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INFLUENCE OF LIGHTING QUALITY ON PRODUCTIVITY AND HUMAN HEALTH

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Abstract:

Measuring the increase in productivity due to the influence of lighting is not a simple task. In a production plant, information about productivity is an important indicator of performance. This paper describes an interdisciplinary approach of experts from the fields of psychology, ergonomics, medicine and lighting technology jointly applying a set of measuring instruments to describe and analyse the effects on well-being and stress, motivation and sleeping quality, the capacity to regenerate after work, as well as the quality of the lighting situation could be useful.

Key words:

lighting quality, illuminance, colour spectrum, lamps, luminaries.

INTRODUCTION

In a production plant, information about productivity is an important indicator of performance. Measuring the increase in productivity due to the influence of lighting is not a simple task. Where an increase is observed, this may often be due to a variety of influences. In the sphere of lighting, there are many possibilities to create good visual conditions, even through static lighting meeting standard requirements as a minimum. For dynamic brightness sequences, it is possible to modify the brightness or colour temperature of the lighting. The effect on the workers may be assessed through various interviews, questionnaire surveys and measurements.

DEFINING LIGHTING QUALITY

Lighting quality is depends on several factors. It depends largely on people's expectations and past experiences of electric lighting. Those who experience elementary electric lighting for the first time, for example,in remote villages in developing countries, have different expectations and attitudes towards lighting from office workers in industrialized countries. There are also large individual differences in what is considered comfortable lighting, as well as cultural differences between different regions. Lighting quality is much more than just providing an appropriate quantity of light. Other factors that are potential contributors to lighting quality include e.g. illuminance uniformity, luminance distributions, light color characteristics and glare.

There are many physical and physiological factors that can influence the perception of lighting quality. Lighting quality can not be expressed simply in terms of photometric measures nor can there be a single universally applicable recipe for good quality lighting [2]. Light quality can be judged according to the level of visual comfort and performance required for our activities. This is the visual aspect. It can also be assessed on the basis of the pleasantness of the visual environment and its adaptation to the type of room and activity. This is the psychological aspect. There are also long term effects of light on our health, which are related either to the strain on our eyes caused by poor lighting (again, this is a visual aspect), or to non visual aspects related to the effects of light on the human circadian system [12].

A number of different approaches have been suggested to define lighting quality. The definition that seems most generally applicable is that lighting quality is given by the extent to which the installation meets the objectives and constraints set by the client and the designer. In this way lighting quality is related to objectives like enhancing performance of relevant tasks, creating specific impressions, generating desired pattern of behaviour and ensuring visual comfort [2, 3].

The constraints may be set by the available financial budgets and resources, set time-lines for completing the project and possible predetermined practices and design approaches that need to be followed. Lighting quality means achieving an optimum balance among human needs, architectural considerations, and energy efficiency, Figure 1 [13].

