Lighting and health of building occupants: a case of Indian information technology offices

Sutapa Das

Department of Architecture and School of Infrastructure, Indian Institute of Technology Kharagpur, Kharagpur 721 302, India

This pilot study explores the possibility of using architectural design to positively influence the health and well-being of information technology (IT) professionals using more daylight in their offices. Literature review, visual observation, office lighting survey and illuminance study at the premises of two IT companies in Kolkata, India indicated common health issues of their occupants which can be more critical than sick building syndrome. This can be possibly linked to disruption of the circadian clock or in turn lack of exposure to daylight and its natural variation. Mere 18% contribution of sunlight in the indoor illuminance affirmed this point. Bespoke space planning and fenestration design to allow more daylight without compromising the privacy were set as the goals of a further study to augment the latest research in healthy office lighting.

Keywords: Building occupants, circadian clock, daylight, information technology, office lighting.

Introduction

CURRENTLY, information technology (IT), including business process outsourcing (BPO), is one of the most prominent industries in India. The sector has maintained a double-digit growth over the last few decades[1]. In 2012, it contributed to 7.5% of the country's GDP, i.e. about 60.8 billion US dollars and provided direct employment to about 2.8 million people while indirectly benefiting 8.9 million people[2]. Out of this workforce, 97.4% includes young professionals in the age group of 20–30 years[3]. Sixty-nine per cent of IT revenue comes from foreign clients and most of such projects have workforce split between India and aboard with significant difference in time zone.

The flipside of this trade is also a fact as meticulously noted by several researchers. Occupational health and safety in white-collared job, including IT is lately receiving attention, though there is no apparent physical hazard like manufacturing, mining or construction industry. Common health issues related to IT offices are[4–9]:

- Acoustical discomfort: noisy environment in call centres, continuous use of headphone.
- Visual discomfort: tired eyes, glare from computer screen.
- Musculoskeletal disorders: spondylosis, carpal tunnel syndrome mostly from poor ergonomics.
- Psycho-social problems: stress, depression.
- Others: fatigue, sleeplessness in spite of being tired.

IT professionals are identified with higher vulnerability of work-related stress and depression compared to other industries[10]. In a cooperative study on workers from mechanical engineering and IT, the latter group showed higher stress in the similar physical work environment[11]. This may be attributed to the fast changing and highly competitive nature of the IT industry. In the coming decades, heart disease, diabetes, cancer and chronic respiratory problems though non-communicable in nature, will spread like epidemics[12]. Among these, cardiac problems will be on top claiming about 35% lives of working professionals by 2030, mostly from the outsourcing industries, including IT–BPO[13].

From this discussion it is evident that the future of Indian economy dependent on the productivity and comfort of its young workforce in the IT sector is at stake. According to NASSCOM[13], companies can encourage their employees to join health programmes or stress management initiatives, but they have limited scope to interfere in their personal lifestyle such as sleeping pattern. It further argues that the IT–BPO industry has its own characteristics of higher pay and work pattern which adult professionals have chosen themselves[14]. But it is a fact that the late work hours brought by globalization[15] cannot be reset to traditional nine-to-five office hours.

In this context, it is of paramount interest to design IT office buildings with special emphasis to ensure a comfortable work environment for spending long hours till late evening. It is interesting to note two points here. First, the common ailments of IT professionals such as visual discomfort, depression, fatigue, poor mental alertness, etc. can be associated to a disrupted biological clock and poor visual comfort. More about this is explained in the literature review. Secondly, despite many of the IT offices having modern facilities and benchmarked performance attributes, the occupants have building-related health issues which do not disappear upon exit from the building, as in the case of sick building syndrome. To address this lacuna, the aim of this study was to establish

e-mail: sutapa@arp.iitkgp.ernet.in

the positive role of lighting and its possible connection with the well-being of IT professionals such that healthy day lighting in IT offices can be achieved through special architectural features.

