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# LIGHT AND COLOUR IN THE BUILT ENVIRONMENT

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**ABSTRACT**

In the Book of Genesis there is a dramatic change in the world when God says: *Fiat Lux* (Let there be light)! Chaos was ended. In our everyday life when we hear a noise while asleep at night, we are afraid because there is no light, and if there is no light we don't see anything, i.e., we do not know. When we turn on the light, everything around us gets organized: light ends the chaos of darkness. In fact, we rely more than 80% on our sight sense to bring us what is happening around us.

Light is the genesis of visual perception, and colour is its vehicle. We understand the world around us by the organization of colour stimuli received by our eyes, transmitted to our brain and interpreted there. We can say that colour is the form of space because it is through colour that we perceive the limits and the forms of our environment. Therefore, colour should be studied, together with light, its origin, as the main actor in space perception, and therefore in architecture.

With these assumptions in mind, we have to distinguish between Inherent Colour and Perceived Colour. The first is the colour of the surfaces, which could be read by a colorimeter, without the interference of the human perception or the outside lighting conditions. The second is the colour perceived by the human being, always different according to three variables: light, the observer and the surface. If any of these variables change, the perception will be different: if the light changes its position, or its characteristics, if the observer moves to another place or looks in a different direction, if the surface is placed under or above the observer, or with a different angle, etc. Our work as Colour Consultant proves that the knowledge of this continuous variation in colour perception is a tool that we can use to design better spaces for human life and comfort.

**KEYWORDS** Light; Colour; Perception; Built Environment; Architecture

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## 1. The importance of a holistic approach to colour and light: the ancient discipline of Optics

Colour is nowadays seen as something that makes part of our daily choices concerning objects, clothes, cars, etc., and we tend to see it as something very personal. Light, on the other hand, is something that we only think about when we do not have it, when it is too dark for us to perform the tasks we need. And usually we do not correlate them as something that in fact constitutes the main origin of what we could call "our reality". If we consider that sight is the main vehicle for conveying sensations from our environment (more than 80%) to one's self, that light is the cause to all visibility, and that colour is the unavoidable interaction between light and matter, we begin to understand their importance, and their fundamental relationship.

This holistic approach, and its importance, was recognized throughout History from the classic world to the XIX century where it becomes divided in various specific fields of knowledge corresponding to the scientific specialisation that exist until today. In ancient Greece, the discipline of Optics had a vast epistemological scope and was seen as the most fundamental way to study and understand Nature, the key that could unlock and reveal its most hidden secrets (Lindberg, 1976, p.ix). Euclid's and Ptolemy's *Optics* were among the first pillars for discussion of the subject, but we find discussions on it from the Atomists, Plato, Aristotle, Galen, the Arabs Al Kindi and Al Hazen, to the "modern" *Optics* of Kepler and Newton, just to cite some. The discussion of processes of visual perception was crucial to the progress of knowledge. This discipline of Optics could encompass subjects such as anatomy and physiology of the eye, the mathematical principles of perspective, psychology linked to visual perception and the nature of light and the laws of its propagation. It has always been a domain of

reflection for thinkers and philosophers and currently one can easily recognize the characteristics and controversies of the main currents of thought throughout the various eras. Optics was a holistic field of knowledge for the explanation of the universe and its relationship with the human being.

We should think again of light and colour within this interdisciplinary frame because it is the only way to understand their importance for the perception of our environment and therefore, for architecture and the built environment.

## 2. Light and colour perception in Architecture

In order to have visual information through our sight sense we must have light; hence, light is considered the first condition for visual perception. Additionally, whenever there is light there is colour. Being the result of light's interaction with matter, colour is responsible for space perception, so we can state that colour is the form of space.

In *De Coloribus,* Aristotle notices this fact when considering that visibility is only possible with light, just as bodies' visibility is only possible through colour (Aristóteles, 2001).

The importance of colour in space perception is well expressed by Goethe in his *Theory of Colours*. He claims that nature seeks to manifest itself to the sense of sight through colours (Goethe, 1988). But more than concurring Aristotle's previous perspective, he innovates when saying that colours are directly related to emotions:

*Since colour occupies so important a place in the series of elementary phenomena, (… ) we shall not be surprised to find that its effects are at all times decided and significant, and that they are immediately associated with the emotions of the mind* (Goethe, 1988, p.304).

