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Design to Thrive

Natural versus artificial lighting use in an office building under clear sunny skies

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Abstract: Under clear sunny skies, a building requires more knowledge in terms of architectural daylighting design because of the complexity of the phenomenon and the wide variety of its parameters and impacts. This study focuses on office employees' behaviour in relation to natural and/or artificial lighting and investigates the relationships between: i) the natural/artificial lighting use, ii) the perceptual views induced/generated by the related internal luminous environment, iii) the impact of the external natural luminous environment on the recourse to natural and/or artificial lighting, iv) the office conformation, v) the internal movable shading devices use, and vi) the users' characteristics. This POE investigates an office building located in the city of Biskra in Algeria, where a clear and sunny sky combined with a hot arid climate prevails. The study results revealed that: i) the office employees perceive daylight somehow differently from their attitude towards it, ii) the window location and some of the users' characteristics dictate artificial lighting usage, iii) no direct relationships were found between the use of the movable shading devices and the recourse to the artificial lighting, whilst vi) the impact of the external natural luminous environment on the use of the movable shading devices was confirmed.

Keywords: Daylighting, artificial lighting, office building, POE, clear sunny sky

Introduction

The environmental lighting issues in buildings could be summarized as: i) a matter of well-being, and ii) an economic question. Due to the psychological effects consequent to a biological deprivation from natural light that have been revealed by different research works, some old therapeutic practices gained a new interest and more daylighting design guidelines are recommended (Fontoynont et al, 2011; Boubekri, 2008). In contrast, and particularly in hot arid regions where clear sunny skies prevail, sunlight overexposure could be harmful for the human body and the buildings furniture as well as causing overheating problems (Alshaibani, 2015; Baker and Steemers, 2002).

From an environmental and energy point of view, the natural light is an eternal and potentially economical source (Giovannini et al, 2015). Also, the substitution of artificial with natural light allows a reduction of the cooling requirements (Ghisi and Tinker, 2005; Krarti et al, 2005). In fact, for a similar luminous flux, natural light will produce two to three times less heat load than artificial light (Danny et al, 2009; Doulos et al, 2008).

Methodology

A post-occupancy evaluation is undertaken in order to investigate the relationships between the internal luminous environment (natural and artificial), the external luminous environment, the architectural space (conformation and usage) and the users. Various data collection research methods are used: i) questionnaire, ii) observation maps, iii) architectural survey, and iv) photometric measurements.

Theses methodological tools draw from an operationalization of the concept 'Ambience' (Belakehal, 2013) and the related literature review on daylighting and Post Occupancy Evaluations (POE) (Zimring, 2002; Fontoynont, 1999; Hygge and Löfberg, 1999; Ander, 1995). The questionnaire included seventy three questions, evaluating the occupants' responses on a five point scale. A non-parametric statistical analysis of the collected data was carried out. Univariate, bivariate and multivariate statistical analysis was used as relevant to the nature of the variables.

This paper presents the relationships between: i) the use of natural/artificial lighting, ii) the perceptual views induced/generated by the related internal luminous environment, iii) the impact of the external natural luminous environment on the recourse to natural and/or artificial lighting, iv) the office conformation, v) the use of internal movable shading devices, and vi) the users' characteristics.

Case study

The selected case study office building is situated in the city of Biskra located in the northern-east part of the Algerian Sahara and where: i) the sunny sky is frequent for 80 to 85 % of the year (Figure 1) , and ii) the external horizontal illuminance values are about 8800 lux (Zemmouri, 1987)