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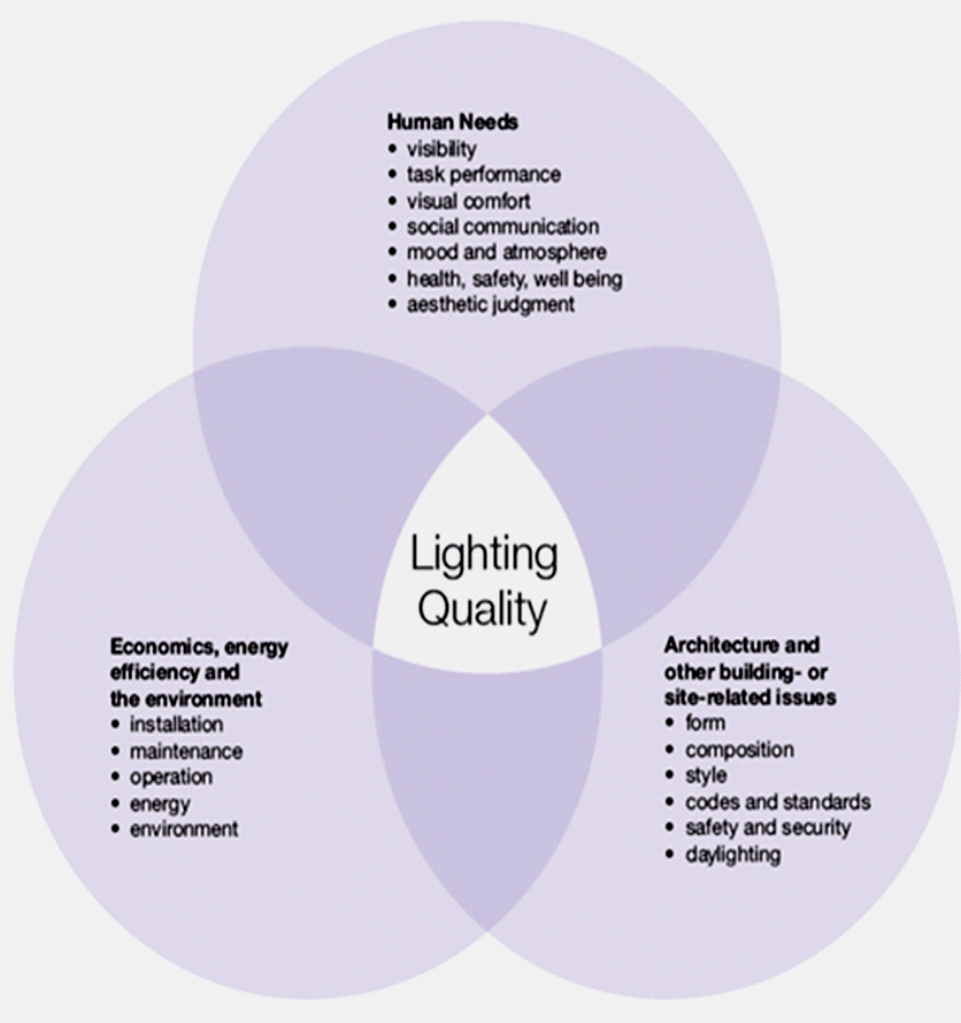

Figure1: ***Lighting quality***

VISUAL ASPECTS OF THE LIGHTING

The influence of artificial lighting on the psychophysiological well-being and the productivity of workers in a production plant depends on kind of lighting source that with respect to:

- brightness - *illuminance*,
- light colour - *spectrum* and
- light distribution - *luminance distribution* in the room.

The effects of artificial lighting on people are more pronounced,that natural influence of daylight inside working hours is very low especially during winter season. One of the major aspects of the lighting practice and recommendations is to provide adequate lighting for people to carry out their visual tasks. Ensuring adequate and appropriate light levels - quantity of light is only an elementary step in creating comfortable and good-quality luminous and visual environments. Lighting that is adequate for visual tasks and does not cause visual discomfort is not necessarily good-quality lighting. Depending on the specific application and case, both insufficient lighting or too much light can lead to bad-quality lighting. There are a number of lighting-related factors that may cause visual discomfort . The current indoor lighting recommendations give ranges of illuminance values for different types of rooms and activities [3].

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In addition, guidelines on light distribution in a space, the limitation of glare, and the light color characteristics are given. The color characteristics of light in space are determined by the spectral power distribution (SPD) of the light source and the reflectance properties of the surfaces in the room. The color of light sources is usually described by two properties,

- namely the correlated color temperature (CCT) and
- general color rendering index (CRI).

The color appearance of a light source is evaluated by its correlated color temperature (CCT). For example, incandescent lamps with CCT of 2700 K have a yellowish color appearance and their light is described as *warm*. Certain type of fluorescent lamps or white LEDs have CCT of around 6000 K with bluish appearance and light described as *cool*.

The CRI of the CIE measures how well a given light source renders a set of test colors relative to a reference source of the same correlated color temperature as the light source in question of International Commission on Illumination (CIE). The general CRI is calculated as the average of special CRIs for eight test colors. The reference light source is Planckian radiator (incandescent type source) for light sources with CCT below 5000 K and a form of a daylight source for light sources with CCT above 5000 K. The higher the general CRI, the better is the color rendering if a light source, the maximum value being 100. The Light source spectrum, i.e. radiant power distribution over the visible wavelengths, determines the light color characteristics. Examples of spectra of the lamps are shown on Figure 2 - 4 [12].

