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ABSTRACT

Despite the decades of research, it was only in 2002 that David Berson discovered the connection between light and a third type of photoreceptor in the retina and this was the missing link in the description of the mechanism of biological effects controlled by the light and dark cycle. This discovery revolutionized the research on the spectrum, the intensity, the duration and the type of light that affects biological responses. This work addresses the issue of non-visual impacts of human exposure to light, in an attempt to relate the quality of lighting design to health, comfort, and well-being of female retail store employees.

The sample for the cross-sectional study was randomly established with female volunteers. Three groups of ten employees each were selected: street retail stores with outside contact and daily working hours (9 a.m. to 6 p.m.), shopping mall retail stores with no window facing outside, with daily working hours (9 a.m. to 6 p.m.) and evening working hours (2 p.m. to 10 p.m.).

Assessment of lighting considered the occurrence of glare, color appearance of light, flexibility, and possibility of lighting control by employees. The tools to assess well-being and health were psychometric scales internationally validated by the psychiatric field to measure depression, anxiety, and stress symptoms. Assessment of sleep conditions and analysis of the activity/rest rhythm was carried by a wrist monitor with attached luximeter and the analysis of the body temperature rhythm was made by a temperature sensor, to which each participant was submitted for five consecutive days.

The lighting pattern’s influence on the circadian system was verified by measuring saliva melatonin and cortisol levels. The degree of satisfaction of employees and their preferences regarding work environment lighting were surveyed by applying questionnaires.

Data were analyzed using Pearson correlations, ANOVA, and stepwise regression. The study concludes that it is necessary to review the stores’ lighting design strategies, to seek new guidelines able to solve the possible conflicts between light oriented to sell products and that which considers the store as a workplace. The results indicates that the improper choice of fixtures and poor lighting design, can actually have negative consequences for health and also for work performance and well being.

Keywords: lighting design, health, melatonin, retail stores.

1. INTRODUCTION

The architectural typology adopted in shopping mall buildings in Brazil and the type of service provided generate many environments without outside contact and work shifts that advance into the night, both potential factors for the alteration of biological rhythms.

A major challenge in the past years in the illumination field has been to define how light affects health, not only in aspects related to vision, but also related to metabolic processes (studies of circadian rhythms and tumor development, for instance). A population of special interest for the study of the relationship between light and health conditions is that comprising shopping mall employees, who are subject to artificial lighting in environments without windows during the day and often work until late at night. These individuals seem to be potentially more susceptible to diseases related both to excess lighting and to insufficient lighting. Although literature presents several studies on offices (Veitch, Newsham, Boyce, Jones, 2008; Vallenduuk, 1999), there are very few works relating commercial space employees to lighting...
Both in the area of architecture and marketing or behavior, in which only Bitner’s work (1992) stands out for including the employee and not only the consumer. Furthermore, Brazil has a nocturnal culture. Brazilians have the habit of doing a lot at night, prolonging the time exposed to artificial lighting even during their recreational activities such as going to fitness centers, restaurants, or shopping centers, which never close before 10 o’clock in the evening or are open around the clock. During the day, the geographical situation of the country gives it abundant natural light with many days of sun; however, the workers in shopping centers are submitted to artificial lighting that is usually at a brightness level that is low when compared to the natural situation. Consequently, many shopping mall buildings have uncomfortable conditions for occupants, who, out of necessity, end up adapting themselves to the environment (Martau & Duro, 2005; Martau, 2009). According to Vischer (2000), a lot of energy is spent to deal with these stressing factors from the environment and, certainly, shop owners would prefer that their employees spend their energy on work and social relationships to this adaptation.

2. BACKGROUND

The knowledge about the relationship between lighting, man, and Architecture can be analyzed regarding human performance through the visual, perceptive or circadian systems. However, the knowledge about the relationship between lighting and the so-called human circadian system (24-hour daily rhythms) is still in the beginning. Exposure to light may have both positive and negative impacts on human health. These impacts may become evident shortly after exposure or only after many years. Understanding how light influences the human body helps describe the impact of lighting on building occupants.

