The 40th International Conference on
Mechanics of Solids, Acoustics and Vibrations &
The 6th International Conference on
"Advanced Composite Materials Engineering"
ICMSAV2016& COMAT2016
Brasov, ROMANIA, 24-25 November 2016

CONSIDERATIONS ON PUPIL BEHAVIOR IN DIFFERENT LIGHTING CONDITIONS

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Abstract: *Sensations and visual analyzer plays an important role because they control at least 90% of all activities, including body balance. In all professional work and especially in the precision, vision intake plays a leading role. Natural or artificial light is the main stress factor for human visual analyzer. Regardless of the category it belongs, light workrooms exert a strong influence on the intensity effort in the work process and the degree of workers fatigue. A correct lighting should provide favorable conditions of visual comfort, such as a work plan to be seen precisely and effortlessly along the length of, and the eye can see objects and can distinguish their details without too much eye strain.*
Keywords: *Eye, Pupil, Illumination, Experimental Testing, Ergonomics.*

1. INTRODUCTION

The connection of the body with the environment is established through analyzers, which acts on simple attributes of the objects of the material world. These attributes are analyzed and reflected by subjective sensations. These include: color, light, smell, taste, weight, temperature etc.
Sensations are divided into two categories [1]:
- sensations that reflect the attributes of objects and phenomena of the external world, such as the visual, auditory, skin, smell and taste;
- sensations which reflects the movement of the body or parts of the body and the condition of internal organs, including kinesthetic sensations, balance and internal (organic);

Anatomic and physiologic elements, through which the sensations are analyzers, composed of three parts or segments (figure 1):
- the receiver or peripheral segment;
- afferent pathway (sensory, centripetal), leading excitations in the cortex;
- the cortical segment of the analyzer (neuronal projection area);

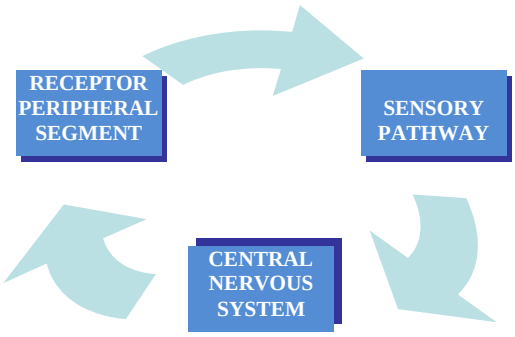


Figure 1. The structure of an analyzer

Visual sensations are caused by the action of radiant energy of electromagnetic waves on visual analyzer. The electromagnetic spectrum has an incomparably greater area than the visible. Electromagnetic waves visible to the human eye are the wavelength between 396 and 760 nanometers. Visual capacity includes visual acuity, contrast sensitivity and speed of perception [2]. Visual acuity is the eye's ability to distinguish very small objects or surfaces. It is characterized by selective capacity (power to distinguish two points at very small distances between them) and the sensation of forms. Contrast sensitivity is the eye ability to perceive very low differences of luminance. Speed perception is characterized by the time that elapses between the presentation of an object and its perception.
As [3] notice, physical environment is an important component of the design process ergonomic workplace. Etymologically notion of ambience refers to material and social environment in which a person or corporate body operates. In the office environment design factors should be considered: general nature of the work, the specific content of the work, imposed demands at work, psychosocial factors. Also important are the possibilities material, technical and economic implications of these structures. The main factors are the physical environment: lighting, microclimate (temperature, humidity, air velocity, and air purity), color and noise.

2. LIGHT AMBIENCE IN WORKSPACES

Lighting is one of the factors that exert an important influence on the productivity of employees and upon their level of fatigue. An improper lighting can cause visual discomfort and an unnatural position of the body, and is thus a hindrance to performance. Research shows that 80% to 85% of the information that reaches assimilate visually, so visual comfort is essential [3]. Manner of lighting affects not only the visual comfort, but also the physical.

