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The colour of lighting as a new tool to design urban interiors: the transformation of underground spaces of the cities

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1. Introduction
The contemporary city appears as a chaotic entity, in continuous evolution and diffusion due to a constant request of fast connections: for this reason a high number of new spaces are dedicated mostly to support mobility flows on long/medium distances, privileging the use of underground spaces, such as stations, passages, corridors and galleries. These new infrastructures are perfect and efficient interiors, conceived as “machine spaces” and designed ergonomically for a stereotype traveller[1]. As an opposite trends, nowadays, several underground urban interiors are designed taking into account the qualitative perception of the space through the use of lighting, colours and materials. The space is completely transformed in a sort of container of emotional and perceptive experiences especially through coloured and varied lighting: the quantity, intensity and distribution of light and also the dynamics of both the CCT of white light and the hue of the coloured lighting can create a more interesting and comfortable environment.
This paper is a work-in-progress analysis, trying to describe the impact of white and coloured light on the perception of the user of underground interiors and to define the relationship between light, human beings and environment in order to prefigure new possible guidelines for the lighting design of public urban environments.

2. Methodology
The methodology of this study is based on a multi-disciplinary bibliographic review in the fields of colour, light, perception, architecture and design, exploring together the perception of the users, in order to understand the relation between human beings and built underground public interiors under certain specific artificial lighting condition. The paper is organized in a prior part concerning the review of literature about the previously mentioned topics and a secondary part of analysis of case studies using three main elements, light and colour, environment and human beings, that are described through some common features that contribute to compare the cases and better describe the parameters of high quality lighting conditions, how they are perceived by human beings in a built underground environment. In particular they are analyzed as the following:

- **lighting and colours**: the natural/artificial, the cool/warm CCT, the brightness/intensity, the distribution of light in a balance of variety and contrast and a balance of unity and complexity, the chromatic complementary selection, the symbolic/artistic value, the wayfinding value, the dynamics, the enhancement of architecture.
- **environment**: the spaciousness, the enhanced architecture and materials, the identity, the animation.
- **user**: evaluative impressions such as pleasant, interesting, comfortable, safe; opposite feeling such as arousing-calming.
3. Interaction between human beings, environment, light

The focal point of this paper is the interaction between human beings and their perception of the space in relation to white and coloured lighting: the aim is to understand what kind of lighting attributes are perceived and preferred and what kind of lighting scenarios can define a comfortable and safe environments, enhancing the perceived quality of an artificially lit underground urban scene.

3.1. Environment: analysis of the underground urban interiors

In the big urban areas, the necessity of new infrastructures to support mobility flows of people is an emergent and spread phenomena. The evolution of the city is based on connective networks into urban anonymous locations, enormous underground pathways, dark galleries into the bowels of the earth and connective corridors that host million of passengers, citizens and travellers each day for a short period of their transit. Constantly lit by artificial lighting, the underground spaces are often perceived negatively because their features are too unnatural and poorly designed: these places shows a lack of identity, because they are not characterized by the people that inhabit the space, they are not relational because they do not create reciprocal relationship between users and they are not historical places because they do not remind people their cultural belonging. According to Marc Augè, these “non-places” consider a stereotype user in order to create efficient structures based on standards and ergonomics parameters: from an architectural point of view, everything is calculated for the maximum result in terms of decibel, lux, length of pathways, typologies and quantity of information given [1].

3.2. Human beings: social and behavioral aspects

The underground station is the space of exchange of millions of individuals that cross each day without relating each other. It is a sort of “terrain vague” made of casual social meeting and rigid behaviours because they are strictly regulated by few but mandatory rules. The relationship between the non-place and the inhabitants occurs usually through symbols, words and pre-recorded voices. Despite the fact that the passenger of the subway is thought as a common subject or just a client of a service, in the book “Un ethnologue dans le metro”, Marc Augè describes some behaviours of the travellers of the subway in a very iconic way. He mostly uses the concept of threshold, the dynamic distance between two subjects, and the otherness theory that is the possibility to understand the own identity by comparison with others [2]. He speaks about the repeated social rites that take place, day by day, in the urban playground of the subway station: the activity is recurrent, regular e without surprises to the observers that repeat the transit each day. The ritual and social paradox of the subway is that all individuals are alone in their activity but in the meanwhile they live a social and collective situation: they are a crowd without participating to any feast but they are also alone without isolation [2].

The users of the subway deal with time and spaces adapting himself to the situation and being somehow obliged by a chronic hurry, moving quickly in the corridors and on the stairs. This particular places of interchange are very meaningful because they symbolize the space where people pass from an activity to another, from one place to another, transforming their social rules.
3.3. Light

Light is an indispensable environmental input for human beings, above all in controlling the basic functions of the human body. The presence of light, its colour and warmth has physiological and psychological effects on human beings [3]. Primary importance of light for human beings is the vision: through vision people use the space, orient themselves, perceive the physical surroundings. Light induces psychological effects on human beings because it increases the amount of information received about the space, fostering their sense of security. In addition to this, the colour of light arouses definite emotional and aesthetic reactions: colour is a sensation that communicates an immediate emotion. Zumthor defines colour as something related to our emotional and instinctive perception, something the human beings need to survive [4].