The unavoidable relationship between light and colour is also well expressed by Johannes Itten in his book *Art of Color*, where he considers colour as the *daughter of light* (Itten, 1997). He also poetically relates these elements saying that *Light, that first phenomenon of the world, reveals to us the spirit and living soul of the world through colors* (Itten, 1997, p.13).

Colour is an emotional link between the human being and what lies around him. Cézanne used to say that *Colour is the place where our brain and the universe meet* (Merleau-Ponty, 1993). To better understand these concepts, we must empty our mind of any preconceived ideas and establish a new understanding for the role of light and colour in architecture.

Light is a metaphor for knowledge. To see is to know. Accordingly, when we design spaces we must take into account that it is through light that we reveal (or conceal) the architectural spaces, their forms, their proportions, their textures and colours. Light shapes our perception, as stated in Le Corbusier's (Le Corbusier, 1977) definition of Architecture: *the learned, correct and magnificent play of volumes in light* (Le Corbusier, 1977, p.16). And as architectural spaces are revealed through light, we must not simply imagine their outcome during the day, but also during the night under artificial light. Architects should not rely on Electric Engineers for the aesthetical outcome of architectural spaces at night.

Since the spaces are revealed by light, the role of colour is inherent to their formalization: if spaces are defined by their visible limits, these limits have a certain materiality that is brought to us by their colours. It should be made clear that when we talk about colour we are dealing with everything we see in our environment, including raw materials like wood, stone, metal, etc. Jan de Heer (2009) in his *The Architectonic*

*Colour* states that *Polychromy (…) involves the treatment of the surfaces that are exposed to everyday use. In present-day architecture, this often relates to the choice and ordering of the materials* (De Heer, 2009, p.6).

Colour is intertwined with light. The presence of a colour in space depends on its illumination: a strong colour could have a subtle presence if it is dimly illuminated and a subtle colour could have a strong presence if it is brightly illuminated. Furthermore, there are colours that need more light to accomplish their identity, like some reds, and colours that live well in the shadow, like some Blues (Le Corbusier, 2006). On the other hand, our colour perception also varies with the circumstances of observation (distance, space location, etc.) and with the characteristics of the object's surface (texture, gloss level, etc.).

In order to understand light and colour's relationship with space we have to admit that they play a continuous game of variations. Colour perception is the result of three variables: Light, Object and Observer. If any of these variables change, the colour perception will be different. But the colour measured over the surface, for instance with a colorimeter, will be the same because it has no interference with the human perception or the outside lighting conditions. For this reason, we have to define two kinds of colours: Inherent Colour and Perceived Colour. For each inherent colour, i.e. the colour measured over a surface; there will be thousands of perceived colours, depending on the variation of the light, the object and the observer's point of view.

Josef Albers (1975), a prominent artist and a Bauhaus teacher, based his work upon the variations of colour perception, stating: *In visual perception, a color is almost never seen as it really is - as it physically is. This fact makes color the most relative medium in art* (Albers, 1975,

p.1). We can follow this notion back to the work of Aristotle (Aristóteles, 2001), probably the first to isolate the colour phenomenon, when he says:

*We do not see any of the colours pure as they really are, but all are mixed with others; or if not mixed with any other colour they are mixed with rays of light and with shadows, and so they appear different and not as they are* (Aristóteles, 2001, p.17).

In Architecture, perceived colours are the ones that interest us, which we can model with light, transforming the space perception. But when it comes to formalizing a Colour Study and transmitting our ideas to be applied at the worksite, we have to use colour codes, that is to say, inherent colours.

**3. Design using light and colour variation**

Variation is the key for perception: if one's perceptive visual field lacks variation, one cannot distinguish forms or volumes (like in a foggy day). Colour and light variation allows us to form coherent associations, detach figures from the background, and in this manner, form a mental space where we can act and move safely.