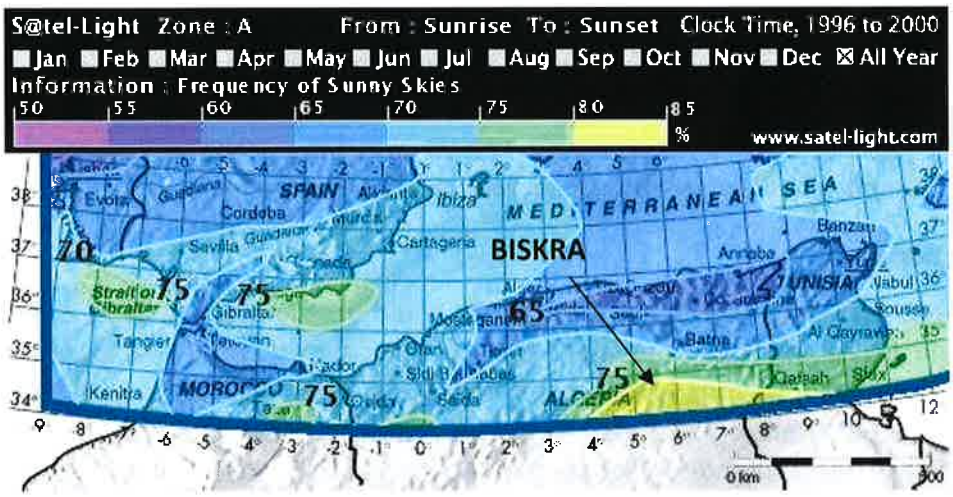

Figure 1. The frequency of sunny skies for the city of Biskra, Algeria. (Source : www.satel-light.com)

The office building CNAS *(Caisse Nationale des Assurances Sociales)* is a detached building with the main façade located on a main street of the city and the other three in secondary narrower streets. They are oriented north-west, south-west, north-east and south-east (Figure 2). The five levels (G+4) of the building are organised around a narrow and deep courtyard (Figure 3). An important number of the offices are small in size (private

office type) but open work spaces exist on each floor but in a small number (Figures 4 and 5).

Figure 2. Views of the north-east (left) and the south-east (right) facades of the CNAS building.