Response of humans to light

Visual response

Commonly light is associated with vision because we see things when light falls on them, gets reflected and is then perceived by rod and cone cells of the retina in the human eye. The two aspects of vision, namely visual performance and visual comfort are quantitative and qualitative in nature respectively. The first one deals with illumination, lighting level, glare and uniformity[16,17], whereas the second involves colour rendition, colour appearance, composition and contrast[18].

Non-visual clinical response

Therapeutic property of light has been known since long, though not scientifically explained. According to the Hindu epic *Mahabharata*, Lord Krishna's son Shambo recovered from leprosy by solar exposure at certain angles for certain durations. Synthesis of vitamin D in the body in the presence of sunlight can cure Rickets[19]. 'Heliotherapy' or treatment by sunlight was popularized by Auguste Rollier in Europe during late 19th to mid 20th century to deal with infection, blood sugar, blood pressure, cholesterol, tuberculosis and skin ailments. The healing power was not only due to exposure, but had some unexplained relation with vision because sunrays were ineffective if the patients used sunglasses[20]. But after 1930s, with the onset of antibiotics, heliotherapy took a backseat[21].

Moritz[21] has linked insufficient solar exposure with higher physical and psychological vulnerability to elucidate the phenomenon of seasonal affective disorder (SAD) or winter depression in colder countries. During long, dark winter, people demonstrate escalated symptoms of irritability, fatigue, illness, obesity, insomnia, depression, alcoholism, suicide tendencies, etc. which subside naturally with the arrival of spring or artificial exposure to bright illumination[22]. Van Someren *et al.*[23] regularized the disturbed sleep–wake pattern of Alzheimer's patients by treating them with bright blue artificial light or rays of the early morning sun.

Circadian response

Several physical, psychological and biochemical processes of the human body follow a rhythmical pattern with a frequency coinciding with one solar day[24]. This internal rhythm has sunk into our genes over the ages leading to the concept of biological clock or circadian cycle ('circa' means approximately and 'dies' means day). Though early researchers[25–27] have found the functional connectivity between circadian cycle with suprachiasmatic nucleus (SCN) of the brain, the non-visual effects of light on human health were scientifically explored only in 2002 with the discovery of retinal ganglion cells as the third photoreceptor during an experiment on rats at the Bearson Laboratory, Brown University, USA[28]. These cells are connected to SCN. Its malfunction or rather disrupted photoreception may result in disorder of various organs and metabolism because SCN has the following major functions:

(1) To regulate circadian clock of the body by adjusting the secretion of melatonin or sleep hormone and cortisol or stress hormone from the pineal gland of the brain – commonly called the hormone centre.

(2) To control local biological clocks, i.e. maintain functional rhythm of various organs such as lungs, kidneys, liver, heart, pancreas and digestive system[29].

(3) To help the neurons in sending electrical signals from the brain to other organs and synchronize their functions.

Hormonal response

Cortisol and melatonin hormones secreted from the SCN complement each other to set equilibrium of alertness and sleep respectively. Level of cortisol or stress hormone increases as the day progresses, peaks at mid afternoon, wanes in the evening and becomes almost zero after midnight. On the contrary, level of melatonin or sleep hormone is highest after midnight and almost zero at midday. In brief, bright bluish light promotes cortisol secretion and darkness facilitates melatonin secretion. That is why normally people are energetic in the morning hours, drowsy in the late evening and sleep soundly after midnight. This hormonal pattern regulates the circadian clock and body temperature (Figure 1)[18]. However, high level of cortisol for a prolonged duration or excessive suppression of melatonin makes people feel exhausted.

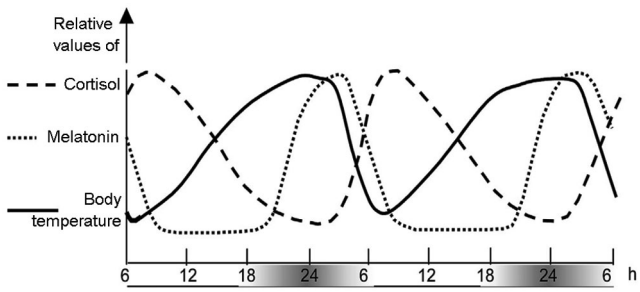

Figure 1. Cyclic variation of temperature, melatonin and cortisol in humans in the 24 ± 0.5 h biological rhythm[18].

