VISUAL ERGONOMICS, A REVIEW IN A PUBLIC ENTITY

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ABSTRACT

The lighting levels must be evaluated for each type of task based on national and international standards, for this article is the result of research related to visual ergonomics in office users with administrative functions of a higher education institution of the city of Bogota. A review of the literature on lighting in the jobs in Colombia, Latin America and Europe was carried out with the objective of knowing the criteria, lighting standards in the national and international scope and applying a case study, in which Evaluation of luxometries at 242 work points and a survey of perception was applied to workers on the types of lighting, the existence of a maintenance program, subjective evaluation of the level of lighting of the worker in the workplace and pathologies related to vision.

KEYWORDS: Visual Ergonomics, Interior Occupational Lighting, Luxometries

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1. INTRODUCTION

Colombia is a country that gives legal and formal guarantee to workers in terms of rights against adequate lighting, therefore it seeks to ensure good working conditions and health, however, what recommendations or possible adjustments should be made to the Colombian regulations on lighting in enclosed spaces, and specifically, in workspaces based on case studies? The objective is to analyze the visual ergonomics of the work environment, taking as a study variable the lighting levels that influence the performance of the administrative activities of the administrative staff of a higher education institution.

This investigation has three levels (perceptual, apprehensive and comprehensive). The perceptual level corresponds to the exploratory and descriptive phase of the subject, here a bibliographic review was carried out in the databases (elsevier, IEEE, etc.) and standards of the Ministry of Labor and Social Security, RETILAP, Icontec and ISO, international standards (Real Decree 486/1997 and document EN-12464-1) with emphasis on lighting. Since the lighting levels for offices must be evaluated for each type of task, a case study was drawn up taking as reference the national and international standards of the analytical study.

At the apprehensive level, the comparative and analytical phase was carried out in which, using surveys and field measurements, lighting was compared and analyzed based on a case study in Colombian work spaces, compared to Latin America and Europe.

The previous development of the perceptual and apprehensive level of these allowed to reach the comprehensive level in which the advantages and disadvantages of Colombian regulations are explained versus regulations of Latin America and Europe, to finally make recommendations.

During the last decade, knowledge about the effects of visual ergonomics in the workplace has gained great importance, which influences the emotional state, health and well-being of office workers. Although the mechanisms behind the effects of light that are relevant in the workplace and the creation of suitable environments in office designs have been investigated to encourage collaboration, concentration and creativity of workers (Küller, Ballal, Laike, Mikellides, & Tonello, 2006; Veitch, Stokkermans, & Newsham, 2013). However, much is still unknown about how lighting affects the worker in the office work environment. Therefore, the research question that arises from the subject of lighting in workspaces is what recommendations or possible adjustments should be made in the Colombian regulations or on the reference values given by the regulations regarding lighting in work spaces, which allow improving the perceptions and preferences of administrative staff in order to minimize visual diseases and maximize work performance?

Indoor lighting is a variable in the analysis of work environments, poor lighting can cause illnesses and poor work performance on the part of the worker, so studying this problem will help to: a) Optimize the perception of visual information used in the work development; b) Maintain an adequate level of performance; c) Guarantee maximum security; and d) Provide adequate visual well-being (Noriega Y, 2016).

2. REVIEW OF LITERATURE OR RESEARCH BACKGROUND

This article reviews the work of some authors on the effect of lighting on the cognitive performance of workers in the workplace. In (Government of Spain, 2004; Head of State, 1995) the authors carry out two experiments in which they investigated the effect of interior lighting on cognitive performance through mood. In both experiments, gender was introduced as an additional grouping factor. Results in experiment 1 showed that a less negative mood-inducing color temperature improved performance on long-term memory and problem-solving tasks, in both genders. In experiment 2, the combination of color temperature and illuminance was the one that best-preserved positive mood in a genre, improving the performance of this genre in problem solving tasks. Therefore, the subjects' mood swings and their cognitive performance varied significantly with indoor lighting. This suggests, in practice, the interior lighting should be reviewed, also taking into account the emotional and cognitive responses of women and men.

Based on the works of the authors (ComiteTecnicoAen / Ctn, 2003; Head of State, 1995; Ministry of Mines and Energy 2008 and 2010; Ministry of Labor and Social Security 1979; Government of Spain 1997 and 2006; Pattini, 1965) in table No 1 the legal and regulatory framework of Colombia is contrasted with respect to Spanish.