Colour variation was Leonardo da Vinci's first concern when teaching painting techniques. In his *Trattato della Pittura* he refers that *the first object of a painter is to make a simple flat surface appear like a relievo, and some of its parts detached from the ground* (Da Vinci, 2002). This idea is interdisciplinary: anthropologist Gregory Bateson (1987) stipulates that perception is based on difference: change is the food of perception. Psychologist James Gibson also defines the variation, or change, as the main factor for visual perception (Gibson, 1986).

We can distinguish two kinds of variation: synchronic and diachronic. When you perceive a red square over a black painted background, you are experiencing synchronic variation. The borders of the red figure detach themselves from the black background, and through that colour variation you perceive a figure you have learned to call "square". When you walk through a space, forms and shapes keep on changing and, even when you stop and look around, your perception varies. That is diachronic variation. Another example of this concept could be the changes of colour and light in a room, which are dictated by the movement of the Sun during the day. If we consider that even in the first example of synchrony you detach the square figure from its background by moving your eyes following the difference between red and black, we can say that variation is allays related with movement, and therefore with time.

The human being is naturally related to variation. Our body, and its functions, is regulated by the twenty-four-hour cosmic circadian cycle, alternating light and dark, activity and rest. From our prenatal period, we learn to associate various stimuli with variation: bright hues, intense light, noise (active period) and dark hues, low lighting, silence (period of rest). Variation is a natural element; constancy is not.

Until the end of the XIX century, light variation (and consequently colour variation) was a natural presence for twenty-four hours. Even at night, the illumination resulting from burning materials (like candles or petrol lamps) always produced movement. In our days, artificial light produces a static environment at night, always with the same intensity and direction provoking an immobility that is not natural to us. Jean-Paul Sartre names this fact *the look of Medusa* over things, paralyzing them. The colours caused by artificial lighting will not change over time and the objects will remain motionless in their

appearance, as well as their shadows. This unnatural immobility of light and colour perception could cause psycho-physiological disturbances like fatigue, stress, etc. Light and colour variations are indeed a natural and meaningful attribute for space perception and for human comfort.

Knowing all this, how can we use light/colour variation to design better environments?

**a) Accentuate different functions within a space**

In a classroom, the colour of the wall behind the teacher should be darker than the others, in order to focus students' attention and promote comfort for their eyes. A bright colour in the teacher's background would cause pupil muscle's fatigue in trying to adapt to different luminous fields: the teacher's face and the bright background. In FIG. 1 we can see that, before the colour study, the walls and ceiling were all painted white. The colour study applies a greyish Blue at the teacher's wall and in the ceiling promoting a focus of attention and reducing the excess of glare coming from the large window.

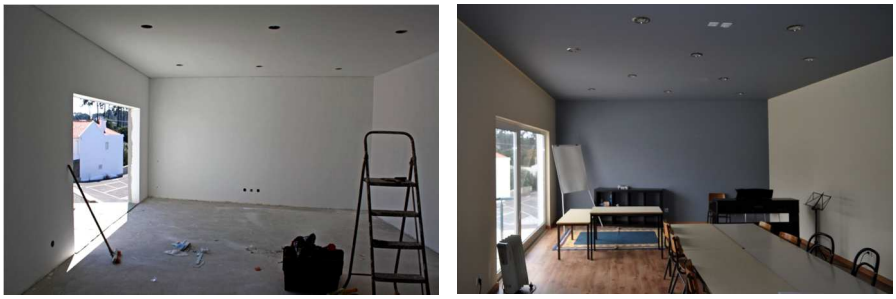

FIG. 1 - Before and after: colour could be used to focus attention in a classroom. SAMP School. Colour Study: João Pernão.

Other example of the use of colour variation to accentuate space functions is seen on FIG. 2. A wall dividing two different areas in a classroom could be painted in a strong colour to emphasize its centrality. In this case this wall is covered with a soft material that absorbs sound and allows for papers and drawings to be fixed on it.

FIG. 2 - Colour could emphasize centrality. Cenfic School, Lisbon. Colour Study: João Pernão.

Photo Margarida Dias.

**b) Accentuate differences between spaces with different uses**

The variation between spaces with different functions could be accentuated by light and colour. In the transition of some environments it is advisable to produce differences in space perception in order to induce different behaviours, for instance from offices and meeting rooms to corridors and lounge areas; from classrooms and study areas to corridors and relaxing areas (FIG.3).