Several experiments have been conducted to understand the hormonal response of the body towards light exposure. Vandewalle *et al.*[30,31] found that compared to other colours, blue light has the maximum positive influence on alertness and cognitive performance of the brain during daytime, though such temporary exposure does not notably influence the circadian clock. In a similar study, blue light of 6500 K colour temperature (CT) was found to be effective even at a very low illumination level of 40 lux. Here significant suppression of melatonin gave rise to mental alertness[32]. In another experiment by Wood *et al.*[33], subjects stared at white bright light of self-luminous tablets at night. After 2 h, it caused melatonin suppression and sleeplessness when the viewing took place through the naked eye and clear-lens goggles fitted with blue LED (light emitting diode), but not through orange-tinted viewing glasses to cut-off blue light. Accordingly, it was recommended to incorporate spectral power distribution in electronic devices to regulate cortisol–melatonin stimulation depending on the hour of usage.

At each daybreak, the bright blue sunlight resets the circadian clock and smoothens out any cortisol–melatonin disruption of the previous day, thus ensuring proper body functions. However, a prolonged disbalance of day–night cycle due to natural causes (e.g. SAD, yellowish lens of an aging eye) or enforced causes (e.g. working late, prolonged computer usage, shift work or travelling across time zones) may affect the circadian clock and in turn people's health in the short or long run. For example, micro-sleep, sleep disorders, jet lag, irregular heart rate, lower immunity, depression, fatigue, obesity, high blood pressure, high blood sugar, Alzheimer's disease and cancer[34,35]. Many of these health concerns used to be observed only in elderly people. But recently, these symptoms are prevalent among many young IT professionals.

Healthy light in building design

Traditionally, office lighting meant using artificial light only. After 1990s, with increased awareness for energy efficiency, daylight was included in the lighting scheme[36]. Both approaches aimed for good visual performance and visual comfort. Very recently, non-visual, i.e. health aspects of light are being incorporated[37] and such lamps are now commercially available[38].

'Dynamic lighting' scheme (Figure 2) by Van Bommel[39] includes variation of both the illumination level and colour throughout the day to synchronize the biological clock. Stimulating white light (6000 K CT) resets the clock in the morning, re-energizes the body after the afternoon siesta and freshens up people in the evening for their return trip home at low intensity for a short spell. At other times, warm white (3000 K CT) light is used to save electricity. At lunchtime this light is lowered to 500 lux for 'biological relaxation' facilitating a 'power nap' for a productive afternoon session. The position of the light source may also be beneficial to reduce fatigue and improve sleep quality if the light creates high level of vertical illuminance[40].

However, till date, the effort of illumination engineers to promote healthy lighting is not complemented enough by architects in terms of building layout, space planning and fenestration design. Building occupants prefer windows with daylight and view[41], and daylight is an important ingredient of the healing environment[42]. For residential lighting, Veitch[43] recommended guidelines for: (1) architectural features to balance illumination level with glare and (2) windows or skylights for the additional benefit of distant views and aesthetics. Customization through personalized age-wise lighting near eye level and orientation of different rooms are also possible[44]. But deeper investigation is recommended for a more scientifically acclaimed solution.

Methodology

This study is the pilot phase of a bigger research project for special architectural design of IT offices to incorporate healthy lighting to reduce work-related stress. The pilot study was divided into three parts, namely, (1) visual observation, (2) subjective study (questionnaire-based opinion survey) and (3) objective study (field data collection). The aim was to determine if there was a need for bespoke architectural design for IT offices. This being a preliminary work, rigorous sampling methods, statistical analyses of data or detailed questionnaire design were not planned.