The circadian rhythms can be regulated by a variety of external indicators, but light (light/dark cycle) is the primary and most important variable in the synchronization (or desynchronization) of humans with day or night rhythms (Gronfier, Wright, Kronauer, & Czeisler, 2008). Light, in addition to synchronizing the biological clock, can reduce winter depression and, through direct brain stimulation, enhance attention (especially at the end of the working day), mood, well-being and performance (Tenner, 2003). Another study (Edelstein, Doctors, Brand, Denton, & Crazn, 2008) demonstrated the relationship between immune function, sleep, and disease recovery, which warrants more in-depth studies in the field of lighting and health. The activity-rest rhythm, the body temperature rhythm and the hormone levels (melatonin and cortisol), are examples of light-regulated biological rhythms in the body that can be measured. When an individual is in a healthy state, all of his/her rhythms have a natural relationship, we say that said individual’s phase is normal (Kaplan, Sadow, & Grebb, 1997). When the system is disturbed (by staying up at night, for instance), some biological rhythms become disarrayed (e.g., cortisol or melatonin rhythms) and are considered to be out of phase. The fact that the biological rhythms are out of phase contributes to the harmful effects experienced by the individuals. Some disorders have phase disturbances among their symptoms. When the rhythms are in disarray, a certain rhythm may have an abnormal phase advance, beginning earlier than usual, or a phase delay, beginning later than usual. Under experimental conditions, a phase response curve for the biological rhythm may show that a certain stimulus (e.g., light) causes a phase advance or delay, when it occurs at different times in a cycle.

Melatonin is a very important hormone in the investigation of human biological rhythms regulated by the light/dark cycle (Kaplan, Sadow, & Grebb, 1997). The relationship between melatonin inhibition and light is direct, and melatonin responds to lighting only. Its rhythm is considered an excellent phase marker for the endogenous biological clock (Arendt, 2005), and it may also be a great indicator for the quality of lighting in relation to employees’ health.

Cortisol is another hormone that takes part in the so-called adrenal axis, also comprising the corticotropin-releasing hormone (CRH) from the hypothalamus and the adrenocorticotropic hormone (ACTH) from the anterior hypophysis. Cortisol shows a clear circadian rhythm, with its peak around the time the individual wakes up (Kudielka & Kirschbaum, 2003). Cortisol plasma concentrations are higher in the early morning (around 6 a.m.) and their values are lower in the afternoon and evening. As cortisol is controlled by the biological clock in the suprachiasmatic nucleus (SCN), cortisol rhythm and
concentration are expected to be influenced by light.

The body also has an endogenous temperature rhythm called body temperature rhythm, which is considered to be the most stable body rhythm in relation to external variations (Noguera, Riu, Hortensi, & Cucurella, 2007). The body temperature variation in a healthy person is around 0.4°C (Van Bommel, 2004).

The hormones cortisol (stress hormone) and melatonin (sleep hormone) play an important role in the sleep/wake regulation, and there are some rhythm relationships between cortisol, melatonin and body temperature. In order to maintain one’s health, it is important that these rhythms remain steady. The observation that a reduction in body temperature is one of the factors preceding sleep (Krauchi & Wirz-Justice, 2001) and that melatonin leads to this reduction is relevant. Biologically, the time and duration in which light (or darkness) is received play a crucial role in establishing body temperature (Boyce, 1997).

Studies have shown that stress is also associated with lighting conditions. Stress changes rhythmically with diurnal regulation, as well as with cardiac regulation and neuroendocrine responses, which seem to be responsible for the higher rates of cardiovascular disease found in chronically stressed individuals (Monk, 1983). Thayer et al. (2006) demonstrated that the physical features of workplaces, including artificial lighting and natural light variations, were associated with the regulation of day/night differences in cardiac responses, which are important stress and health risk indicators.

3. GOALS AND METHODOLOGY

The general goal of this study was to evaluate how lighting conditions interfere with the health and well-being of street retail store and shopping mall retail store employees in Porto Alegre, a city located in south Brazil. For this purpose, specific goals were also defined: to characterize the relationship between lighting conditions and emotional variables such as depression, anxiety and stress; determine if differentiated lighting conditions interfere with the biological rhythm (sleeping conditions, activity/rest rhythm, and body temperature rhythm); determine the levels of the hormones melatonin and cortisol in female employees’ saliva in relation to different lighting conditions in stores; and verify female employees’ satisfaction and preferences in relation to lighting systems at the workplace.

The research was characterized as an exploratory study, with empirical investigation of phenomena in their actual context, with multiple evidence sources (variables), through a phenomenological or interpretative approach, using a cross-sectional study as strategy. The study sought to assess and relate visual, biological and emotional aspects of lighting in the stores analyzed from the perspective of the individuals who worked therein (Figure 1).

