognitive functions (Dolan, 2002), as we shall see in detail.

4.2. *The lightness effect on Attention*

Visual attention comprises a set of mechanisms that modulate sensory and cognitive processing to select the most behaviourally relevant stimuli for further limited-capacity processing. Which of the many retina-affecting stimuli will be selected is determined by both the task goals (top-down factors) (Folk, Remington and Johnston, 1992) and the current stimulus processing (bottom-up factors) (Itti and Koch, 2000). How top-down and bottom-up mechanisms interact in selection is still much debated (Beck and Kastner, 2009). The effects of light and lightness are visible in human behavior. These include behavioural changes throughout the day (circadian rhythm), in fact, the reaction times (in terms of behavioural response to any daily task) are generally longer in the early morning and decrease for the day only to increase again during the night and peak in the early morning (Posner and Petersen, 1990). These measures reflect other diurnal changes such as body temperature and cortisol secretion. This essentially modifies an attentional mechanism called “alertness” (Petersen and Posner, 2012); in this case there are at least two definitions of alertness, namely, the terms phasic and tonic alertness (Posner and Petersen, 1990). Phasic alertness refers to the orientation response (Sokolov, 1963) and tonic alertness will be used as a synonym for vigilance and sustained attention, these mechanisms can be influenced by colour lightness.

For example, the psychophysiological and behavioural effects mediated by light stimulation, this by assessing differences in illumination (Badia et al., 1991). The level of alertness, assessed with EEG through beta brain waves (14-30 hertz), showed a significant increase in the strong light condition, which also had the effect of decreasing drowsiness and increasing body temperature, going to modulate the alert attentional state. In another very relevant study (Cajochen et al., 2005) the focus was on the chromatic component of light (blue light with a peak at 460 nm and yellow light at 550 nm). In the blue light condition, in addition to observing a reduction in melatonin, there was an increase in body temperature, heart rate, and level of alertness of the subjects involved. This did not occur with exposure to yellow light. Similar results were also observed where participants were in a normal office setting (Smolders, de Kort and Cluitmans, 2012). The results showed that with the brighter lighting the subjects had shorter reaction times, higher alertness level, and increased heart rate, especially towards the end of the hour of exposure to the stronger light. These results would demonstrate that even under normal daytime conditions, not in the dark and temporally away from rest periods, i.e., under physiological conditions other than those in which melatonin regulation comes into play, brighter light can improve feelings of alertness and vitality, as well as subjective performance and level of physiological activation.

4.3. *The lightness effect on Memory*

Memory is now defined in psychology as the ability to encode, store, and retrieve information (Squire, 2009); focusing on these processes, one research study investigated the effects of different wavelengths of light on brain waves associated with memory processes (Okamoto and Nakagawa, 2016). Cortical activity was monitored using magnetoencephalography (MEG) The experiment was conducted by exposing subjects for 30 minutes (during the day) to two different lighting conditions, green light (with a peak wavelength of 520 nm) and blue light (with a peak wavelength of 470 nm). The results showed that blue light increased cortical activity related to active maintenance of working memory. Similar results were also observed in research in which, instead of monochromatic lights, they used two white lights 3,000 (warm light) and 5,000 K (cool light), noting that the 5,000 K light stimulates the central nervous system more (Noguchi and Sakaguchi, 1999). Working memory in the human cognitive system is a part of memory, with a time-limited capacity, that supports the temporary storage of information available for brain processing (Wynn and Coolidge, 2011). This cognitive structure is important in reasoning and in guiding decision-making and behavioral processes. It should not be confused with short-term memory, which simply stores information temporarily but is not directly related to the brain's processing of information (Cowan, 2009). Working memory is a central theoretical concept in cognitive psychology, neuropsychology, and neuroscience in general. it is essential for learning activities and problem-solving.

4.4. *The lightness effect on Memory*

A popular way to study decision-making is undoubtedly the studies on consumers going so in the field of marketing. Recent studies in this field are studies on cross-modal associations (two senses in one) (Spence and Parise, 2012) in this regard the lightness of the color is associated with characteristics such as hot-cold, or sad-happy (Kaya and Epps, 2004). The effects of the new correspondences between somatosensory and visual perceptions (warmth and color lightness) extend

from capturing visual attention to preference formation, as well as on how attitudes toward sensory experiences (i.e., positive reactions to sensory experiences) play a critical role in preference formation. The results showed the existence of cross modal correspondences between the sensation of warm and light colors (Motoki et al., 2019). Thermal environment and product color are important considerations when designing marketing strategies for many business settings. Stores can usually control the ambient temperature using air conditioners, and light/dark colored products are displayed in such locations. Recognition of the impact of sensory experiences in natural shopping environments has led to increased attention to the effects of such experiences on consumer behavior (Krishna, Cian and Aydınoğlu, 2017). Still, other studies, show how the color of a dark (versus light) product encourages higher durability ratings but lower ease-of-use ratings (e.g., a PC) (Hagtvedt, 2020). Both of these influences are related to the impact of color brightness on perceived weight: darker (compared to lighter) colors cause objects to appear heavier (Sunaga, Park, & Spence, 2016). However, there is still little evidence in this area of study.