Table 1: Contrast of the Legal and Regulatory Framework of Colombia with Respect to Spanish

AGREEMENT		
Convention No. 155. of the OIT. 1981	Convention No. 148. of the OIT. 1977	Convention No. 120. 1964
Health and Safety of Workers	Work Environment	Hygiene in Establishments of Commerce and Offices

LEGISLATIVE REGULATION (SPAIN)			
Law 31 of 1995	Royal Decree 486 - 1997	Royal Decree 488 - 1997	Royal Decree 314 - 2004
Prevention of occupational hazards	Minimum health and safety provisions in the workplace.	Minimum health and safety requirements for working with equipment including display screens	Technical building Code

LEGISLATIVE REGULATION (COLOMBIA)			
Resolution 180540 of 2010	Resolution 180606 of 2008	Resolution 2400 of 1979	Law 9 of 1979
Technical regulation of lighting and Public lighting – Retilap	Technical requirements that high-efficiency light sources used in Public Entities headquarters must have	Establishes some provisions on housing, hygiene and safety in work establishments	Sanitary Measures Articles related to Hygiene and Safety at work Art. 84.85

TECHNICAL GUIDES (SPAIN)	
For the Prevention and Evaluation of the risks related to the use of workplaces.	Evaluation and Prevention of risks related to the use of equipment with display screens

TECHNICAL GUIDES (COLOMBIA)
Does not exist

TECHNICAL REGULATIONS (SPAIN)
UNE-EN 12464 - 1: 2012
Workplace lighting part 1 Indoor workplaces

TECHNICAL REGULATIONS (COLOMBIA)
ISO 8995 of 2003 , adapted in GTC 8.
Indoor workstation lighting

3. MATERIALS AND METHODOLOGY

Resolution 180540 of 2010 of the Ministry of Mines and Energy -RETILAP, the ISO 8995 standard - adopted in GTC 8-, which expresses the legal framework applicable to lighting in workspaces for the Colombian context, was revised and contrasted with an international standard (Spanish Royal Decree 486/1997), where through document EN-12464-1 they establish the minimum health and safety provisions in the workplace.

A total of 100 surveys were carried out to characterize the administrative personnel who work from the 6th to the 9th floor of a higher education institution, to later perform luxometric measurements in 100 jobs (242 points), in order to determine the lower limit of control LIC, upper limit of control LSC and the median of these theoretical values indicated in the Colombian regulations. In figure 1 in a circle the jobs are shown), which were analyzed in the morning and afternoon with the help of a flowmeter Model: HD450 Dimensions: Meter: 170 x 80 x 40 mm Photo detector: 115 x 60 x 20 mm (4.5 x 2.4 x 0.8") extech brand, Power source: 9V battery, Battery life: 100 (backlight off) Weight: Without battery: 13.8 ounces (Approx.). With battery: 390 oz. (Approx) Low battery indication: battery symbol appears on LCD Sensor cable length: 1 m (3.2 '). The measurements were taken with either natural or artificial light to record the measurements and in any case based on normal operating conditions

In the perception survey, the following were taken into account: the types of lighting, the correct maintenance of the lighting systems, the existence of a maintenance and cleaning program, the existence of damaged lamps, the existence of light differences in the workplace, signs such as annoying flickering, as well as subjective assessment of the level of illumination of the worker in the workplace, regulation of the level of illumination by the same, generation of visual symptoms and finally pathologies related to vision.

The measurements obtained were systematized in the minitab software and the average illumination calculations were compared with the Technical Regulation for Public Lighting and Lighting RETILAP (section 410.1), which regulates illuminance levels: minimum of 300 Luxes, the average is 500 Luxes and the maximum to 750 Luxes in order to comply with current legislation, as well as with Royal Decree 486/1997. In the same way, a visual inspection was made of the state of the lights.

The data from the surveys and measurements are tabulated to later make an analysis based on some descriptive statistical units such as the mean, the median and the standard deviation supported by a graphical representation of bars, cakes and frequency histograms, verifying if it complies with what is stipulated in Colombian and Spanish regulations. Based on these results, recommendations were established in terms of preventive and corrective actions for the lighting system of the evaluated offices.

4. RESULTS

The luxometry data with measurements taken in the morning (8 am-12m) and in the afternoon (14-17 hours) corresponding to the administrative headquarters (sixth to ninth floor) should be in a range of 300 lx to 750 lx according to the RETILAP of offices, however the measurements show (figure 2) that the median of these values is below the lower limit of 300 lx (208 lx in the morning and 185 in the afternoon).

In the morning 3% of the data is above the upper limit range and 88% is below the lower limit of acceptance, that is, only 9% of the data is within the acceptable range. In the data taken in the afternoon, only 1% of these are above the upper limit and 90% are below the lower acceptance limit.