FIG. 3 - Colour and light used to enhance transitions. CENFIC School, Lisbon. Colour Consultant: João Pernão.

In FIG. 4, we clearly state through colour the difference in behaviour inside a classroom, with low saturated colours, and on the stairs, with bright and saturated colours enhancing movement. In this way, we are supporting and directing the psychological environment derived from the functions established by the architectural project.

FIG. 4 - Colour used to establish variation in behaviour. CENFIC School, Lisbon. Colour Consultant: João Pernão

Photos: Margarida Dias.

**c) Define transitions between exterior and interior**

The moments of transition between spaces are one of the most important issues in Architecture. Transition between exterior and interior spaces is perhaps the most dramatic one because it involves many levels of perception and many senses: it's a transition of scale, temperature, sound, smell, and, of course, light and colour. In FIG. 5 the complementary effect of colours (red/green) is used to establish a contrast between the green colour of nature and the interior walls.

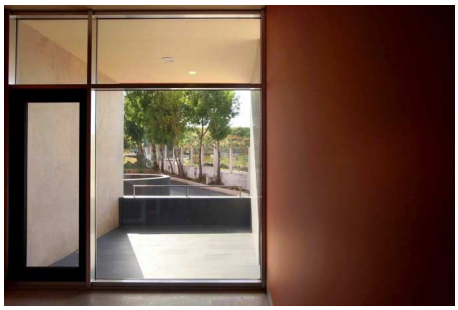

FIG. 5 - Using Colour to accentuate exterior/interior transition. CENFIC School, Lisbon. Colour Consultant: João Pernão.

Photo Margarida Dias.

In a social housing rehabilitation, we use different entrance colours to promote identity and distinction between buildings (FIG. 6).

FIG. 6 - Entrance differentiation through colours. Bairro das Descobertas, Moita.

Colour Consultants: José Aguiar and João Pernão.

This variation in buildings otherwise all alike, gives inhabitants the sense of recognition of each ones' house as unique.

**d) Using colour difference to promote way-finding**

Colour is an important tool in recognizing the visual references of our environment; it is through that recognition that we establish a series of key-points or anchors that define our position in space. The *legibility* of our built environment is determinant for a good relationship between the space users and the architecture (Lynch, 1982).

In a colour study for the interior of a hospital facility, we create a correspondence between the access units (stairs and elevators) and a colour (red). The same colour was used to detach the reception spaces on each infirmary. This facilitates orientation of the visitants that used to be lost in the maze of similar galleries and corridors. In FIG. 7 red was used for the infirmary's reception desk, on the right, and to sign the stairs at the end of the corridor. Green and yellow were also used for orientation: the infirmary rooms are on the green side; the yellow side is for medical exams and staff offices.

FIG. 7 - Before and after: using colour to promote way-finding. Hospital de Santo André, Leiria.

Colour Study: João Pernão, Luís Bissau, Carla Lobo.

**e) Using natural light variation to enrich the architectural experience**

We have studied two ways for applying this concept: texture / gloss difference, and colour reflection.

The interplay between light and matter is a key issue in designing good architecture. Peter Zumthor (2006) argues that the materials in architecture should be chosen by the way they reflect light. Stone, wood and other raw materials' finishing, as well as the gloss level of paint, are fundamental decisions for space perception. Glossy finishes

have the ability to convey and reflect light and colour variations from the environment in a much stronger manner than matte ones. But it is the difference between them that produces balanced and aesthetically pleasing spaces. In FIG. 8 we can see a simulation of the difference between a choice of matte paint on the walls, on the left, and glossy on the right. The choice of the glossy surface produces a virtual expansion of the space's dimensions through the reflection on the walls.