Ambient light is characterized not only by the quality of light, but also the quantity. It is estimated depending on brightness, direction, uniformity of placement and intensity. The brightness or light density express the brightness of the surfaces form the environment, and is considered the property of enlightened bodies. Uniformity of the light placement is the property of luminous flux to ensure the same density (brightness) on the entire stretch of the working surface. This is expressed through the following equations [1]:

$$F_u = E_{min}/E_{med} \quad \text{or} \quad F_u = E_{min}/E_{max} \tag{1}$$

where E_{min}, E_{med} and E_{max} are minimum, medium and maximum illumination for room or work plan. The value of uniformity factor (F_u) varies depending on the nature of the work demands.

The light intensity is the volume of luminous flux that falls on a certain surface. It is the light that achieves a luminous flux distributed on a surface. Especially light intensity varies depending on the nature of work, working conditions and age of the worker.

The lighting in the workplace can be divided into 4 categories [4]:

- Ambient lighting usually is given a ceiling-mounted light source (fluorescent tube). Sometimes this is the only source of light in the workplace.
- The illumination using office lamps. Although it offers individual comfort, this type of lighting is absent in most jobs.
- The directed illumination is usually provided by light sources face down lights or "tracking". It is used to illuminate certain objects or increasing intensity.
- Natural light coming through windows, doors or glass walls. It has a positive effect on humans, but it is not always available.

The key to good lighting is balance [1]. Thus, it can be said that lighting is effective when employees enjoy visual comfort and visibility in a room balanced in terms of luminosity. An obvious example is that of workspaces. Lighting contrasts between the workplace and its vicinity must be large enough so as to allow the worker to see clearly office. A general rule is that the office should be illuminated 3 times stronger than the nearest 5 times stronger than general working space and 10 times stronger than the most distant neighborhood. Problems occur when the eyes of the worker are forced to adapt to strong contrasts or repeated changes of intensity. The eyes get tired very quickly if the worker is forced to charge too much contrast whenever looked up at the office. A more obvious example is that of drivers who are forced to drive at night in busy traffic when their eyes are subjected to very different light intensity value or exposure time. Another example refers to the location of the computer to the window to see the view from outside. Outside light, stronger than the office usually causes difficulty viewing the characters on the screen and your eyes will have to focus whenever it raises worker from the computer and the outside.

Therefore, lighting is the most important element of the visual environment. Efficient lighting, quality, ensure the comfort, increased productivity and a higher degree of security.

2.1. Types of lighting

a. Natural lighting

In the case of natural lighting, the light source is sunlight and heavenly vault, radiation which penetrates through the gaps in workrooms practiced construction elements. Natural light is characterized by constant change depending on the position of the sun and the coverage by clouds of heaven. As such, natural lighting design is not considered a certain amount of enlightenment, but the ratio of interior lighting and exterior lighting.

b. Artificial lighting

Artificial lighting is usually done with light sources in the electricity grid powered by low voltage. Artificial lighting to complement natural lighting shall be such as to ensure the work plan, with natural lighting, illumination rated at least provided. Variation natural lighting during the day is compensated by appropriate location and orientation of the lighting and power supply by splitting of the lighting installations or devices variation artificial lighting.

For design and implementation of lighting will consider the following [4]:

- room (space) destination;
- distribution of jobs;
- categories of works with visual function and lighting levels;

- quality of lightening ambience (illumination uniformity, luminance distribution, the existence of glare, light color, color rendering etc.);
- type of lighting and luminaries;
- possibility of lighting installations and glass surfaces maintainable.

Lighting is achieved by following systems: uniform or localized general lighting and general lighting uniformly complemented with local lighting. Light level, its quality and adequate choice can influence an important measure efficiency of workers. Some lighting systems must be adapted to physiological aspects of the eye (e.g. assembly works, mechanical works etc.), while others consider an important component of human psychology (e.g. in classrooms or halls sports, etc.).

There are several types of lighting, which differ depending on the effects that need to be obtained [3]:

- light to view - requires general lighting obtained through the ceiling, floor and apply;
- light to look - must offer maximum light intensity, for this purpose using table lamps and hanging fixtures;
- light to contemplation - facilitates the observation of a painting, a mobile, a precious object, which is highlighted in the center of an island of light towards which converge the beams directed;
- light contemplate - represents a type of lighting decorative purposes only.

A modern lighting system must meet while following requirements: be functional, aesthetic and with proper cost.