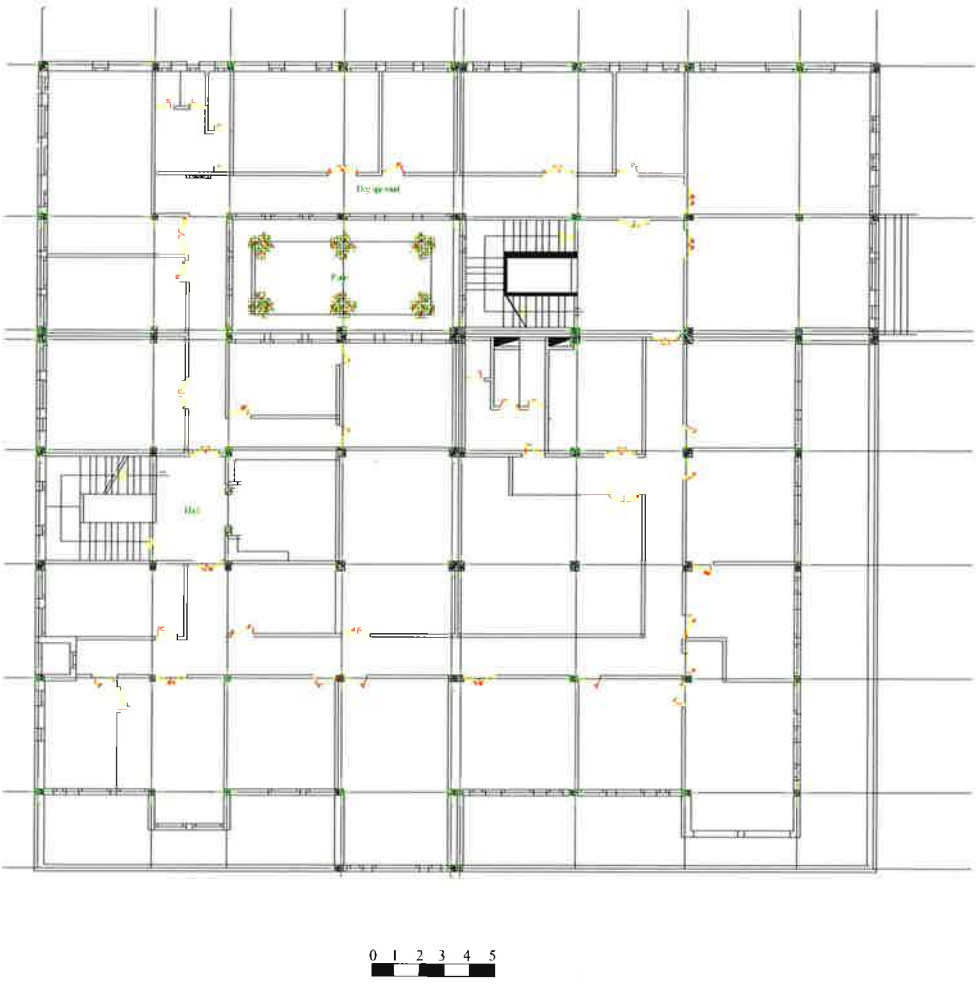

Figure 3. The selected offices in the third floor of the CNAS building.

The building includes different-size of windows with either external fixed shading devices and internal movable heavy dark colored curtains. The windows facing the inner

courtyard are of the same dimensions with curtains only. Twenty-five offices, representing 46 % of the total number of the CNAS building offices were selected for this research work. The number of the office employees taking part in this study is thirty-nine which represents 20 % of the total number of the CNAS office employees. The survey was held during the summer season where all offices were air-conditioned.

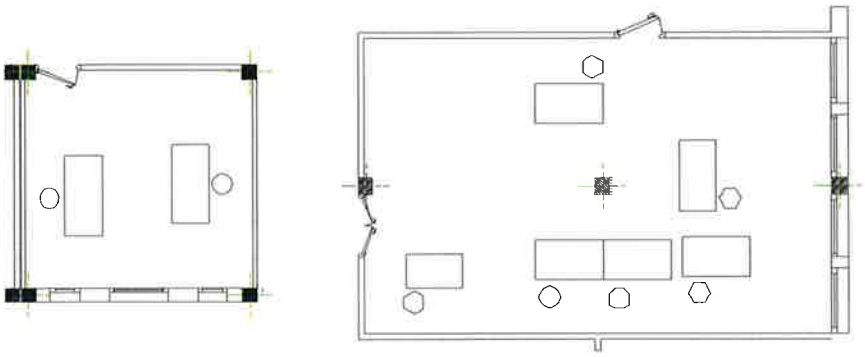

Figure 4. The small size office (on the left) and the Open office (on the right) in the CNAS building.

Figure 5. Internal views of the small size office (on the left) and the Open office (on the right) in the CNAS building.

Work duration and luminous environment

Generally, most of the office employees are working at their desks more than the half of their daily work duration: i) 46.2 % spend from 7 to 8 hours, ii) 41 % from 4 to 6 hours and iii) only 12.8 % are in for less than four hours. When the office luminous environment is too gloomy or glaring, a small number of employees confirmed being capable to work in such conditions whilst half of the office employees stated they never worked in such conditions.

Respectively 71.8 % and 59% of the office employees stated that the suitable condition for a continuous work in the office is an 'appropriate' that means a visually very comfortable luminous environment and 'clear' so a visually comfortable one. The opposite case of 'gloomy', that is to say a visually comfortable luminous environment, is not an

unanimously accepted condition. However, the third of the office employees declared operating under such condition throughout the work day (7 to 8 hours).

Natural versus artificial luminous environment?

The questionnaire data reveals that the office employees actually work often (61.5 %) and occasionally (17.9%) in a natural luminous environment. However, it must be noted that fifth of them never entirely worked in such conditions. These luminous working conditions remain unchanged throughout 2/3 of the year for employees involved in this study. One tenth of them worked in a natural luminous environment except in wintertime where they recourse to artificial lighting.

Additionally, the data collected during the field work, by means of observation, allows some results in relation to the luminous environment. For instance, during the summer morning work time, it was found that 48.7 % of the employees work in a natural luminous environment whilst 51.3 % perform in a mixed one.

Perceptual patterns and luminous environment

The statistical analysis, such as Mann and Whitney test, did not confirm any relationship between the employees' use of artificial and/or natural lighting and their evaluation of the luminous environment or their eyes fatigue. However, the application of the Chi2 and Cramer's V tests confirm the relationship between the artificial lighting use and the preference in terms of luminous environment (Chi2 calculated= 10.40 > Chi2 read= 5.99; V=0.51).