The case-study companies

Though the main sampling frame consists of 110 companies which are registered units of the Software Technology

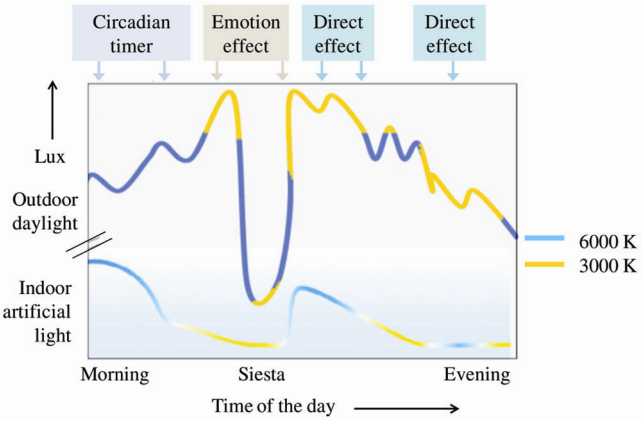

Figure 2. Compassion of the effect of random variation in the colour temperature of outdoor daylight and gradual variation in colour temperature of artificial indoor light on the work environment[39].

Park (STP), Kolkata, India[45], the pilot study was conducted in typical office floors of two different companies. For confidentiality, their names are not mentioned here. Both companies are of Indian origin and serve global clients, but vary greatly by size. The first one (henceforth called as Firm A) has many branches all over the world and in Kolkata mainly operates from its own office buildings and very few rented floors in multi-tenant offices. The second company (called as Firm B) is much smaller with only three branches, including one office in Kolkata situated in few floors of STP IT Park. Firm A has over 40 years of operation and has an employee strength of about 3000 in Kolkata, while Firm B is just 15 years in IT sector and has only 240 people in the Kolkata office.

Both firms occupy typical office buildings with common features like central air-conditioning, glass curtain wall, open office plans within the main work area and highly secured access control system. The work pattern is also similar. Though the official work hours are 9 h/day for a 5-day week, work starts at different times for different types of projects and often continues till late evening due to workload or in order to have overlapping schedule with foreign clients. Few teams in maintenance and support work 24 × 7, but in shifts. In brief, the peak office hours are from 12 noon to 10 pm.

Visual observation

Data security is a critical clause in the job contract of these firms and hence, photography is strictly prohibited inside the office. Photograph of facade has been taken from the outside and presented here in order to reveal closely the fenestration and at the same time not to expose the identity of the buildings. Visual note taken during an escorted walkthrough helped to select the locations for field reading.

Subjective study

Opinion of IT professionals was collected using office lighting survey (OLS) method. It is a simple approach to administer yes/no-type questionnaire to evaluate the satisfaction level of occupants for office lighting[46,47]. Information was obtained about: (1) age; (2) gender; (3) years of experience (or designation); (4) average time spent in the office; (5) usual sleeping hours; (6) quality of daylight in the work area; (7) quality of artificial light in the work area; (8) whether they suffer from any particular illnesses (e.g. high blood pressure, blood sugar, cardiovascular disease, headache and eyestrain); (9) presence of those illnesses in the family history; (10) regularity of morning walks, and (11) remarks, if any. Irrelevant or confidential data such as name of the respondent, corporate policies or ergonomic/musculoskeletal discomfort were purposefully excluded. The questionnaire was circulated via the company's group e-mail in Firm A, and in hardcopy format for Firm B.

Objective study

Objective study was conducted in the main work area of the office floors – not in individual cabins. Illuminance level (lux level) was measured using Lutron LX-1102 light meter (Figure 3). This hand-held device can take instantaneous measurement at a range 40–4,000,000 lux with 0.025% precision in five categories (40,400, 4,000, 40,000 and 4000,000 lux). Readings were taken at the desk near window and the inner area (3 m or more distance from window). Data were taken thrice daily (11–11.30 am, 3–3.30 pm and 7–7.30 pm) on 8 and 9 December 2014 in Firm A and in same manner in the next two days in Firm B. All the days had clear bright sky and sunset times were between 4.51 and 4.52 pm. Considering the aim of this study, other visual parameters such as glare, surface reflectance, colour rendition, etc. were not evaluated. Though colour of the light (in K CT) is an important criteria for the study, it was omitted due to the fact that there is no scope of colour variation or dynamic lighting as only bright white compact fluorescent lamps (CFLs) were installed.