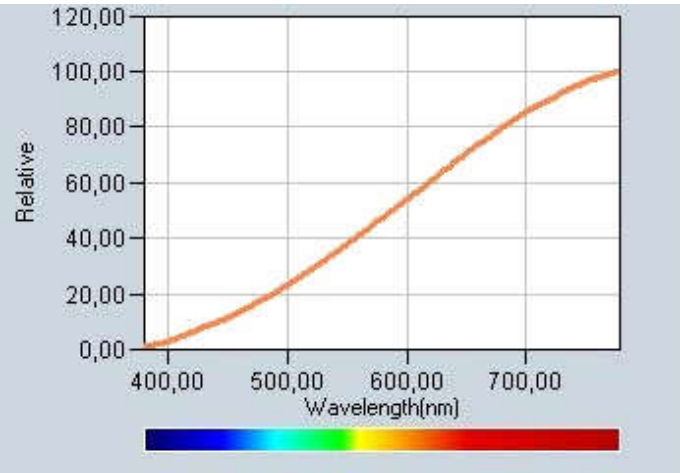

Figure 2: Light source spectrum - Example of spectra of an incandescent lamp (CCT= 2690 K, CRI= 99)

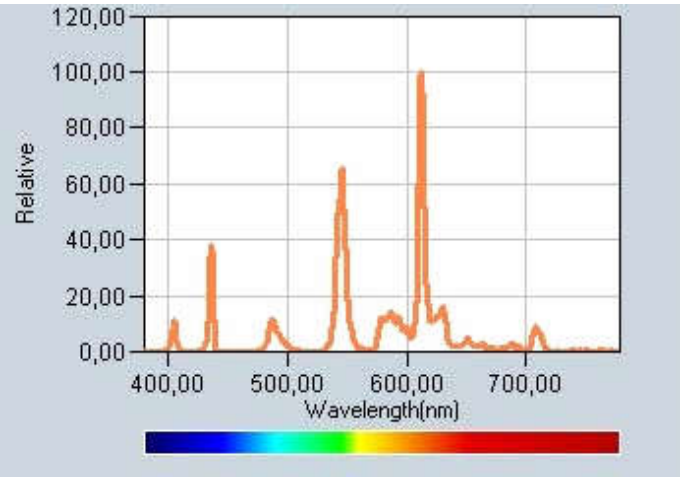

Figure 3: Light source spectrum - example of spectra of a compact fluorescent lamp (CCT= 2780 K, CRI = 83)

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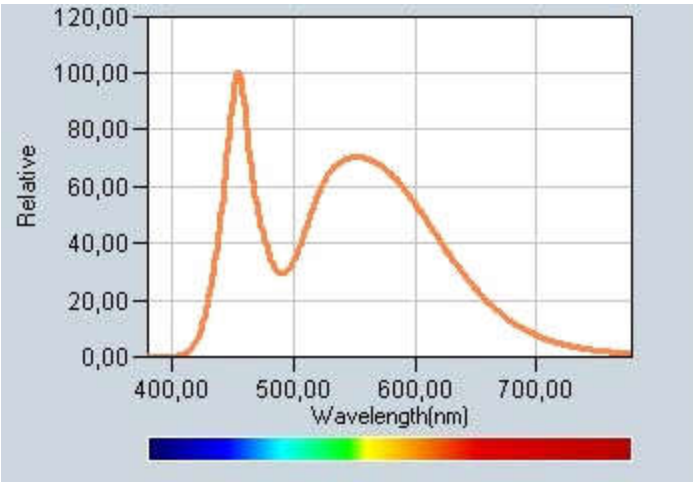

Figure 4: Light source spectrum - example of spectra of a white LED lamp (CCT= 6010 K, CRI = 78)

UNIFORMITY OF LIGHTING IN SPACE

A completely uniform space is usually undesirable whereas too nonuniform lighting may cause distraction and discomfort. Lighting standards and codes usually provide recommended illuminance ratios between the task area and its surroundings according ETN EN 12 464-1 [7]. Most indoor lighting design is based on providing levels of illuminances while the visual system deals with light reflected from surfaces i.e. luminances. For lighting there are recommended luminance ratios between the task and its immediate surroundings **[7]**. Room surface reflectances are an important part of a lighting system and affect both the uniformity and energy usage of lighting. Compared to a conventional uniform lighting installation with fluorescent lamps, LEDs provide opportunities to concentrate light more on actual working areas and to have light where it is actually needed. This provides opportunities to increase the energy efficiency of lighting in the practise.