Remarkably, most of the employees who preferred to work in a natural luminous environment did not use the artificial light, whereas an important number of those preferring a combined luminous environment used artificial lighting.

Impact of the external luminous environment

The histogram extracted from a Kruskal-Wallis' Anova application reveals that the use of the artificial light is: i) particularly present in the offices receiving an external vertical illuminance, at the window vertical plane, under 20000 lux, and ii) to a lesser extent for those passing more than 50000 lux. Artificial light is not used in the offices where the external vertical illuminance levels are between 20000 and 30000 lux. Such relationship was more deeply examined through the dependency on the artificial light use with the solar orientation. This is due to the fact that all the lighting related monitoring field work was done during the morning period. This dependency was revealed as significant by the Chi2 test (Chi2 calculated= 21.09 > Chi2 read = 12.59) and by the Cramer's V test (V = 0.73). The extracted histogram shows that the offices where artificial light is used are mostly the ones exposed to sunlight rays during the morning.

Office conformation

The weakness of the relationship between the recourse to the artificial lighting and the employees' location in/out of the luminous effectiveness zone is attested by the Chi2 test (Chi2 calculated = 0.014 < Chi2 read = 3.84). However, an average dependency between the artificial light use and the window position in relation to the office layout is revealed by the Chi2 test (Chi2 calculated = 4.357 > Chi2 read = 3.84) and the Phi test (Phi = 0.334). The

corresponding graph shows that the employees working in offices with a centred window use the artificial light more than those working with an off-centre window (Figure 6).

Movable shading devices

The recourse to the artificial lighting by the office employees due to the use of the movable internal shading devices (curtains) has not been confirmed by the Chi2 test and the coefficient Phi. Among the employees using or not the movable shading devices, there is a similarity between those having recourse or not to the artificial lighting.

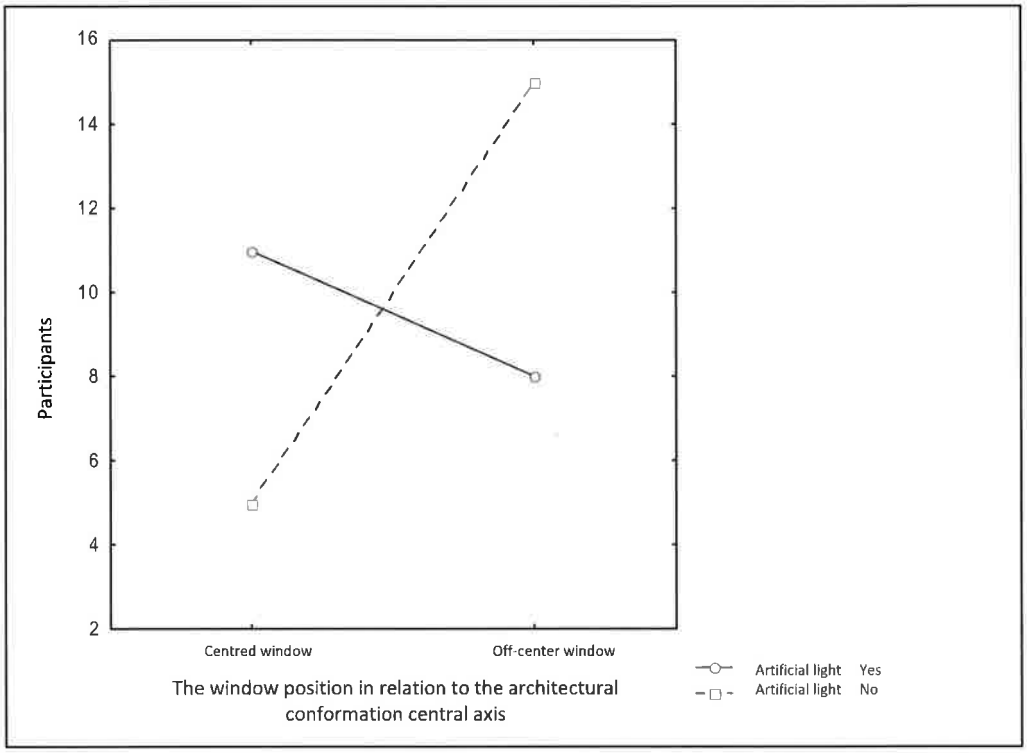

Figure 6. The relationship between the recourse to artificial lighting and the window position.