Results and discussion

Total 68 respondents (56 from Firm A and rest from Firm B) participated in the survey. Among them, 35 were 20–30 years old, 23 were 30–40 years old and rest 11 were above 40 years of age. People from various hierarchy levels were targetted in the survey; only 41 junior (<5 years of experience) and 17 mid-level (5–10 years of

Figure 3. The hand-held luxmeter used in the study.

experience) staff responded. No response was obtained from higher officials with more responsibilities and usually with no fixed office hours.

Visual observation results

For the sake of data security, photography was allowed only from outside. The facades of both buildings (Figure 4) show that the fenestration (glass curtain wall in Firm A and window in Firm B) has tints, blinds or curtains to prevent any view of the computer monitor from outside. As a result, from workstations, it is nearly impossible to precisely find the sky condition, time of the day or colour of the daylight. However, presence of outdoor natural light can be sensed. With limited scope of daylighting, the work floor is illuminated with white bright light from CFLs arranged in grid and mounted in the false ceiling. But there is no provision of task lighting.

For the Firm A office building, the approximate area of a typical floor is 2160 sq. m. It has a symmetric rectangular plan with fenestration fitted only on the NW and SE facades. The other two sides have solid decorative wall, except openings for toilets and other services at the back. For the 840 sq. m office floor of Firm B, the main work area had the longitudinal axis in SSE–NNE direction and windows faced north or south. The cabins were on the eastern wall, whereas the western wall had services, store, UPS room, air handling unit, etc. adjacent to it.

Figure 4. Facade of office building of Firm A (glass curtain wall) and Firm B (window).

Results of subjective study

Apart from answering the yes/no questions, respondents expressed their interest in the current research through their comments. In brief:

- Extended office hours (in reality about 11.5 h/day against official 9 h) reduces about 1.8 h from recommended 8 h of sleep on weekdays. People compensate this often by sleeping extra in the mornings during weekends.
- The office lighting is enough for work, but there is no variation. It creates a factory-like environment without any human touch. Especially in the cafeteria, this light prevents any kind of mental relief. Yellowish or coloured light is rarely found only in the reception area.
- High blood pressure (72.5%) and high blood sugar (66.3%) are common. Headache (80.7%) and eye-strain (87.4%) occur almost daily forcing about 53.9% staff to take over-the-counter medicines.
- After reaching home very tired and late, people are unable to fall asleep even in a dark room. Lack of sleep (34.4%), sleep disorders (70.6%) and consumption of sleeping pills (26.6%) make it hard to rise early next morning. People need to rush to the office even if they are still sleepy. So need of regular morning walk or exercise is strongly felt by 68.4% of the respondents, but not practised.
- About 82.8% of staff, including youngsters (20–30 years old) suffer from various common diseases such as cold, cough, fever, stomach upset, dust allergy, asthma, etc. indicating lower immunity.
- Undesirable weight gain, especially in the abdominal region is also common (63%). Almost all overweight respondents appreciated the need of regular exercise, but also mentioned the issues of fatigue and hectic schedule.
- The diseases discussed here are present in the family members of 44.3% of the respondents, but their symptoms started at a much later age.

In a nutshell, the respondents expressed their lifestyle as if ‘in a loop’ or a vicious circle. In spite of good healthcare and stress management initiatives by the company, they always felt tired and could seldom avoid medicines. To cope with fatigue and mental stress, they opted for extra food or beverage, which made them overweight and feel further tired. Exercise is urgently required, but there is no time. Several people believe that in the IT sector, burn-out or ageing is faster and their friends or relatives in the similar age group, but from different professions, have better physical and mental health.

Results of objective study

Illuminance level in terms of lux was measured at workstations. As the floor plan is symmetrical in Firm A, data collection was allowed only in one wing with the help of an escort. Figures 5 and 6 present the illumination levels at different times of the day for Firms A and B respectively. Table 1 provides the location of these data points with respect to the windows.