PSYCHOLOGICAL ASPECTS OF LIGHT

The luminous environment can be perceived in many ways e.g. as more or less agreeable, more or less attractive, more or less appropriate to the function of the space, more or less highlighting the company image. Variations of luminances and colors can strengthen attractiveness, trigger emotions, and affect workers mood, the impact of lighting depends much on the individuals and their state of mind. Unacceptable lighting conditions may impact on task performance and thus productivity through motivation. A lighting installation that does not meet the user's expectations can be considered unacceptable even if it provides the conditions for adequate visual performance. People perceive their luminous environment through their eyes. [10]

BIOLOGICAL EFFECTS OF LIGHT

Light has also effects that are fully or partly separated from the visual system. Biological effects of light are called also the non-visual effects of light, related to the human circadian photoreception. The biological effects of light and their effects on human performance are not yet very well known. Research work is needed to generate an improved understanding of the interaction of the effects of different aspects of lighting on behavioral visual tasks and cortical responses and on how the biological effects of lighting could be related to these responses. The biological effects of light and their effects on human performance are not yet very well known. Lighting should be designed to provide people with the right visual conditions that help them to perform visual tasks efficiently, safely and comfortably. The luminous environment acts through a chain of mechanisms on human physiological and psychological factors, which further influence human performance and productivity, Fig.5 [4].

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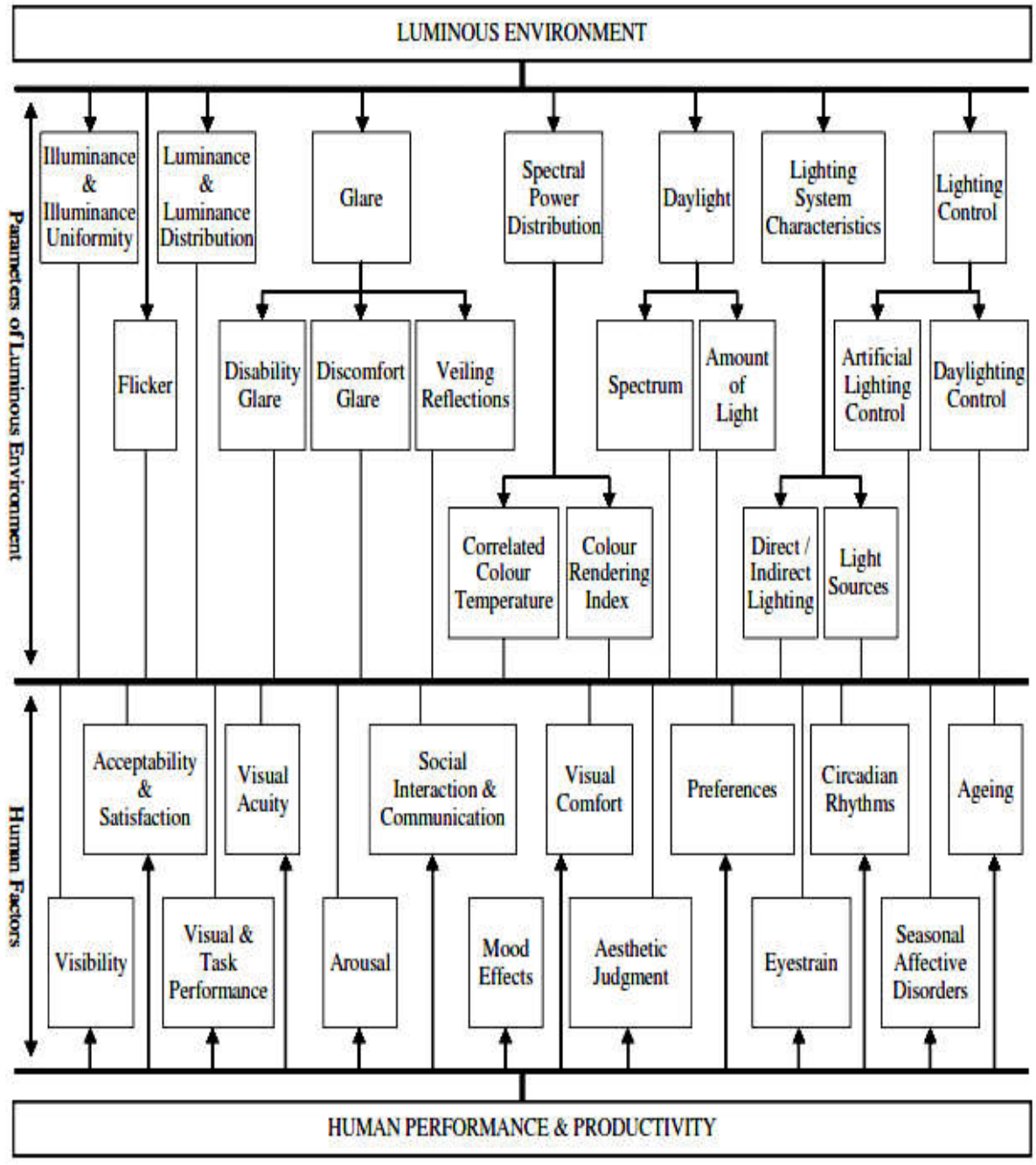