However, a dependence between the evaluation of the office general environment and the use of the movable shading devices was confirmed by the Kruskal-Wallis test (Chi2 Calculated = 8.87 > Chi2 Read= 5.59). This result revealed an important use of the shading devices by the users judging their luminous environment as appropriate as well as by few employees considering it as too clear. In addition, no one of the users considering their luminous environment as gloomy is using the movable shading devices.

User profile and the recourse to the artificial lighting

The users' education is revealed as the only characteristic among the users' profile ones in relation to the recourse of the artificial lighting as attested by the application of a Mann and Whitney test. A multiple correspondence analysis gives more explication to this relationship. The office employees with a higher level of education did not use the artificial lighting. This latter is specially used by the users having been only in primary and middle schools. The users who were in high school are divided into two nearly equal categories in respect to the use or not of the artificial lighting, with a little tendency towards the second category.

Discussion

The working time duration spent by the office employees seem to be influenced by the luminous conditions. This impact is revealed as globally homogeneous for all users' behavioural intentions. They confirm working as long as possible in a visually comfortable, that is not a gloomy luminous environment. This helps explain the difference between the results revealed by the questionnaire and those made known through observation. The first results indicate that the presence of the natural light characterizes almost exclusively their offices luminous environment and artificial lighting is used only during winter; whereas, the second results show a different behavior illustrated by a constant use of the artificial lighting. However, the good interaction between the office employees' behavior and their preferences reduce and clarify this gap. In general, it is possible to assert that the revelations of the behavioral intentions show that, at the perceptual level, the presence of the natural light is strongly important but at the behavioral one the situation is different because of the common presence of the artificial light.

Because the office configurations receiving more natural light are those where the artificial light is more used, these previous results require more clarification and particularly about the impact of the luminous environment on artificial light usage. The reasons of such phenomenon seems not to be dependent on the external luminous environment in quantitative terms but on a lighting related perceptual pattern. In fact, previous studies revealed that gloomy ambiences are not exclusively related to the lighting conditions but are in accordance with the thermal prevailing conditions. The employees try to create a tolerant internal ambience in contrast with the unbearable outdoor climatic environment (Baker, 2000). This could be validated for the case of the hot, dry and arid regions with clear and sunny skies where the obscurity is perceived as freshness, clemency and calm (Belakehal et al, 2004; Rouag-Saffidine, 1987).

Additionally, the impact of the conformation has been revealed only through the window position with respect to the conformation axis. The off-centered position of the window could be recommended for buildings under clear sunny skies because it allows the best distribution of natural light due to its natural reflection on side (Butera et al, 2014). This could explain the fact that artificial lighting is less used in offices with off-centered windows. Also, switching on all lights and the use of the curtains create a uniform luminous environment which seems to have no impact one the employees' desks location.

This study's indicates that the employees' level of formal education may express the consciousness of those with higher education about energy savings and other environmental concerns. Such result has not been found in specialized literature and calls for further validation research.

Conclusion

This study investigates a noticeable design problem dealing with the building, its context and users when focusing on the use of artificial lighting by an office building employees in a clear and sunny sky area. The investigation methodology included various research techniques in respect to the variety of the studied phenomenon and their relevance to different but complementary scientific disciplines.

The research results confirmed firstly, some general daylighting design aspects dealing specifically with work in a comfortable visual environment that implies the recourse to the artificial lighting (i.e. cloudy sky in winter time). Secondly, they revealed important space

and emotional aspects such as the influence of the window position in the wall and the perception of the gloomy environment as synonym of coolness. However, some findings on the users' profiles suggested the possibility of further corroborating analysis.

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