The points marked with an asterisk in figure 3 correspond to the atypical data, which could obey for the morning case with the location of the positions and the rising of the sun since it directly affects and significantly increases the lighting levels in the offices near the windows.

Figure 1: Luxometry Data with Measurements Taken in the Morning (8 am-12m) and in the afternoon (2 pm-5pm) Corresponding to the Administrative Headquarters (Sixth to Ninth Floor).

Figure 2: Summary of Luxometry Floors Sixth to Ninth

Figure 3: Hourly Lighting Averages in the Morning and Afternoon

The perception survey applied to the workers is illustrated in figures 4-8 where it was taken into account: the types of lighting, the correct maintenance of the lighting systems, the existence of a maintenance and cleaning program, the existence of faulty lamps, , existence of light differences in the workplace, signs such as annoying flickering, as well as subjective assessment of the level of illumination of the worker in the workplace, regulation of the level of illumination by the worker, generation of visual symptoms and finally pathologies vision related

Figure 4: Lighting System

Figure 5: Maintenance

Figure 6: Lighting Level

Concerning the symptoms, with a percentage of 90% (figure 7), the workers declare having visual discomfort during or after the working day.

Figure 7: Symptoms

Figure shows the summary of the results of the symptomatology survey, finding that 41 have myopia, 18 hyperopia, 24 astigmatism and the remaining 39 do not report associated pathologies at the visual level, which can be associated with the deficiencies of the lighting system and could give way to the establishment of an epidemiological surveillance program in visual health that allows managing this risk agent hand in hand with the review of occupational medical examinations and the survey of health conditions.

Figure 8: Visual Diagnosis

5. DISCUSSION AND CONCLUSIONS

This article focused on the evaluation of interior lighting in work spaces, taking as reference the national regulations of Colombia and international (Spain) to evaluate the impact of the standards established by each legislation based on a case study of interior lighting, in work spaces, in administrative activities of a higher education institution in the city of Bogotá.

A statistical analysis was carried out, where the median and mean of the data of lighting levels taken in the morning and afternoon are not within the admissible ranges of RETILAP and less than the international standards at the level of Latin America and Europe. These two measures of central tendency are located below the Lower Control Limit or 300 lx, the lighting levels (natural and artificial) being deficient and given the spatial location of the administrative building, in the mornings it is over lit, widely exceeding the limit. superior control, for the case 750 lux, reaching levels higher than 1300 lx, these excesses and deficiencies in lighting levels denote how the lighting system does not meet the criteria of: optimizing the reception of visual information, maintaining a level adequate performance, guarantee the safety of personnel, in short, provide adequate visual well-being.

The results show that 66% of the jobs have a general lighting system but the maintenance and cleaning is poor, which is verified since there are burned out or damaged lamps and 62% of the working population refers that the lighting system qualifies it as somewhat annoying, annoying and very annoying. Therefore, the visual conditions lead to symptoms such as eye fatigue, headache in a high proportion and to a lesser extent heaviness in the eyelids and blurred vision, it is important to consider that the lighting of the work environment is not necessarily the same as the lighting of the task, in the same way the color of the paint on the walls, the level of reflection of the floor surface, as well as the contrast of the work area surfaces come into play. An additional element responds to occupational medicine activities in terms of occupational examinations where the application of visimetries could detect early visual deficiencies in young and adult workers, improving their visual performance and efficiency. For general office activity (computing), there is no difference in the lighting ranges applicable from Spanish and Colombian regulations. On average 91% of the jobs evaluated are not within the reference parameters, and there are differences in the morning and afternoon lighting averages, generating extreme points, which are located above the upper control limit, but it is evident that most of the lighting levels are below the lower control limit , which gives rise to recommendations to control this type of nonconformity in the work environment.

Colombian technical regulations comply with most international standards to guarantee adequate use of lighting in internal work spaces. However, the new alternatives for future jobs should be prioritized in establishing comparative studies that make it possible to identify and contrast the various ways of approaching the issue of visual ergonomics in work spaces. Finally, the results of the case study are of great importance for the well-being and human resources area of the university institution in order to take preventive and corrective actions for the lighting system of the evaluated offices, which include:

Develop an inspection and maintenance program that specifies the regularity of cleaning procedures, changing lamps and responsible for their execution.

Promote awareness campaigns for the proper use of lights, in order to encourage responsible consumption of energy in off-peak hours as well as in peak hours, seeking to make the most of natural lighting.

Deploy an epidemiological surveillance program for visual diseases in attention to a high degree of visual signs and symptoms, as well as the incidence and prevalence of visual diseases of common origin that can be exacerbated for work

reasons

Share the results of the study with the joint committee on safety and health at work in order to support the opportunities for improvement and follow up on the actions and recommendations emanating from this document.

