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ASSESSMENT OF OCCUPANTS' BEHAVIOUR ON THE INDOOR LUMINOUS AMBIANCES OF COLLECTIVE RESIDENTIAL BUILDINGS: A CASE STUDY FROM ANNABA, ALGERIA

Abstract: The rise of ecological approaches to designing and constructing homes, which prioritize energy efficiency and sanitation, has garnered significant attention. Ecological architecture is especially pertinent in its integration of natural light into the design process. Changing patterns of living and space utilization necessitate a reassessment of priorities and the adoption of new techniques in living space design. This study aims to evaluate the satisfaction of occupants in residential buildings in the Oued el-Fourcha neighborhood in Annaba through a post-occupancy assessment. The assessment explores the intersection of designing for daylighting and designing for how occupants interact with their indoor environment. Additionally, it investigates the impact of daylighting and human behavior on the lighting environment. The study examines the qualitative aspects of daylighting, considering the preferences, health, and behavior of building occupants. The research findings indicate that window size and occupant behavior can have a detrimental effect on the lighting environment of occupied spaces, which can subsequently impact occupant health.

Key words: daylighting, occupant satisfaction, human behavior, health, indoor space, Annaba

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Introduction

With current concerns about global warming, energy conservation from fossil fuels, and the negative effects of artificial lighting, it is critical to recognize daylight as a significant factor in discussions about climate change and the environment. Daylight provides advantages in terms of comfort, health, and energy savings (Atamewan, 2022; Garcia-Fernandez & Omar, 2023). It is one of the most significant renewable energy sources and is often wasted in buildings. The building industry should utilize natural sunlight to illuminate indoor spaces without causing overheating (Köster, 2013).

Indoor daylighting can reduce building energy costs by up to one-third while also enhancing occupant satisfaction (Shafavi et al., 2020). Studies have shown that occupant satisfaction with indoor spaces is a major factor in the preference for daylight as the primary source of indoor lighting, and that exposure to daylight can reduce the risk of vitamin D-related diseases (Holick, 2004), and is preferred by occupants as the primary source of indoor lighting. Daylight also affects people's preferences for window design (Dogrusoy & Tureyen, 2007), as well as their mood and visual perception (Lee et al., 2013). The absence of sunlight in space design is often considered dull, as daylight enhances design beauty (Marzouk & El-Sharkawy, 2022), and improves occupant satisfaction (Myriam B.C. Aries et al., 2010). The absence of sunlight in space design is often considered dull, as daylight enhances design beauty supported by research conducted in 2013. In addition, a well-lit space creates a comfortable indoor atmosphere and enables the creation of distinct ambiences suitable for different activities (Singh Rana & Malhotra, 2021; Atamewan, 2022; Mousavi et al., 2018; Ayoosu, 2016).

Given that humans spend 80-90% of their time indoors (Al horr et al., 2016; (Roulet, 2014; Marzieh Nazari et al., 2023), with the majority of that time spent at home (Brasche, & Bischof, 2005), it is crucial to prioritize space planning and design. These factors directly impact people's daily activities and overall well-being, as building functionality, lifecycle costs, and energy savings are just a few aspects of building performance. Additionally, the evaluation process should focus on users' perspectives of buildings, as it currently does (Mustafa, 2017). The level of satisfaction with daylighting should be the primary factor considered in lighting comfort research. Since satisfaction with daylighting is moderate, behavioral characteristics significantly impact lighting comfort. Therefore, users and occupants play an essential role in the evaluation process (Xue et al., 2014).

Multiple studies have shown that artificial lighting can significantly impact people's perception and emotions in indoor environments (Morales-Bravo & Navarrete-Hernandez, 2022; Young Yun et al., 2012). To ensure a balance between natural and artificial lighting, buildings and facilities are designed to allow sufficient natural light to enter through transparent parts of the building envelope, which can be supplemented with artificial lighting (Hassanain, 2008; Sanni-Anibire & Hassanain, 2016). To gain a global perspective, it is important to consider daylight, artificial lighting, and visual comfort simultaneously (Al horr et al., 2016). Therefore, studying the indoor environment is crucial.

Algeria has launched the "TAKA NADIFA" program, co-financed by Algeria and the European Union, to support the renewable energy sector, particularly in electricity, and improve energy efficiency in Algeria. The program is part of the strategic energy partnership between the European Union and Algeria, which began in 2015

(Kaddour, 2023). It proposes a series of actions to make buildings more efficient and ecological from a regulatory standpoint. This text discusses building thermal regulations, methods, and tools, as well as measures to promote energy efficiency improvements in existing buildings. It also mentions the reinforcement of inspection bodies and laboratories. Additionally, it highlights Algeria's potential for solar energy in the Mediterranean region (Morini & Calabrese, 2021).