The subjects were women aged between 18 and 65 years, who lived in the city of Porto Alegre. All subjects were employees in commercial spaces and must have been working for at least one year at the place and shift under study and could not be working double time. Despite minor variations in entry, lunch, break and exit times, female employees who worked for five to eleven hours on a daily basis were included. All of them volunteered for the study. They were divided in three groups:

- Group A: Ten street retail store employees with presence of daylighting and daytime work (8 a.m. to 6 p.m.);
- Group B: Ten shopping mall retail store employees, without presence of daylighting, and daytime working hours (10 a.m. to 6 p.m.);
- Group C: Ten shopping mall retail store employees, without presence of daylighting, and afternoon and evening working hours (2 p.m. to 10 p.m.).
Lighting conditions were evaluated by taking photos of the luminous environment and by completing a survey form in which the main aspects of the physical environment and lighting system were recorded: ground plan of the spaces under study, containing the shape and basic dimensions, description of materials and colors, list of light bulbs and luminaries. Items such as color appearance of light bulbs were obtained from the manufacturer’s technical specification catalogue. The entrances were marked (if any) and the distance between the employees and the entrance was measured. The general illuminance of the space was measured at four points (to average general illuminance) and at work planes with a portable lux meter. The spaces with day lighting were measured at noon, within the climatic period referred to as spring/summer, on days without rain and at times without direct insulation into the space. All the spaces analyzed had an artificial lighting system activated throughout daytime or at least most of daytime, day lighting in these spaces being, therefore, only quantitatively complementary. The visibility of visual tasks was checked by using the Snelling Chart, which is a standard test to assess visual acuity at preset distances. Undesired reflections were evaluated by moving around the space and placing a reflective surface at different positions to check the presence of undesired reflections.

To evaluate employees’ satisfaction with the store lighting, a questionnaire was applied which was developed from other lighting quality evaluation tools (Bean & Bell, 1992; Boyce & Eklund, 1995; Veitch & Newsam, 1995; Veitch, 2001), as well as adaptations of part of the guide proposed by the Commission Internationale de l’Éclairage (Commission Internationale de l’Éclairage, 1986 & 1972) to evaluate lighting in office environments, with adjustments to the type of existing visual tasks in commercial spaces.

It comprises three parts with close-ended, open-ended questions and Likert-type graphic scales to verify satisfaction with diverse factors of the luminous environment. The multiple-choice questions and open-ended questions aimed at evaluating preference and satisfaction with the luminous environment in workplaces. The evaluation was carried out by the frequency of positive and negative answers concerning lighting, and the criteria for an individual to be considered satisfied with the lighting system of the space were approximately 70% of satisfaction or scores higher than seven (Boyce & Eklund, 1995).

To evaluate emotional aspects, the so-called psychometric scales were used, validated for Brazilian Portuguese. These are: Self Reporting Questionnaire - SRQ-20 (psychiatric disorder) (Mari & Williams, 1986), Montgomery-Asberg Depression Rating Scale (Dractu, Ribeiro, & Cal, 1987), Beck Depression Inventory – BDI (Gorenstein, Andrade, Vieira Filho, & Tung, 1999), Hamilton Depression Scale (Hamilton, 1967), State-Trait Anxiety Inventory – STAI (anxiety) (Spielberger, 1983) and Lipp’s Adult Stress Symptom Inventory (LSSI) (Lipp & Guevara) for stress assessment.

Assessment of sleep conditions was made using the Pittsburgh Sleep Quality Index questionnaire – PSQI (Buysse, Reynolds, Monk, Berman, & Krupfer, 1999) and the Epworth Sleepiness Scale (Johns, 1991) were used to evaluate quality and daytime sleepiness.

Assessment of the timing system involved the temperature rhythm and activity/rest rhythm. Body temperature was measured continuously, for five days, by means of a thermistor (Ibutton, 2008) used together with an actigraph (Mini Mitter, 2007) to check if there were changes in the body temperature rhythm between the groups. It was fixed with an adhesive on the internal region of the forearm (Figures 2 and 3). The activity/rest rhythm was measured by an actigraph with a coupled lux meter (Figure 2), for a period of five consecutive days, always including the weekend. The use of an actigraph allowed the illuminance patterns to be analyzed for 24 h in each employee.
Figure 3. Placement of a thermistor on the internal area of the wrist of the non-dominant hand.