2.2. Requirements for lighting workspaces

Lighting concept is a complex process that must harmonize requirements to ensure a comfortable working environment in terms of functionally corresponding with aesthetic requirements, economic and labor security.

According to SR 6646-1 (1997): "Artificial lighting. Technical requirements for indoor lighting assemblies and enclosures of buildings" [5], the choice of lighting is done taking into account the requirements of visual and technical and economic, considering:

- destination room (space);
- distribution of jobs in workspace;
- quality lighting conditions;
- categories of visual works;
- energy consumption, investment and maintenance expenditures;
- specific terms of lighting quality;
- requirements of beneficiary / investor.

Lighting conditions for workspace refers to values that are given to various parameters that characterize luminous ambience provided by a lighting installation.

The purpose of the lighting system consists in:

- providing the work area of a quantity of light capable of providing accurate and fast charging visual task;
- distribution of this light so as to achieve a good balance of luminance in the room and on the work surface;
- accurate color reproduction;
- user security lighting wiring;
- ensuring a better utilization coefficient, so the above objectives to achieve maximum savings on capital and operational costs (maintenance, electricity).

The main parameters that characterize the bright ambience of an area are:

- overall average of luminance on the plane or on the work surface;
- illumination uniformity;
- reflection coefficients of the main surfaces (roof, walls, surface, floor, equipment, facilities);
- ratio of luminance work surface and overall visual field;
- ratio of illuminations main areas making up the visual field;
- angle of protection of general and local lighting;
- appearance areas they work;
- character pulse of light that reaches the work plan;
- color rendering index for the light sources used;
- light diffraction;
- impairment factors of lighting.

The lighting level:

The illumination surfaces or objects must have a value large enough to match the activities being executed in the area served by the lighting system. Depending on the size details, the contrast between details and background and brightness of working background, safety standards of work determine the levels of lighting for workspaces from interior, exterior and traffic routes, to be provided by visual works that be carried out. In spaces with normal and continuous amount of time illumination, lighting installation generally must be at least 200 lx on horizontal plane limited by the room’s walls and located at a height of 0.8 m to 1 m from the floor [4].

In determining the level of lighting in the workspace, it takes into account depreciation over time of the lighting system, impairment that is based on the category of impairment of the luminaries and the elements influencing feature of the work environment (e.g. emission of particles from inland or external sources, conditions of adhesion, color dust particles).

The uniformity of illumination:
Facilities for general or local lighting cannot provide a constant light on the work surface or plan. To avoid disrupting the vision, illumination variation must remain within certain limits. Illumination uniformity is expressed by uniformity factors E_{min}/E_{med} and E_{min}/E_{max}, with limit values that are given in the applicable standards (SR EN 12464-1 (2011): Light and lighting. Lighting jobs. Part 1: Jobs interior and SR EN 12464 -2: (2007): Lighting jobs. Part 2: Outdoor work places) [5]. To maintain uniformity while lighting, lamp replacement lamps is used by at least the same power, the same luminous efficacy and color bright light.

2.3. Luminous ambiance quality

If the light levels provide projected visual efficiency, the following aspects for light ambience quality are satisfied [1]:
- avoiding or limiting direct or reflected glare;
- to avoid the emitted light pulse or strobe effect when using gas discharge lamps;
- more accurate color rendering;
- shaping the structure corresponding visual field general;

To prevent or limit direct and reflected glare is pursuing the following parameters:
- finishing of the main surfaces of the room;
- ratio luminance for working surfaces;
- ratio of illuminations of the surfaces main bounding general field of vision;
- protection angle of the luminaries;
- the appearance of the working surfaces.

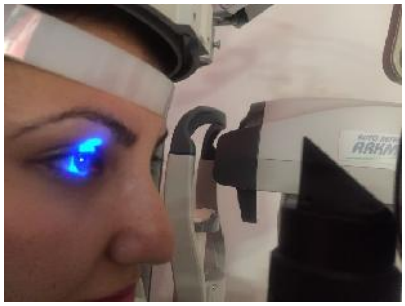
In this respect, it recommends the adoption of one or more of the measures specified below:
- positioning the viewer or areas with high luminance such as that the angle between the vision line and the source of blindness to be as high typically above 45^o;
- area reducing or eliminating the surface with high luminance in the direction of view, using appropriate screens;
- maintained between certain values, usually 1/3 and 1/10 respectively, of the ratios between detail luminance and luminance of the areas immediately surrounding the background;
- increasing luminance areas that surrounding the source of speech by painting them in bright colors and then increasing the illumination on them.