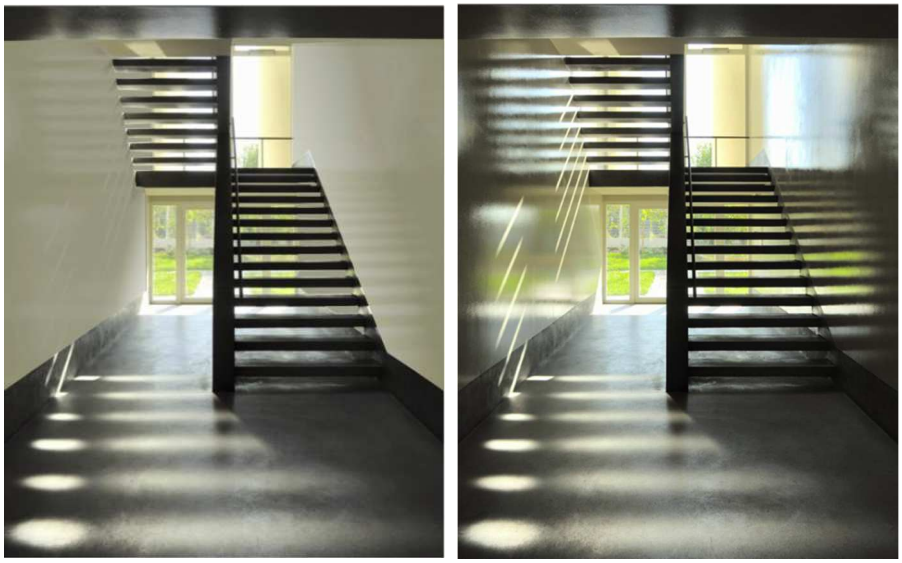

FIG. 8 - Matte or gloss finish could dramatically change the space perception. Francisco Arruda School, Lisbon.

Colour Consultants: João Pernão and Maria Capelo. Photo Laura Castro .Caldas/Paulo Cintra.

In Portuguese architecture, we commonly use glossy glazed tiles (azulejos), as a wainscot in the lower part of the walls, for aesthetic and protective reasons. This glossy part of the wall plays a perceptual game of ephemeral reflections, always transforming space perception as you walk through a room, or as the sun strikes it at different hours of the day. With this in mind, in a colour study for a secondary school we define a unique colour for the wall, but we choose a paint with a gloss finishing for the lower part a matte paint and for the upper part (FIG. 9).

When light strikes a coloured surface, the result is a reflection of coloured light. That coloured light could tinge the space nearby. We

can notice this phenomenon in our everyday life as the sun reflects the blue of a swimming pool, or the green of the grass into a room. This ephemeral variation of the reflected colours could be used as a tool for architectural design, relating space perception with time (Pernão, 2014).

FIG. 9 - Gloss and matte surfaces could bring aesthetical quality to architectural space. Palácio Fronteira, Lisboa / Francisco Arruda School, Lisbon. Colour Consultants: João Pernão and Maria Capelo.

In Braancamp Freire School we tested this concept using yellow to paint the skylights in the atrium, giving that space a continuous variation of warm tones during the day. To balance this accentuation, we paint the auditorium blue, colour which reflects on the white painted walls nearby (FIG. 10).

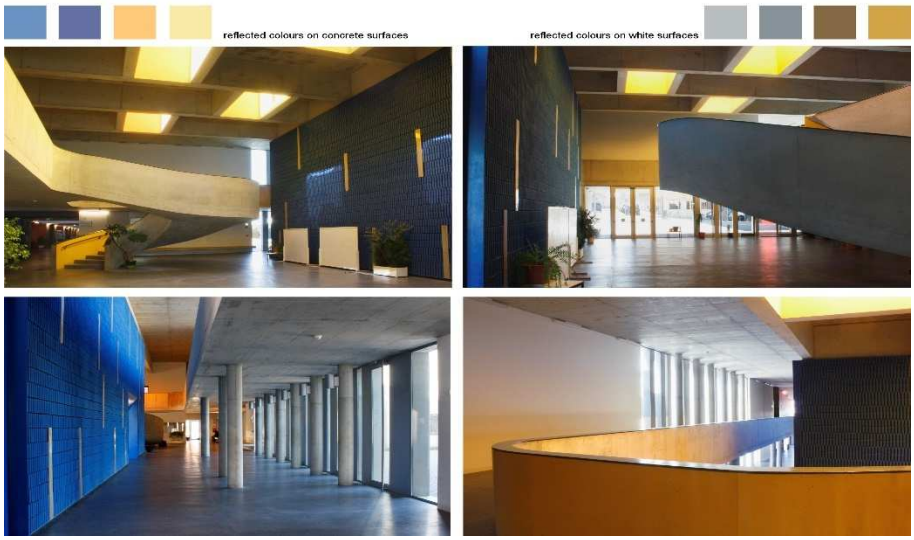


FIG. 10 - Colour and light variation produced by reflected colours transforms space perception during the day.