It can be observed that data points near a window show greater variance in illumination level with time due to higher influence of indirect daylight compared to internal points. In fact, for the first building at 3–3.30 pm; illuminmation level on the eastern side was lower than the same at 11–11.30 am, while this trend was reversed in the west facade due to the presence of the sun in western sky.

Readings taken in the late evening (7.00–7.30 pm) had no input from daylight. Though all values from all data points fell within a narrow range, still uniform illumination values were not seen in the working plane as there is no diffused lighting but direct downward lighting by CFLs. Hence data points near or just below (point a11 in Firm A and point b10 in Firm B) the CFL cluster, show an increase. For offices with computer-related work, the minimum illuminance value is 300 lux, while the recommended value is 500 lux, which can go up to 750 lux[48]. For both buildings, lighting level was within acceptable range with slightly higher values for Firm A.

It is to be noted that the aim of this study was primarily to detect presence of sufficient daylight in the workplace, rather than finding the adequacy of total illuminance. It can be observed from Table 1 that the variation of lighting level during bright and dark outdoor conditions is less than 20% in all cases. That means daylight penetration even near the windows is marginal or in other words, daylight is not properly utilized despite the management being keen to reduce the energy bill. At the same time, long-term occupants are deprived of view and natural light for the sake of data security.

From the detailed literature review and preliminary findings of this pilot study, it can be inferred that IT professionals have several health issues with possible origin of disrupted biological clock not only due to work hours, but also due to lack of daylight exposure. This problem

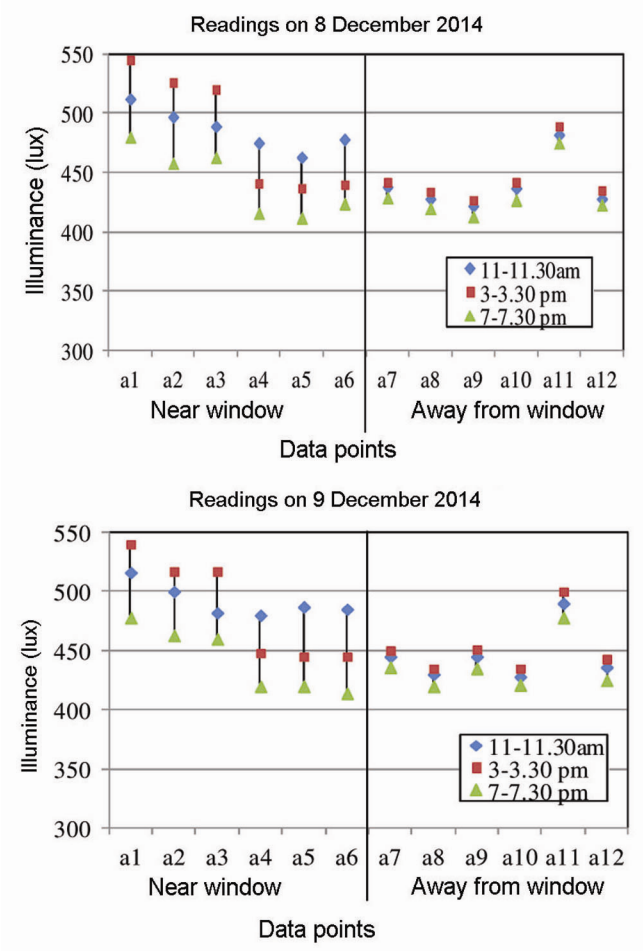

Figure 5. Readings of illuminance level in a typical floor of Firm A.