3. EXPERIMENTAL TESTS TO ANALYZE THE LIGHT INFLUENCE ON THE PUPIL

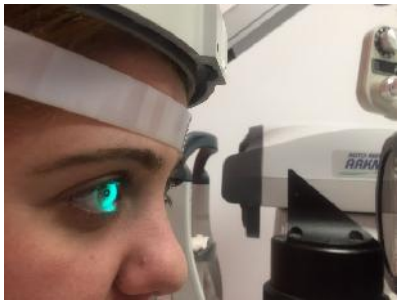
Accommodation means ability of the eye to center on the point and fixed objects located at different distances or different light intensities. In ocular accommodation pupil has an important role. Thus, in the dark or low light pupil dilation occurs. This phenomenon allows the eye to penetrate a larger amount of light, that impress retina (where occurs the image formation). If a high light intensities, the phenomenon is reversed [6].
In accommodation, besides action on the pupil, an imposed stress appears on ciliary muscles. So, if the distance to the object is smaller, the greater is the demand muscles [7]. The point of minimum distance over which it is possible to fix the object is a measure as the ability of accommodation, which decreases significantly with eye fatigue. After long lasting precision work, seeking ciliary muscles responsible for accommodation, point of minimum distance moves away from the eye, which is a sign of diminishing accommodative capacity [8]. The worker accommodation is influenced by age, meaning that the lens elasticity decreases with it, and accommodative capacity is marked reduced (the phenomenon of presbyopia). Also age influences the speed of accommodation.
Also the accommodation speed is influenced by the lighting intensity [9]. Under low light, the point of maximum distance approaching the eyes and one for the minimum distance moves away. At the same time speed and accuracy of the ocular accommodation decrease [10].
To perform the tests we have had into consideration the following:
- Tests were performed on two subjects of the same age, eye color and without ocular vices or photophobia;
- Testing was done on a slit lamp equipped with color filters;
- The luminous flux exposed on the eyes was controlled and measured;
- Pupil diameter measurement was performed automatically immediately after exposure so as not to interfere

phenomenon of ocular accommodation;

- We avoided the eye fatigue, so that the tests were performed with breaks;
- Tested eyes were exposed in artificial white light, ultraviolet light and in complete with color filters.



Subject 1



Subject 2

Filters

Figure 2. Performing tests at the slit lamp

SUBJECT 1 **SUBJECT 2**

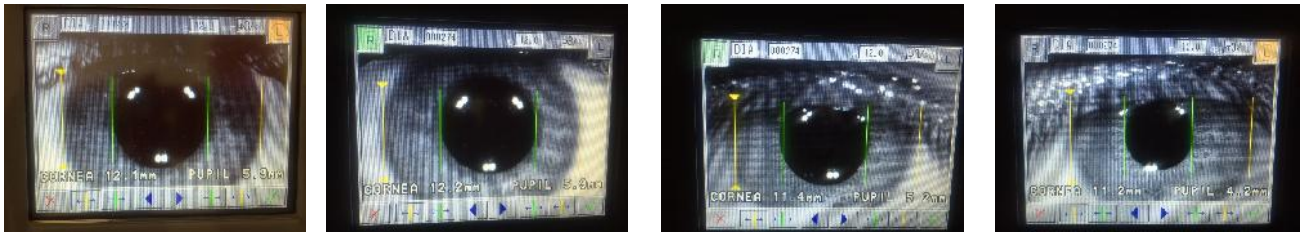


Figure 3. Exposure to artificial light at 4500 lm with fluorescent tube (220V AC)