The information of the perceived urban environment is codified by the human visual system that is able to interpret certain regularities in the luminous phenomena in relation to three characteristics of light: intensity, wavelength and distribution in space. The intensity refers to the perception of luminosity perceived by the visual system reacting to the luminance of objects: it is subjective factor because it is an interpretation modified by psychological factors. The wavelength enables the understanding of colours and it is related to the reactions of the light spectrum emitted or reflected by the objects positioned in the space: it is mainly a sensorial experience. The distribution of light contributes to the transformation of the experience in the urban environments because it shapes the environment itself. The perception of space is not only a visual experience but it bridges different perceptual modalities in a sort of visual synaesthesia.

3.3.1. Perception of light and its effects

The field of environmental psychology presents a considerable knowledge about the human response and preference of lighting: it shows a certain relation between perceived attributes of lighting and emotional appraisals of human beings within the spatial context. Since the 1970s, there has been an increasing interest in the studies that aimed to explore the effects of light on the experience of people in built-environment. The majority of the studies that aimed to systematize the relation between perceived attributes of lighting and emotional reactions reveal that people use brightness and distribution of lighting as a basis for their judgments about an interior space. Moyer stresses that light has the capability to create shape, emotional response, even in a familiar space through the use of compositions and organization of lighting elements [5].

The research of Flynn connects lighting conditions to users’ mood: non-uniform lighting generates relaxation but the feeling of spaciousness is boosted by bright and uniformly lit interiors [6]. The study conducted by the Bartlett group concludes that people generally prefer brightly lit interiors and, according to Moyer, they are attracted by brightly lit objects more than by softly lit objects. On the other hand too high contrast lighting scenes creates confusion and it is necessary a lower lighting between the different spots to form visual bridges in the view.

A series of studies conducted by Flynn and his colleagues on the effects of lighting patterns in interior space concluded that lighting conditions affect mood: his researches point out that relaxation is said to be cue by non-uniformity wall lighting.
Perceptual clarity is said to be reinforced by higher horizontal lighting in a central location. Spaciousness is obtained by uniform lighting and bright walls [7]. The review of literature reveals that lighting is also an important crime prevention tool because it reduces the crime possibility by increasing the visibility, hence decreasing the opportunities for criminal acts and also strengthening the community confidence, cohesion and social control. The public lighting is a primary crime prevention measure, a surveillance form, effective in reducing the fear of crime [8].

3.3.2. Perception of colours and its effects

Literature reveals that people have similar emotional reactions to different colours: this is explained by several psychologists as the result of cultural learning. On the other hand, cross-cultural studies conclude that emotional reactions of people to colours are more innate than learned. Mahnke stresses that colour is a form of energy, and this energy affects body function, mind and emotion1 [9]. Freiling, for example, presents the findings of a study on the psychological effects of coloured light on human beings in 1990. The subjects of this study were asked to look into red, yellow, green, and blue light. Their comments were tape-recorded and presented in accordance with Wundt's "wind rose of emotions." The wind rose separates emotions into the categories of arousing-calming, pleasant-unpleasant, tension-release. The findings of Freilling’s study reveals that red is a stimulating colour, yellow is a tensing colour but releasing at the same time, violet-blue increases the inner reactivation and ability to concentrate and leads to calm, and green stimulates similar emotions as a balanced and diffused light.

Studies have also shown that human beings require a balance of unity and complexity in the built-environment in relation to colour and light, but also to temperature and sound: this is because the natural condition is the balance of changing variables and the unnatural condition is the static or too chaotic situation. Birren [10] stresses that people expect all of their senses to be moderately stimulated at all times in the built-environment. The research reveals that the lack of complexity is not preferable for human beings and it results in adverse psychological reactions. On the contrary, human beings tend to get easily confused when they are subjected to different visual stimuli.

Besides that, other researches point out that human beings can maintain normal consciousness, perception and thought only in a constantly changing environment. Mahnke stresses that in the total environment there should be colours in changing degrees of lightness (light and dark), CCT (warm and cool), and intensity (strong and weak), and the complementary of the dominant colour, providing a good balance of variety and unity: variety is necessary to attract and arouse interest; unity is essential to create a favourable impression.

4. International case studies of underground urban interiors

As previously mentioned, the underground urban interiors are often designed to fulfil practical functions, resulting in grey and monotonous environment. On the
contrary, some projects of underground interiors merge art, design and architecture in the creation of high culturally and perceptive environments lit with coloured, dynamic lighting effects. The selected and analyzed case studies are the best practises useful to understand how light and colours can create comfortable and high qualitative environment, re-qualifying the city for the entire citizenship [11].