The melatonin and cortisol levels were analyzed in the saliva, collected by the employee herself (participants were asked to rinse their mouth with water before collecting saliva). A minimum volume of 1 ml saliva was obtained directly by expectorating into a collecting tube. Food and beverages such as tea, soft drinks, and coffee were not permitted 30 minutes prior to any sample collection. Participants were also instructed not to brush their teeth 30 minutes before saliva collection. The first collection was performed at 6 p.m., the second collection at 12 p.m., and the last collection at 12 a.m. on the next day. The collection times were established to encompass the two hormones, cortisol and melatonin, since each of them had different ideal collection times. After the collections, the saliva was frozen. For melatonin levels, a commercial ELISA kit from APCO Diagnostics® (ELISA kits, Buhlmann Laboratories, AG Swiss) was used. For cortisol levels, a Roche chemiluminescence kit was used for measurement in automated Modular E-170 equipment for serum, urine and saliva. The method was a competition assay that used a specific antibody against cortisol.

Data were organized in a databank using the Excel software (Microsoft). The statistical analysis was carried out with the Statistical Package for Social Science (SPSS) program for Windows, version 13.0. A consistency analysis of the results was performed after the tools were applied by means of the Cronbach’s alpha. The distribution of variables was described as mean and standard-deviation or frequency and proportion, when suitable. Stepwise multiple regression analyses were performed. Correlations between variables were analyzed using Pearson’s Correlation Coefficient and variance analysis (ANOVA). Analyses of some specific variables were performed using the software programs El Temp (analysis of acrophase, amplitude, mesor and activity and temperature rhythmicity percentage) and Actiware-Sleep, from Minnimiter (actimetry analysis and exposure of subjects to illuminance for five days). The potentially confounding variables controlled in the statistical analysis were age, working hours and working shift.

4. RESULTS

4.1 Lighting Conditions

Regarding the color appearance of the light in the environment, addressed by observing and surveying the light sources responsible for general lighting, the predominance of white light was observed in group A (60%, n=10) and warm light in group B and C stores (45%, n=20).

In the quantitative assessment of lighting through the survey of average general illuminance (average general illuminance at four points measured around the work plane), it was observed: Group A present lower illuminance and group C the higher levels. IESNA (Illuminating Engineering Society of North America, 2001) considers a store illuminance of 200-350 lux low, an illuminance of 450-750 lux medium, and an illuminance of 750 lux or more high. It recommends illuminances according to the economic status of the store and the product being sold. In this classification, regardless of the store status, we can say that the group of street stores present, on average, low illuminances (340 lux) and the morning/afternoon and afternoon/evening groups of shopping mall stores have medium illuminances (428-666 lux), and the latter may reach up to 1300 lux of average general illuminance.

Regarding satisfaction with workplace lighting the results found indicate greater dissatisfaction with the workplace lighting in groups B and C than in group A. In group A, the general satisfaction in the rate assigned to the item “possibility of visual contact with the outside” was positively correlated with the rate assigned to "lighting for the employee to feel motivated to work" (r = 0.673*, p = 0.047, n=9), “for feeling happy” (r = 0.707*, p = 0.033, n=9), “lighting for my eyes” (r = 0.732*, p = 0.025, n=9), and “lighting for feeling physically well” (r = 0.797*, p = 0.010, n=9).

In group A, there is a correlation of the Hamilton depression scale with the average general illumination of the store (r = 0.820**, p = 0.004, n=9). There is also an important
inverse correlation \((r = -0.516^*, p = 0.020, \ n=20)\) between the average general illuminance of the store and the rate assigned to the item "lighting of this store considering all factors" in groups B and C. This means that the greater the average general illuminance of the store is, the greater the dissatisfaction with lighting.

Even in street retail stores (group A), a high percentage considers daylighting to be insufficient (55%, \(n = 9\)), which demonstrates that the existing architecture does not enhance the use of natural resources (because, as previously mentioned, only 20% of the street stores analyzed did not have an artificial system activated all the time).

The issues of uncomfortable noises and heat produced by light sources appeared in different correlations with the psychometric scales (anxiety in groups B and C), demonstrating that the non-visual aspects of lighting also have an influence on employees' well-being. In group A this correlation is not observed to appear, although their lighting systems have a worse quality than in shopping malls. This may be explained by the greater external noise found in street stores, masking the noise from light sources, which may make it more harmful. Similarly, the dissatisfaction with the heat produced by the light sources seems to be correlated with emotional variables in shopping mall groups B and C, in which the greater illuminances account for the greater discomfort with this aspect.