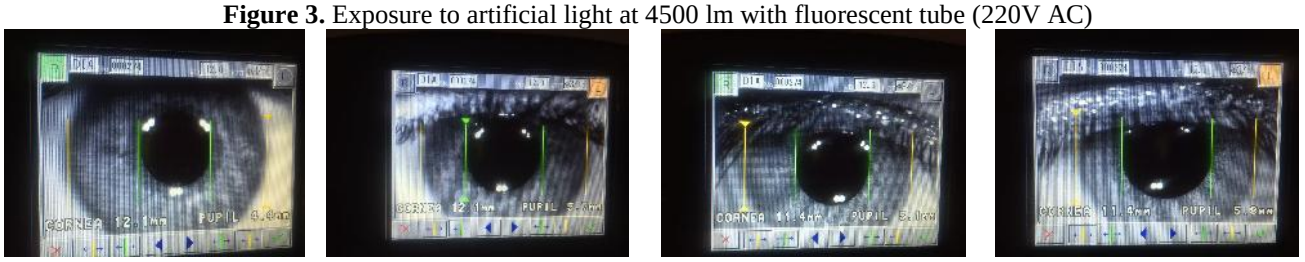


Figure 4. Exposure to ambient lighting at 500 lm

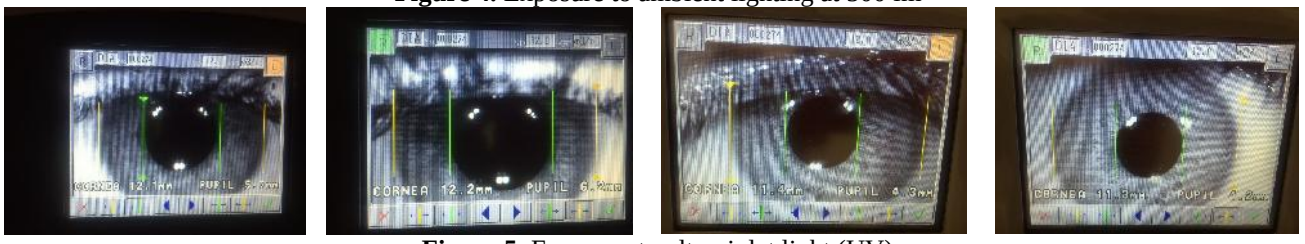


Figure 5. Exposure to ultraviolet light (UV)

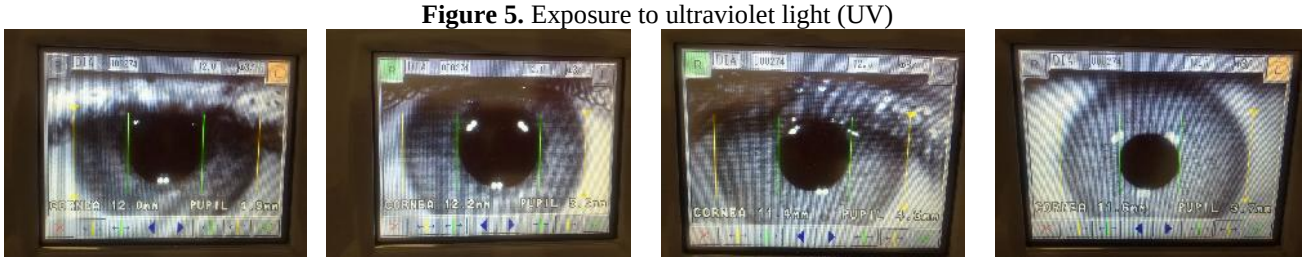


Figure 6. Exposure to ultraviolet light (UV) with red filter

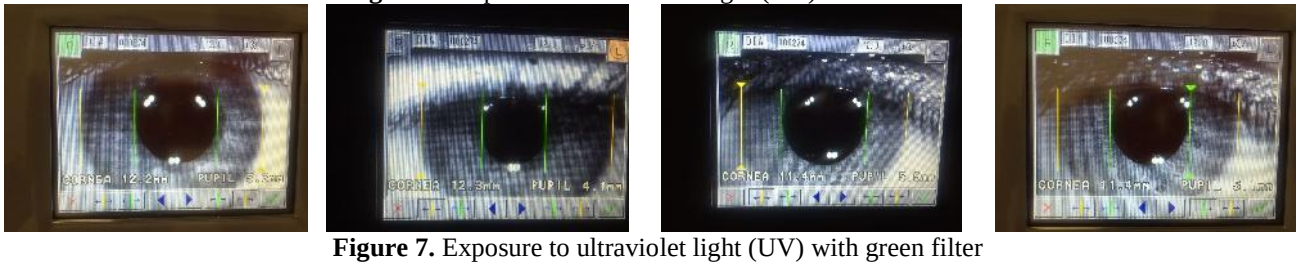


Figure 7. Exposure to ultraviolet light (UV) with green filter

Figure 8. Exposure to artificial light at 4500 lm with ocular situation at resting eye