Our investigations into several collective housing estates revealed deficiencies in the design of the dwellings, particularly regarding natural light. The configuration of the windows was neglected.

- To enhance visual performance and reduce direct solar irradiation, windows should be oriented based on climate conditions.
- When designing residential buildings, use the standardized minimum dimensions for windows.

Residents can compensate for smaller windows by using artificial or hybrid lighting. The residential sector in Algeria is highly energy intensive, accounting for 46% of final energy consumption and 28% of primary energy consumption (Benhalilou, 2008). Domestic lighting alone accounts for 32% of Algerian household electricity consumption (APRUE, 2021).

Therefore, it is crucial to conduct further studies in this field to determine the satisfaction of occupants with their lighting environment. Comfort, which is the well-being of the occupants, is the fundamental criterion that overrides any other measurable parameter (Roulet, 2014). Windows are the primary structural elements that allow occupants access to light and views indoors. Evaluating the well-being of inhabitants in relation to their environment and the use of windows has proven to be an interesting endeavor (Al horr et al., 2016).

This article assesses the lighting ambience of a collective residential building in the Oued El Fourcha neighborhood. Based on our literature review, we concluded that a post-occupancy assessment was the most appropriate tool for our study. Our study aims:

1) To determine if there are significant variations in lighting comfort preferences and practices among occupants of different ages and genders.

2) To gather data on objective elements, such as room and bay dimensions, as well as the near and distant obstructions of the physical environment.

3) To analyze the relationship between these elements and occupants' satisfaction with the lighting conditions.

4) To demonstrate how individual behaviors can influence residents' satisfaction with the lighting environment.

Methodology and Tools

Post-occupancy Evaluation (POE)

POE is a systematic evaluation of building occupants and structures to assess building performance (Preiser et al., 1988; Aliyu et al., 2016). Building performance evaluation involves recording and evaluating user satisfaction, space utilization, and resource utilization in a constructed facility. It is also important to identify critical issues related to build-

ing performance and occupant satisfaction. This definition is based on the work of (Lambros T. Doulos et al., 2020). It provides:

- The objective is to evaluate construction deficiencies (Vischer, 2001) and how they affect the occupants' activities, in order to determine their satisfaction and dissatisfaction levels (Labreche, 2014).
- This approach enables for the identification of the mutual interaction between buildings and occupants' expectations (Mustafa, 2017).
- Based on this evaluation, recommendations can be made for environmental adaptations that will help meet these expectations (Vischer, 2001; Mustafa, 2017).

A Post Occupancy Evaluation (POE) involves activities that aim to understand how buildings operate after construction. It assesses the technical, social, and managerial aspects of how buildings function for their users (Aliyu et al., 2016). The evaluation is based on three criteria: behavioral, technical, and functional.

Functional performance aspects refer to the attributes of a structure that are useful and effective. Behavioral performance refers to how an occupant's actions interact with their physical environment, while technical performance elements impact occupant comfort and well-being (Preiser et al., 1988; Lolli et al., 2022; Mustafa, 2017).

Teasdale-St-Hilaire explains that the POE technique has a flexible framework that can be adapted to different objectives (Teasdale-St-Hilaire, 2013). Preiser has proposed three levels of POE:

- The indicative POE highlights the primary strengths and weaknesses of a building's performance.
- The investigative POE, which provides a comprehensive overview of the reasons for and consequences of building performance problems.
- The diagnostic POE, which correlates subjective assessments of occupant reaction with measurements of the physical environment.

Course of Study

To evaluate and identify daylighting conditions, we conducted a Post Occupancy Evaluation (POE) at the diagnostic level in eight collective residential buildings located in the Oued El-Fourcha housing area of Annaba. The selected indicators are based on the concept of visual comfort. This study will enable us to analyze the lighting conditions of the living space in conjunction with the occupants.

Our approach aims to identify respondents' viewpoints and analyze the interaction between their behavior and indoor lighting environments, as well as the effect of natural light on their well-being, based on a specific protocol.

The studies were conducted in the field from August to September 2023. Questionnaires were distributed in person to 190 respondents, of which only 134 were returned, resulting in a response rate of 83.75%. The analysis was performed using SPHINX Lexica software and processed through a cross-tabulation using seven approaches (Figure 1).