4.2 Emotional aspects: possibility of mental disorder, depression, anxiety and stress

Regarding emotional aspects (Table 1), group A showed better health conditions and well-being than group B (which had greater stress and anxiety than the others) and group C (which had greater possibility of mental disorder and depression).

Table 1. Emotional conditions by groups.

<table>
<thead>
<tr>
<th>Psychiatric disorder</th>
<th>Group A</th>
<th>Group B</th>
<th>Group C</th>
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<tbody>
<tr>
<td>Stress &amp; Anxiety</td>
<td>High</td>
<td>Low</td>
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<td>Depression</td>
<td>Hamilton Lower</td>
<td>Hamilton Lower</td>
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<td>Anxiety</td>
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<td>Higher</td>
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<tr>
<td>Stress &amp; Anxiety</td>
<td>Lower</td>
<td>Lower</td>
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With relation to the rate assigned to the item "possibility of visual contact with the outside", throughout the sample an inverse correlation was found \((r = 0.498^{**}, p = 0.006, \ n=29)\) with the Beck depression scale (in which higher values indicate greater depression). This correlation is not confirmed in group A with the Beck scale (but rather with the Montgomery-Asberg scale, which also indicates depression), but is found in group C, in which the correlation shows greater intensity \((r = -0.730^*, p = 0.016, \ n=10)\). In group A there is an inverse correlation between depression assessed by the Montgomery-Asberg scale and aspects related to the presence of windows: possibility of visual contact with the outside \((r = -0.705^*, p = 0.034, \ n=9)\) and possibility of time orientation \((r = -0.718^*, p = 0.029, \ n=9)\). This means that the more dissatisfied with the assessed aspects the employees were, the more depressed they were. The inverse correlations between the Montgomery-Asberg scale and the satisfaction with items such as "lighting for making me feel relaxed" \((r = -0.814^*, p = 0.014, \ n=8)\), "motivated to work" \((r = -0.691^*, p = 0.039, \ n=9)\), "happy" \((r = -0.701^*, p = 0.035, \ n=9)\) and "physically well" \((r = -0.834^{**}, p = 0.005, \ n=9)\) clearly indicate the importance that the lighting conditions of street stores have for the employees' emotional and physical aspects. Also in group A, there is a strong correlation between the assessment of lighting for making the employee feel relaxed and aspects connected with anxiety (STAI-State, with \(r = -0.833^*, p = 0.020, \ n=7)\) and sleep quality (Pittsburgh Sleep Quality Index, \(r = -0.792^*, p = 0.019, \ n=8)\). In the entire sample there is a direct correlation of regular intensity between the depression scores assessed by the Hamilton scale \((r = 0.446^*, p = 0.013, \ n=30)\), which becomes of strong intensity in group A \((r = 0.820^{**}, p = 0.004, \ n=9)\), and the average general illuminance of the stores.

In group B, in which the illuminances measured were higher than in A, there is a correlation between store illuminance and possibility of mental disorder (assessed by the SRQ-20) which is almost perfect, of very strong intensity to high significance, that is, there is a very small chance of error \((r = 0.959^{**}, p = 0.00, \ n=10)\). Also in this group, there is a strong direct correlation between the general illuminance of the store and higher depression scores assessed by the Beck \((r = 0.752^*, p = 0.012, \ n=10)\) and Montgomery Asberg scales \((r = 0.831^{**}, p = 0.003, \ n=10)\).
These results indicate that high illuminances are associated with a high possibility of mental disorder (SRQ-20) and depression, especially in group B, suggesting that these employees are more emotionally influenced by high illuminance (which may be causing alteration and tendency to loss of cortisol rhythm in this group). In group A there is a strong inverse correlation between anxiety (STAI-trait) and exposure time in minutes per day above 2000 lux \((r = -0.771^*, p = 0.015 \text{ and } n=9)\), 3000 lux \((r = -0.720^*, p = 0.029 \text{ and } n=9)\) and 5000 lux \((r = -0.758^*, p = 0.018 \text{ and } n=9)\). The results show that the longer the time of exposure to high illuminances (natural light) is, the lower the anxiety level in this group is.