3. CONCLUSION

As can be seen in Figures 2-8, the tests showed different variations pupil diameter depending on the subject, the wavelength of incident radiation on the eyes and light exposure. These variations have exceeded 1 mm in case of exposure to artificial light at 4500 lm with fluorescent tube. Also we can notice a difference in modification of pupil diameter between the two subjects. Considering that they are similar in terms of ocular characteristics, it means that these changes occur due to different psychosomatic structure of the two persons.
From the considerations discussed above, results the following main consequences for the organization of workplaces:
- Glare surface of objects to be viewed must be in the same order of magnitude in all the visual field. Otherwise result of differences that can disturb sensitive visual capacity going up to eye fatigue.
- Rapid fluctuations should be avoided for all general lighting because of the sensitivity of retinal adaptation processes is slow.

In the case of a lighting installation, illumination quality is assessed by the luminance value that is obtained on each of the surfaces making up the visual field. Presence at some point in the visual field of a surface with more luminance than the luminance to which the eyes are adapted, can produce glare, which results in reduction of visual efficiency and visual comfort. All sources of artificial light, brightly lit surfaces and their image on shiny surfaces can produce the same effect.
Apart from lighting, other factors can influence pupil diameter [11]:
- Accommodation is more precise and faster as the contrast of objects viewed is greater;
- If the gaze is fixed at the short distance (precision working), the pupil shrinks. For distance vision phenomenon is reversed.
- Vegetative tonus variations can cause changes in pupil diameter. Thus, strong emotions (stress, fear, joy, pain) causes' pupil dilation (mydriasis) and a drowsiness or fatigue causes reduction in pupil diameter (miosis).

Along with accommodation, adaptation phenomenon exists, i.e. nervous and photochemical processes that occur in conditions of optimum vision. Therefore retinal sensitivity substantially increases in the dark or low light. As was stated earlier, adapting to darkness or bright light requires a longer time, and transitions can bring rapid eye fatigue.

REFERENCES

[1] Moldovan M., Ergonomy, Didactic and pedagogical Press, Bucharest, 1993.
[2] Baritz, M.I. Screening method for environmental human stability behavior studies, IMEKO Conference 2008, Hungary.
[3] Enache I., Ergonomic organization of work in office, available at http://ebooks.unibuc.ro/StiinteADM/enache/24.htm
[4] Skansi R., Ergonomics of Light, Balkanlight 2012, Belgrade, Serbia.
[5] http://magazin.asro.ro/index.php?pag=3&lg=1&cls=1&dom=91&gr=160&sgr=10&nrp=2, accesed in october 2016
[6] Loewenfeld I.E., The pupil. Anatomy, Physiology and Clinical Applications, Butterworth Heineman, Boston 1999.
[7] Baritz M.I., Oculomotor Equilibrium Analyze by Retinal Image Processing. The 2nd International Conference Computational Mechanics and Virtual Engineering 2007 Brasov, Romania.
[8] Baritz M., Barbu D., Analysis by Video Methods of Nystagmus in Simulated and Stimulated Movements, The 6th International Conference Computational Mechanics and Virtual Engineering 2015, Braşov, Romania.
[9] Szczepanowska-Nowak W., Hachol A., Kasprzak H., System for measurement of the consensual pupil light reflex, Optica Applicata, Vol. XXXIV, No. 4, 2004, 619-634.
[10] Kardon R., Regulation of Light through the Pupil, Adler's Physiology of the Eye, Chapter 25, 502-525.
[11] Barbu D.M., Analysis and modeling of visual function, Transilvania Univesity Press, 2003.