4.1. Berlin, Potsdamer Platz Station
Since the summer of 2000 the Potsdamer Platz in Berlin has three Heliobus Light Pipes, respectively 14 metres, 17 metres and 21 metres high. They are the key element of the architectural design for the remodelled square because of their iconic structure but also for their sustainable function. They connect the surface level architecture and the underground railway station below providing the necessary light during the day: the tubes bring the sunlight into the station concourses during the day and at night they are internally illuminated to provide an additional vibrant light to the nightlife station. The aesthetics of the Light Pipe is achieved by the use of Heliobus technology, using direct sunlight as the prominent source and reflecting the rays inside a lined glass tube covered internally by a high reflective material [12]. The sustainability of the lighting project is very interesting because of the high level of transferred light from exterior to interior spaces using almost no energy during the day. Moreover natural light provides very changeable effects producing an intensity of colours, luminosity and shades that change rapidly with solar incidence creating different nuances of the same hue. In this underground environment, the daylighting is always dynamic, changing the CCT according to the natural lighting of the sun.

4.2. Munich, Westfriedhof Subway Station
The forty years old subway station "Westfriedhof" (opened in 1971), located at the border of the districts "Neuhausen-Nymphenburg" and "Moosach" in Munich, was re-designed in 1998 by the cooperation of the architecture office Auer-Weber and the municipal Underground Department. Moreover the MVG commissioned the lighting designer Ingo Maurer with illuminating the platforms of the underground station [13]. He conceived a strong identity lighting design atmosphere, creating a place that conveys pleasant emotions and comfortable feelings. Above the platform Maurer and his team installed eleven oversized concave aluminium luminaries, each measuring 3.80 meters in diameter with differently lacquered interiors, bathing the station in blue, red and yellow light and dividing the platform into different colour shadings. The walls and the ceiling are drenched in blue light and lend the station, that is completely realized in concrete, the character of a cave, whereas the platform itself is rather bright. Despite the spotlights there are no dark corners. The lighting project elevates the platform to a stage and immerses it in a warm light: rather than feeling exposed, the waiting passengers feel a sense of protection.

4.3. Munich, Freiheit Station
Another interesting lighting work realized by Ingo Maurer is the Freiheit station of Munich. The aim was to lend the station a fresh, cheerful character, modernizing it with a distinctive look through both the lighting and surface design of ceiling, walls and floor materials. The lighting designer installed 3200 mirror elements on the roof using 204 square caissons and creating, optically, a sense of greater openness reflecting the surround. Two complementary colours dominate the scene creating an
interesting chromatic scenario with a provoking and entertaining vivid atmosphere. A luminous yellow shines from the large walls behind the tracks; the pillars, which are covered with blue tiles, are lit by an appropriate LEDs lighting that also intensifies their colour. The remaining walls and the floor are covered by a unique silvery-grey material. Moreover square cases for the light sources are arranged irregularly on the ceiling, adding a dynamic aspect to the platforms [14].

4.4. Oklahoma City, Light Gallery Underground
Designed in 2007 by the office Elliott + Associates Architects, this underground series of passages located in Oklahoma City and known as “La Conncourse” use coloured light in order to orient, give information and identify specific functions of each underground corridor. The coloured lighting has a functional meaning, useful to enhance the perception of the public space and to identify specific zones of the city. It is used to lit the space in a very iconic way but also to communicate with the passersby, signalling the direction and to create an emotional atmosphere because the environment is completely dipped into colours. The lighting sources are coloured fluorescent T8 tubes: blue lighting conduces to institutions, red lighting to hotels and green lighting is used for connective corridors. More than this, the longest galley is a permanent installation of light. The walls are made of pierced steel, the floor is yellow and the ceiling is backlit with a blue coloured light: when the two colours merge, a white light is created on the opposite wall of the gallery [15].

4.5. Oslo, Nydalen Station
The "Tunnel of Light" is a work of art performed in August 2003: light, music, technology and architecture are shaped together as an integral whole and they also dynamically interacts with the users of the escalator of the Nydalen Station thanks to several sensors integrated in the space. The creation is about the perception of different experiences of travel, in time and space: sounds and lights together perform different seasons, changing the mood of the whole environment. The architect Kristin Jarmund initiated the "Tunnel of Light" project cooperating with a group of artists to develop the multimedia concept: the technical light and sound installation is integrated in a 27 metres long translucent glass tunnel wrapped around the station escalator [16]. The technical light and sound installation comprises 800 individually controlled pairs of Cold Cathode light tubes and 44 individually controlled loudspeakers. The computer control software is useful to control the lighting and sound performance that lasts the half minute long escalator ride experienced by the travellers during their daily route.

5. Conclusions
In the following schematic summary, the interaction of light and colour, human being and environment is defined through a series of features and parameters related to each specific group and interconnected together. The aim is to enucleate specific characteristics of light and colours that occur in a specific environment trying to understand how they results in the perception of the space by the users.
Fig. 1 - Berlin, Potsdamer Platz Station, Heliobus Light Pipe

Fig. 2 - Munich, Westfriedhof Subway Station, Auer-Weber and Ingo Maurer

Fig. 3 - Munich, Freiheit Station, Ingo Maurer
Fig. 4 - Oklahoma City, Light Gallery Underground, Elliott + Associates Architects

Fig. 5 - Oslo, Nydalen Station, Kristin Jarmund and Intravision System

Bibliography

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