4.3 Sleep conditions, activity/rest and body temperature rhythms

The sleep conditions analyzed for quality, through the Pittsburgh Sleep Quality Index (PSQI), showed that the employees in group B \((S=5.50, S_D=3.80, n=10)\) and C \((S=5.70, S_D=3.74, n=10)\) had worse sleep conditions than those in group A \((S=4.60, S_D=2.31, n=10)\), although the differences between the groups were not significant. Regarding diurnal sleepiness (Epworth), group A showed greater sleepiness \(S=10.20 \text{ with } S_D=2.82 \text{ and } n=10\) than group B \((S=8.80, S_D=3.67, n=10)\) and C \((S=6.88, S_D=3.14, n=9)\).

The statistical analysis of the actigraph measurements (activity/rest rhythm) demonstrated that there are differences in the activity between the groups in some parameters. The differences found are in the activity/rest rhythm of the group C employees in comparison with the other groups, in which the ANOVA analysis showed greater variance range and percentage in the activity rhythm \((F=4.81, P = 0.016)\), explained by a specific circadian rhythm in this group, that is, the existence of a more defined activity rhythm that is different from the other groups, which may indicate a greater influence of the environment lighting on the activity in this group. Figure 4 summarizes the analysis of the rhythm of the three groups through Rayleigh’s graphical method, in which the acrophase of rest rhythm (time at which it is more pronounced) in the afternoon/evening shopping mall group is observed to occur closer to dawn, unlike the other groups.

Figure 4. Analysis of the rhythm of the three groups through Rayleigh’s graphical method.

The mean exposure time in minutes per day above a 1000-lux illuminance was similar between the groups (Figure 5). This can be explained because even if quantitatively the time of exposure to certain illuminance is similar, the type of light received is different (regarding spectrum, color temperature, visual access to the outside), which has been demonstrated by literature to be of great importance to people’s health.

Figure 5. Mean of minutes per day above 1000 lux in each group compared with other studies.

The one-way ANOVA analysis of the light/dark factor (light/dark phase ratio) showed significant differences between group C and the other groups \((F=5.597 \text{ and } P = 0.009)\). The light/dark factor in group C was \((S=1.52, S_D=0.52, n=10)\), in group B \((S=2.26, S_D=0.81, n=10)\) and in group A \((S=2.40 \text{ and } S_D=0.51, n=10)\), which also demonstrates that in this group the influence of lighting is different from the others. The correlations between light/dark factor, activity rhythm and 18-h cortisol in this group (C) indicate associations between the lighting conditions of this type of store and the biological aspects of the employees, suggesting that the health alterations found may be related to environmental factors, such as store lighting and 24-h light pattern.

In group C, the light/dark factor also showed a direct correlation with the activity rhythm assessed by the actigraph \((r = 0.714^*, p = 0.020, n=10)\), indicating that the longer an individual is exposed to light (light phase), the greater the robustness of activity.
rhythm is. In Figure 6 is shown the direct correlation found between general satisfaction with lighting and light dark factor in the whole sample.

Figure 6. Correlation between satisfaction with retail lighting and light dark factor in the whole sample.

Body temperature does not present a significant difference in the acrophase value (peak) between groups. In the parameter temperature mesor, a difference was found, in which the shopping mall group C differs from A (F= 4.91 and p= 0.032, n=22), but not from B. Group C is likely to have its melatonin production peak more delayed than the other groups, which may account for higher levels of melatonin at 12a.m and may be related to the lighting pattern in the store environment found in this group, which is different from the other groups (high illuminance), to the lower light/dark factor and the time of exposure to this illuminance (workday until 10 p.m.). There is no change in the rhythm itself, but rather in the temperature rhythm acrophase in this group (Figure 7).

Figure 7. Behavior of skin temperature acrophases in the three groups.

In group C, the average general illuminance showed a direct correlation with temperature acrophase (r= 0.830*, p= 0.041, n=6). This data is very important, because it can imply a link between the several results found in this group. Among them is the advance of acrophase times of skin temperature already discussed, reinforcing the hypothesis that lighting, or rather, the high average general illuminances of the stores in this group, may be causing a phase delay in melatonin rhythm and, thus, generating a negative influence on employees' health and well-being, which may in the long run lead to illness.

4.4 Biological rhythms

4.4.1 Melatonin

The group A shows a condition close to the optimal state in terms of rhythm, that is, there is a greater difference between diurnal and nocturnal levels, melatonin at 12 p.m is significantly higher than at other times among the three groups (Figure 8). Group B already presented greater melatonin suppression between 6 p.m and 12 p.m than the situation of stores with contact with the outside, which may be influenced by the higher average illuminances found in category of shopping mall stores. Group C showed results of higher melatonin levels at 12 a.m than at 12 p.m., with a significant decline (great suppression) starting at 12 a.m until 6 p.m. (period coinciding with the arrival at the workplace with high average general illuminance).