4.5. *The lightness effect on Sleep*

Light and lightness affect the circadian rhythm by compromising sleep (Rossi, 2019). Many people suffer from sleep disorders, which can have different causes and different effects, even of a serious pathological nature, which hinder a healthy daily life both from a physiological and psychological point of view, interfering with emotional states and social relationships (Vgontzas et al., 1999). The most well-known disorder is that of insomnia, which occurs when the individual is unable to fall asleep despite being tired and having an actual physiological need to sleep (Lockley et al. 2008). The effects of insomnia also affect the quality of daily life, as affected individuals often have difficulty concentrating and learning, related to the malfunction of working memory, but also chronic fatigue and irritable mood. In general, the main discomforts, which occur in 40% of cases of people suffering from insomnia, are psychiatric disorders, particularly depression and anxiety (Roth, 2007). Another form of sleep disorder is nocturnal bruxism, which has very serious negative effects: erosion of the teeth down to the dentin, with an increased likelihood of fracture and of developing tooth decay and inflammation of the tongue. It can also induce headaches in the temporal areas, with possible ear discomfort caused by repeated nightly tension of the muscles acting on the jaw. This type of disorder results in restless sleep with nightmares, restless leg syndrome, increased heart rate, and various other types of disorders, including bruxism. It has been shown that approximately 86% of nocturnal bruxism episodes occur during restless sleep (Lavigne et al., 2007). These are some of the most well-known sleep disorders. In this field, some well-known research has shown that the use of bright light in the morning can help with typical sleep disturbances with subjects with an unbalanced circadian rhythm (Figueiro and Rea, 2016), while strong lighting (2,500 lx) after 8:00 pm can help reset the circadian rhythm and alleviate the typical disturbances (Lack and Wright, 2007). A review of the literature examined 21 research studies that investigated the use of light as a therapy for sleep disturbances, such disturbances being much more common in the elderly population. The elements that were considered were the amount of light, spectral power distribution (SPD) of the light, time of exposure to light, duration of exposure, and direction of light (Sloane et al. 2008). The positive effects of light on proper sleep timing and quality have been verified, several effects of light wavelengths have in this context have been highlighted (Figueiro and Rea, 2016). Thus, excluding the need for excessively bright (annoying) lighting that is not applicable in the design reality, and instead of using normal comfortable lighting systems with white light and adequate content of short wavelengths (blue). There is now broad scientific consensus that light can be used as a therapy to improve sleep quality for all individuals (Figueiro and Overington, 2016).

5. Conclusion

The effects of light are varied, and are not limited only to the effects we have mentioned above; in fact, we can go on to say that the effects that light and lightness can have on learning environments have been a topic of research for some time. For example, three studies conducted in Sweden (Küller and Lindsten, 1992) and the USA (Heschong, Wright and Okura, 2002) have demonstrated the importance of the presence of windows and natural light on students' psychophysiological well-being and performance. Two of them also demonstrated that these positive psychophysiological and performance effects are absent in windowless classrooms. We could go on describing other effects of light and lightness on cognitive performance, but while it is true that much has been done so far, it is also true that not enough has been done, due to the experimental limitations outlined above, with the lax way of conducting such research in the field being most to blame. Moreover, the study of psychological effects related to color is a very hot topic, and one should approach it more cautiously without drawing hasty and universal conclusions. Color is too complex a phenomenon or concept to "take lightly" its study, then associated with cognitive functions is an even more

difficult task because of the many variables involved. Just think of the physical characteristics related to color and how difficult it can be to study them rigorously if you then have the "scientific presumption" to associate them to psychological characteristics without taking into account variables such as context and individual variables (just to mention a few) you fall into error. This work shows various limits of research in this field, it is hoped that this overview will let us think about the complexity of the stimulus and the importance of its correct decomposition into physical characteristics. Perhaps by studying these characteristics individually, giving them all the right importance, it will be possible to obtain a more accurate result than those obtained so far; it is hoped that the focus of research will also shift to color characteristics such as lightness because, as shown, it matters a lot and its effects are visible.

6. Future directions

On the subject of the psychology of color (in all its parts) and its effect on emotions, there has been an exponential growth in the number of scientific publications in the last twenty years. Being the topic of interest for several disciplines it is easy to think that the growth of publications will not stop in the recent future. Technological advances have allowed other disciplines, such as neuroscience, psychophysics, visual cognition, and biology, to gain new insights into understanding the complexities of color perception using new populations and/or new methods such as neuroimaging (e.g. fMRI, ERP, MEG), eye-tracking or modeling (computational or mathematical) (Shevell and Kingdom, 2008). The hope is that along with basic research, the results obtained from them can be made applicable.

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