Braancamp Freire School, Lisbon. Colour Consultant: João Pernão.

In classroom spaces, painted white, light is reflected in the coloured concrete exterior surfaces near the windows. The difference between inherent colour and perceptual colour varies during the day, transforming the classroom space in a rich architectural experience (FIG. 11).


FIG. 11 - Reflected colours in the classroom. Braancamp Freire School, Lisbon. Colour Consultant: João Pernão.

**4. Two much or too little colour and light**

Being so important for the perception of the built environment, light and colour are often wrongly used, most of the times due to lack of knowledge, some of the times due to a blind repetition of an aesthetical stereotype.

One of the most common mistakes is related to the use of pure white in architecture as a dominant colour. White has the highest luminous reflectance factor of all colours, and for that reason should be used with caution, once it can easily produce glare that, when accompanied by high levels of natural or artificial light, could be harmful to our health, causing physical, mental and emotional discomfort (Mahnke, 1996). For this reason, white should not be used as the main colour in an environment where people stay for a long period of time, for instance classrooms, offices, etc. The continuous action of the eye muscles, opening and closing the pupil, trying to focus less illuminated subjects, will result in eye fatigue. It is not a question of aesthetics, it has a physiological one, and that should not be questionable.

Another factor is that the white paint nowadays used as default is the strongest and most reflective white ever available in our entire history. This white was only possible with the manufacturing of Rutile (titanium dioxide) as a pigment and it is used because of its chemical stability and excellent hiding power (twice the opacity of pure lead white). But it is very uncomfortable, and looks false (plastic) in architectural surfaces. It has to be subdued with a small percentage of blackness and colour (yellow + red) for correct use as dominant colour.

Architects, in general, have a serious flaw in their education: schools of architecture are increasingly more technical and less artistic, which leads to the total absence of harmony and aesthetic issues in their curricula, such as the use of colour. The colour white appears as a default, a non-choice, something that is neutral. But it is not.

There is another reason for not using achromatic white, related to its psychological meaning: a sterile and cold environment, only related in nature with snow or ice surfaces. The most stressing environments, unfortunately used for sensory deprivation in some extreme police and military cells, like in Guantanamo, are painted white in all surfaces and use high levels of illumination. These environments are inconceivably similar to others connoted with a “clean” and minimalist architectural aesthetic (Pernão, 2010). But for these ones, people generally pay high amounts in order to live in them!

David Batchelor (2007) names this refusal to use color - *Chromofobia* - stating that the issue is not white but the generalization of white (whiteness) because it makes it abstract.

This *Chromofobic* characteristic was well patent in a recent congress about colour and architecture when we were asked the reason why contemporary architects always dress in black and paint their buildings white.

There are international recommendations for the correct percentage of luminous reflectance factor in classrooms and other public spaces designed for long periods of people's permanence. Those numbers aim at 25% of blackness (NCS system) while the common white has 5% of blackness. The negative effect of excessive light reflection in architectural surfaces could be amplified by the use of gloss or semi-gloss finishes, as well as the incorrect layout of light sources.

Adopting these recommendations and thus removing the glare of walls can correct many situations of lack of concentration and eyestrain complaints in work environments.

**Conclusions**

With a phenomenological approach to space perception, we state the importance of light and colour to the quality of the built environment. We should always study these two elements together because they are inseparable, being the cause and effect of our image of reality.

Architects should be more aware of this importance in order to apply light and colour considerations right from the first stages of the architectural design process.

Colour should not only be seen as the paint covered surfaces but also as all the materials that assemble the visual field in the built environment.

Colour perception is based on variation, framed in time and always derives from three elements: Light, object, and observer. Variation, the main factor for perception, should be used conscientiously in architectural design as a tool to enhance the quality of architecture and its relationship with the human being.

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