Figure 8. Salivary melatonin levels at 12 a.m, 6 p.m and 12 p.m.

In group A, a strong, direct correlation is observed between the 12 p.m salivary melatonin levels and the time of daily exposure to higher illuminances (which allows us to conclude it consists of daylighting, since measurements indicate lower illuminances in the internal environments of the stores), described as follows: min/day>1500 lux (r= 0.804**, p= 0.009, n=9), min/day>2000 lux (r= 0.794*, p= 0.011, n=9), min/day>3000 lux (r= 0.803**, p= 0.009, n=9) and min/day> 5000 lux (r= 0.706*, p= 0.034, n=9). In group B, it shows a direct correlation with the light/dark factor, that is, the light to dark ratio in the period under study, melatonin level at 6 p.m and the time of exposure to higher illuminances: min/day > 3000 lux. This correlation with the light/dark factor appears in group B (r=0.755*, p=012, n=10) with greater strength, but does not appear in group C.
4.4.2 Cortisol

Considering the situation of street stores (group A) as the optimal situation among the three groups, especially due to the presence of natural light and visual contact with the outside, groups B and C showed levels and variation between times different from the optimal ones.

The results (Figure 9) found in the saliva cortisol levels (12 a.m, 6 p.m, 12 p.m) indicate a rhythm change (tendency to loss) in group B, in which a small variation between levels at three different times is observed, when a clear circadian rhythm is almost not perceived, with a peak around the time the individual wakes up12.

Figure 9. Salivary cortisol levels at 12 a.m, 6 p.m and 12 p.m.

In group A, a strong, positive correlation was found between the salivary cortisol level at 24 h and the depression level assessed by the Montgomery-Asberg scale (r=0.805**, sig. 0.009 and n=9), indicating that the employees with more elevated cortisol levels at this time had higher depression scores. The employees with higher cortisol at 12 a.m were the ones with higher anxiety scores assessed by the STAIT-Trait (r= 0.708*, p= 0.049 and n=9).

An inverse correlation was also found between the light/dark factor value and the salivary cortisol at 6 p.m in the afternoon and evening shopping mall group (r= -0.656*, p= 0.039 and n=10). This means that the greater the amount of light in relation to dark, the lower the cortisol was at that time.

In group B, there was an inverse correlation between the 24 h cortisol level and higher scores for possibility of mental disorder assessed by the SRQ (r= - 0.637*, p= 0.048 and n=10), depression assessed by the Hamilton scale (r= - 0.660*, p= 0.038 and n=10) and diurnal sleepiness assessed by the Epworth scale (r= - 0.645*, p= 0.044 and n=10). These correlations deserve more specific studies of cause and effect, which could not be explained in this study.

In group C, there was a correlation between the 12 p.m salivary cortisol and the amplitude of temperature rhythm (r= 0.970*8, p=0.001 and n=6). Considering that there was a positive correlation between the general illuminance of the store and the temperature indicator (acrophase), a hypothesis can be raised that an indirect mechanism exists involving the amount of light in the store and the cortisol levels of the employees.

5. DISCUSSION

The study demonstrated that the female employees in the retail stores responded differently to lighting conditions in the three groups analyzed.

There is a high degree of dissatisfaction with the lighting system in the three groups and satisfaction with lighting design was demonstrated to be associated to emotional and biological factors. By demonstrating this relationship, one can encourage entrepreneurs to invest in female employees’ satisfaction with lighting and, indirectly, in their productivity.

The results point to a greater dissatisfaction with the workplace lighting in the category shopping malls (groups B and C) than in street stores (group A). In all psychometric scales applied, the results pointed to higher mean scores for symptoms indicating a possibility of psychiatric disorder, depression and anxiety in groups B and C in relation to group A.

The most consist finding, which has a greater impact on the current lighting practice in shopping malls is the inverse correlation found between the average general illuminance of a store and the satisfaction with lighting, as well as the positive correlation of this variable with scores showing a possibility of mental disorder and depression, in group B, and with biological indicators (24-h temperature and melatonin acrophase) in group C.

Since circadian rhythm regulation depends on the time and duration of exposure to light, the workers in group C seem to be more influenced by the light in the workplace, perhaps because they are exposed to high illuminances until a later time than the other groups.