Figure 5: Luminous environment and human performance [4]

THE EFFECT OF LIGHTING ON PRODUCTIVITY

Lighting should be designed to provide people with the right visual conditions that help them to perform visual tasks efficiently, safely and comfortably. The luminous environment acts through a chain of mechanisms on human physiological and psychological factors, which further influence human performance and productivity [4].

The effect of lighting on productivity is ambiguous. The difficulty in finding the relations between lighting and productivity is that there are several other factors that simultaneously affect human performance. These factors include motivation, relationships between workers and the management and the degree of having personal control to the working

conditions **[2]**. With appropriate lighting the ability to perform visual tasks can be improved and visual discomfort can be avoided. This can provide conditions for better visual and task performance and, ultimately, productivity.

The difficulty of field studies in working environments is the degree of experimental control required. Several studies have investigated the effect of increase in illuminance on task performance. However, illuminance is only one of the many aspects in the lighting conditions. In making changes to lighting, which lighting aspects are changed (e.g. illuminance, spectrum, and luminance distribution) and whether there are other factors that are simultaneously changed in the working conditions (e.g. working arrangements, people, supervision of work) need to be controlled and analyzed. Recently, several studies are investigating the effects of light spectrum on human performance and the possibilities to use blue-enriched light to improve human performance through the non-visual effects of light. Poor lighting conditions can easily result in losses in productivity of employees and the resulting production costs of the employer can be much higher than the annual ownership cost of lighting.

DISCUSSION

The effects of lighting conditions on productivity have been published in the several studies The earliest studies indicated that lighting conditions can improve performance by providing adequate illuminance for the visual tasks. Their results are sometimes contradictory. For example, a study in office work indicated that an increase in illuminance from 500 lx to 1500 lx could increase the performance of workers by 9% , while another study showed that lower illuminance levels (150 lx) tended to improve performance of a complex word categorisation task as compared to a higher level (1500 lx). A field study in industrial environment measured direct productivity increases in the range from 0 to 9 % due to changes in lighting. The literature shows some examples of null results than clear-cut effects of illuminance on task performance, over a wide range of illuminance levels and for a variety of complex and simple tasks in working environment [5].

CONCLUTION

Observing the effect of light on human beings and health is a topic that is addressed by various sciences such as psychology, medicine, ergonomics and lighting technology. The interdisciplinary application of methods shows that measuring the effect of lighting on human beings is complex. If no results are obtained, that does not mean that there is no effect, but that the instruments of observation and measurement have not been optimally used. Further efforts are required to improve the measuring methods, instruments and ealuations.

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