REFERENCES

1. COMITE TECNICO AEN/CTN. (2003). *Iluminación de los lugares de trabajo*. 43. Retrieved from https://enerfigente.files.wordpress.com/2015/08/une-en_12464-12003.pdf
2. Gobierno de España. (2004). RD 486/1997 Disposiciones minimas de seguridad y salud en los lugares de trabajo. *Boletín Oficial Del Estado*, 1–17. Retrieved from <http://www.oect.es/vgn-ext-templating/v/index.jsp?vgnextoid=cf606c63e6f70210VgnVCM1000000705350aRCRD&ctTax=882aaf27aa652110VgnVCM100000dc0ca8c0TAXC&tipo=e628719ae6a70210VgnVCM1000000705350aTAXC>
3. Jefatura del Estado. (1995). *Prevención de Riesgos Laborales*. Instituto Nacional de Seguridad e Higiene En El Trabajo INSHT, 44. Retrieved from <https://www.insst.es/InshtWeb/Contenidos/Normativa/TextosLegales/LeyPrevencion/PDFs/leydeprevencionderiesgoslaborales.pdf>
4. Küller, R., Ballal, S., Laike, T., Mikellides, B., & Tonello, G. (2006). *The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments*. *Ergonomics*, 49(14), 1496–1507.
5. Ministerio de Minas y Energía, Resolución 180606 de 2008, “por la cual se especifican los requisitos técnicos que deben tener las fuentes lumínicas de alta eficacia usadas en sedes de entidades públicas”, disponible en: <https://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=30118&dt=S>
6. Ministerio de Minas y Energía, Resolución 180540 de 2010, “por la cual se modifica el Reglamento Técnico de Iluminación y Alumbrado Público – Retilap, se establecen los requisitos de eficacia mínima y vida útil de las fuentes lumínicas y se dictan otras disposiciones”, Anexo General del Reglamento Técnico de Iluminación y Alumbrado Público, Capítulo 4, Diseños y cálculos de iluminación interior,” disponible en: http://www.alcaldiabogota.gov.co/sisjur/adminverblobawa?tabla=T_NORMA_ARCHIVO&p_NORMFIL_ID=431&f_NORMFIL_FILE=X&inputfileext=NORMFIL_FILENAME, consultado el 20 de Noviembre de 2018
7. Noriega Y, P. G. (2016). *La Prevención De Riesgo En Los Lugares De Trabajo*. 13. Retrieved from <http://www.istas.ccoo.es/descargas/gverde/ILUMINACION.pdf>
8. Real Decreto 314 del 17 de marzo 2006, “Código Técnico de la Edificación”, disponible en: <https://www.boe.es/buscar/doc.php?id=BOE-A-2006-5515&a=a&orden=conte#refpost, consultado el 15 de noviembre de 2018.>
9. Real Decreto 486/1997, de 14 de abril, por el que se establecen las disposiciones mínimas de seguridad y salud en los lugares de trabajo. BOE n° 97 23-04-1997, España, disponible en: http://www.insht.es/InshtWeb/Contenidos/Normativa/TextosLegales/RD/1997/486_97/PDFs/realdecreto4861997de14deabrilporelqueseestablecenlas.pdf, consultado el 15 de Noviembre de 2018.
10. Real Decreto 488 del 14 de abril 1997, “Disposiciones mínimas de seguridad y salud relativas al trabajo con equipos que incluyen pantallas de visualización”, disponible en: <https://www.boe.es/buscar/act.php?id=BOE-A-1997-8671&p=19970423&tn=6, consultado el 24 de noviembre de 2018.>
11. Resolución 2400 de 1979. Ministerio de trabajo y seguridad social. Por la cual se establecen algunas disposiciones sobre vivienda, higiene y seguridad en los establecimientos de trabajo. De la higiene en lugares de trabajo orden y limpieza. Artículo 29 al artículo 37. De la iluminación. Artículo 79 al artículo 87. (1979).

12. Pattini, A. (1965). RECOMENDACIONES DE NIVELES DE ILUMINACIÓN EN EDIFICIOS NO RESIDENCIALES. UNA COMPARACIÓN INTERNACIONAL. *The British Journal of Psychiatry*, 111(479), 1009–1010. <https://doi.org/10.1192/bjp.111.479.1009-a>
13. Veitch, J. A., Stokkermans, M. G. M., & Newsham, G. R. (2013). Linking Lighting Appraisals to Work Behaviors. *Environment and Behavior*, 45(2), 198–214. <https://doi.org/10.1177/0013916511420560>