By analyzing comparatively the melatonin and cortisol results, melatonin showed greater sensitivity to the workplace lighting pattern than cortisol. In the group C stores,
melatonin suppression is directly related to the beginning of the workday. However, cortisol is apparently more related to the employee’s 24-h light exposure pattern, that is, the time at which she was exposed to natural light.

The employees in street retail stores (A), where we found lower illuminances (up to 300lux), showed higher drowsiness during the day and higher dissatisfaction with issues related to task visibility. Probably, it would be necessary to increase general illuminance in the category street stores, since dissatisfaction with lighting and daytime drowsiness may be indirectly associated to low illuminances (likely little circadian stimulation). The presence of windows and visual contact with the outside was an important factor for this group to present better conditions in the assessment of depression and stress, as well as the normal behavior of cortisol and melatonin levels.

The female employees of shopping mall stores working in the morning and afternoon shifts (group B) showed the worst conditions in the assessment of anxiety and stress among the three groups because they had no contact with natural light during the day as a result of their work time. The altered cortisol levels may be related to the high stress in this group and the lack of contact with natural light to stimulate it. Allowing them to have visual contact with the outside and access to natural light, whenever possible, is a precondition for health and well-being, since the results indicate direct and indirect correlations between this factor and higher depression and anxiety scores.

This means that the project must prioritize the presence of windows, employing technical resources currently available to deal with issues of potential color fading caused by light, such as placing filters and special films on window panes.

The female employees of shopping mall stores working in the afternoon and night shifts (group C), where the highest average general illuminances were found (up to 700 lux) and the time to which they are subjected is later than the other shifts, showed physiological alterations in melatonin production and worse conditions in the assessment of depression. It is necessary to reduce general illuminance, since the alteration of the hormones melatonin and cortisol and the dissatisfaction in the shopping mall groups are directly and indirectly associated to high illuminances in the workplace. It also seems to be advisable to avoid using only one type of light bulb (same spectrum), reducing, thus, the risk of the existence of only one type of wavelength in the environment that may be harmful to the circadian system, until we learn what kind of spectrum is the most suitable and how these spectra interact with one another in a real environment. We must be careful so as not to use sources that are more suppressive of melatonin at night time and pay attention to new technologies until their influence on people is confirmed.

The results for the amount of light in stores indicate a need for adopting lighting techniques that incorporate intense light spotlighting the merchandise – which is the key to the process of attracting customers to buy – and milder general lighting for employees, light sources with reflected or indirect light being the most suitable for this, which is important for their health and well-being. It is crucial to review the international legislation that dictates high general illuminance for this type of stores.

The shopping mall typology must be reviewed since the lack of visual contact of employees with the outside is related to higher depression scores in these groups. In stores without visual contact with the outside, the variation and control of artificial lighting systems by employees or the use of a programmed system should be enabled, varying the amount of light and color appearance, since great dissatisfaction was found with the lack of variability in the luminous environment of stores without openings.

An important question for discussion raised by this study was that of the methodology used, which tested the variables to assess the quality of lighting focusing on human needs (visually, biologically and emotionally), as well as the tools brought from the fields of Psychology and Medicine. The methodology was deemed to be appropriate, since countless associations (correlations) were found between the variables under study, and the results were convergent and coherent between the different tools used. However, the methodology was found to be too complex and long for the employees, which resulted in a high number of drop-outs (12 people) after the start of the evaluation. A new research is beginning now considering the spectrum that could not be included in
the first one because there was no appropriate portable equipment at that time.

6. CONCLUSION

The study demonstrated that in retail stores selected there are real conflicts in retail lighting and employee’s satisfaction and well being. Currently all the concerns related to retail store lighting are apparently directed to a smooth sales process that take into consideration the product and consumer behavior. There is a need of changing focus since the comfort of the employees seems to be at risk as well as their health, in a greater or lesser degree, and consequently their productivity. Quality lighting for employees’ should consider the VBE Model (visual, biological and emotional), although this model has to be defined by further studies (Figure 10).

Figure 10. The question is: what is quality lighting for employees in retail spaces?

Lighting design needs to be regarded as a multidisciplinary field of knowledge aiming at developing and applying information on human behavior and physiology to environment lighting. The conceptual-theoretical base that is being established in the field of lighting design allows us to point out that, as human requirements become understood, a new paradigm is needed for contemporary lighting design. The technological solutions of lighting systems will remain of key importance, but it will be necessary to learn how to reorganize design guidelines in order to render them user centered.

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