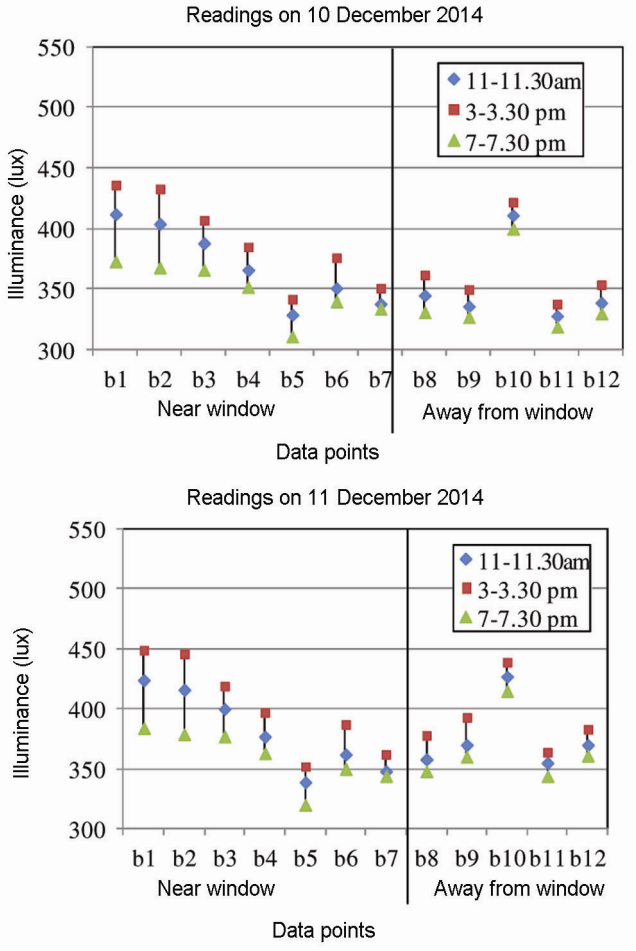

Figure 6. Readings of illuminance level in a typical floor of Firm B.

Table 1. Datapoint locations and corresponding variation in illuminance

Firm A					Firm B				
Location	Direction	Data points	Max : min (day 1)	Max : min (day 2)	Location	Direction	Data points	Max : min (day 1)	Max : min (day 2)
Near window	NW	a1	1.14	1.13	Near window	SSW	b1	1.17	1.17
	NW	a2	1.15	1.12		SSW	b2	1.18	1.18
	NW	a3	1.12	1.12		SSW	b3	1.11	1.12
	SE	a4	1.06	1.07		SSE	b4	1.09	1.09
	SE	a5	1.06	1.06		NNE	b5	1.10	1.10
	SE	a6	1.04	1.07		NNE	b6	1.11	1.11
						NNE	b7	1.05	1.06
Away from window	–	a7	1.03	1.03					
	–	a8	1.03	1.04	Away from window	–	b8	1.09	1.09
	–	a9	1.03	1.04		–	b9	1.07	1.09
	–	a10	1.04	1.03		–	b10*	1.06	1.06
	–	a11*	1.03	1.05		–	b11	1.06	1.06
	–	a12	1.03	1.04		–	b12	1.07	1.06

*Datapoint just below CFL lighting fixture.

can be solved to a certain extent by special lighting responsive to the circadian rhythm. To complement this effort, customized facade design or space planning can be attempted to overcome the limitation of restricted transparency of fenestration and enhance daylight indoors. However, it is not scientifically justified to tag every issue reported by the respondents to a disrupted biological clock. For example, apart from sleep debt, obesity can be due to food habits, sedentary lifestyle, medication, genetic background, etc.[49]. Keeping all other parameters fixed, whether more daylight in the work area can alleviate the common health issues can offer a probing insight.

Conclusion

This pilot study explores the possibility of healthy lighting to promote the well-being of people in the IT industry through architectural design. Knowledge elicited from the literature review, visual observation, questionnaire survey and objective data collected from two case-study buildings together indicate that IT professional have some common ailments even at an younger age, which may be linked to disrupted circadian clock or in turn their inadequate exposure to natural variation of daylight. The IT offices having limited daylight entry need special type of space planning or facade design to allow more daylight without compromising on privacy. A more precise and scientifically acceptable conclusion can be drawn by increasing the sample size, studying other aspects of visual performance and observing the effect of installed healthy light, personalized light or proposed fenestration on the occupants over a longer period of time. This study is the basis of a main research to complement the recent developments in illumination engineering to promote a productive work environment.

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