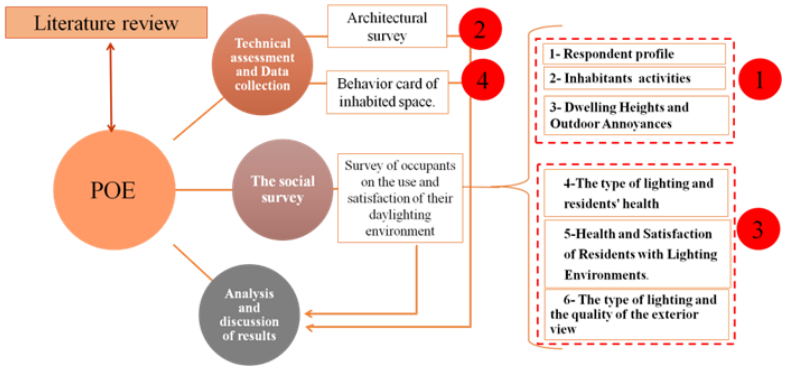

Fig. 1. Flowchart of the method with objectives number

Overview of the study area

The study was conducted in the Oued El-fourcha residential area, located west of Annaba, a city in northeastern Algeria. This area is bordered by (Figure 2): in the North by the "Edough" mountains; the "Belaid Belkace neighborhood" to the south and the west; and the "Pont blanc neighborhood" to the east. In 2002, the estimated density was nearly 25 logs per hectare, with a built-up area of 92.20 hectares. This indicates that 35% of the area is occupied by collective housing (Ilknur Turkseven Dogrusoy, Mehmet Tureyen, 2007).

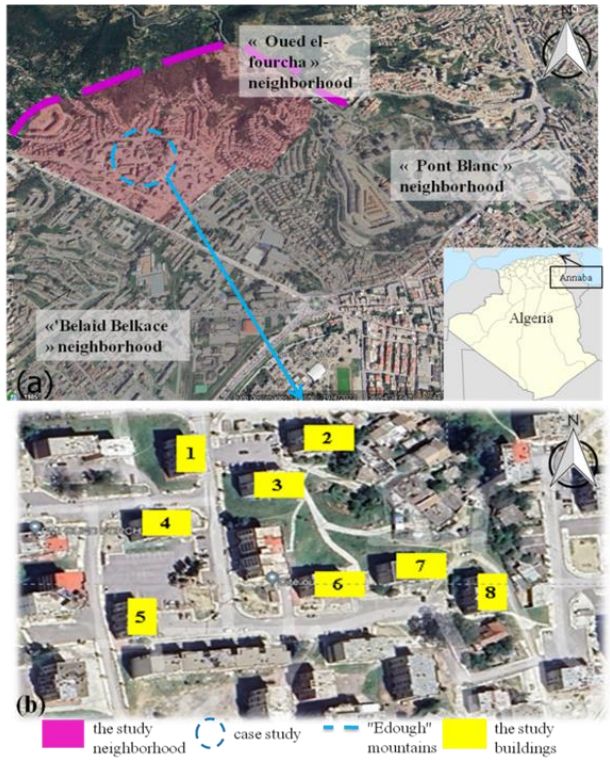

Fig. 2. Location Map (a) Case of Study Location (b) Aerial view of study buildings

The physical data of the housing environment

Annaba has a typical Mediterranean climate with seasonal variations. Summers are hot, while winters are cold, wet, and temperate. The main wind directions are from the north to northeast. Daylight hours in Annaba are long throughout the year, ranging from 9h:43:49 in December to 14h:27:02 in July (Table 3, Table 4).

Tab. 1. Annaba's minimum and maximum temperatures

maximum temperatures (August)	minimum temperatures (January)
31.4°c	6.9°C

Source: based on data from 1978-2007 provided by the "Les Salines" meteorological station

Tab. 2. Average daylight hours in Annaba

January	February	March	April	May	June
10:00:48	09:50:22	12:01:11	12:46:25	14:11:45	14:13:29
July	August	September	October	November	December
14:27:02	13:34:56	12:03:15	10:54:07	09:55:45	09:43:49

Source: dateandtime.info

Building characteristics

For this study, eight identical residential buildings were selected. Each building has four floors with four units per floor, and each unit has two facades (Figure 3). From the exterior, it is evident that many residents have made modifications to their dwellings.

Fig. 3. A sample of study buildings

The most of residents use curtains and screens on their windows to ensure privacy and comfort in their living spaces. Some ground floor residents have added plant masks, using small gardens and plants to create a barrier between their homes and the outside world. The surrounding buildings are mostly similar in type, consisting of other five-story buildings and single-story housing.

Occupant behavior

Indoor lighting is mainly affected by the behavior of occupants in their living space. Due to the limited interior space compared to the size of the family, occupants use various areas for impromptu activities. For example, the kitchen balcony is used to install appliances and expand the interior space for other activities, and a clothesline is added for drying laundry. Additionally, the living room is used for sleeping and the kitchen table is used for studying. As a result, the living spaces receive less natural light (see Figure 4).

The residents did not consider lighting when arranging furniture in the living rooms and bedrooms. As a result, the interiors appear cluttered, and some furniture is blocking natural light. Additionally, the slats on the kitchen balcony were closed by adding a window, which has made the kitchen space darker (see Figure 5).

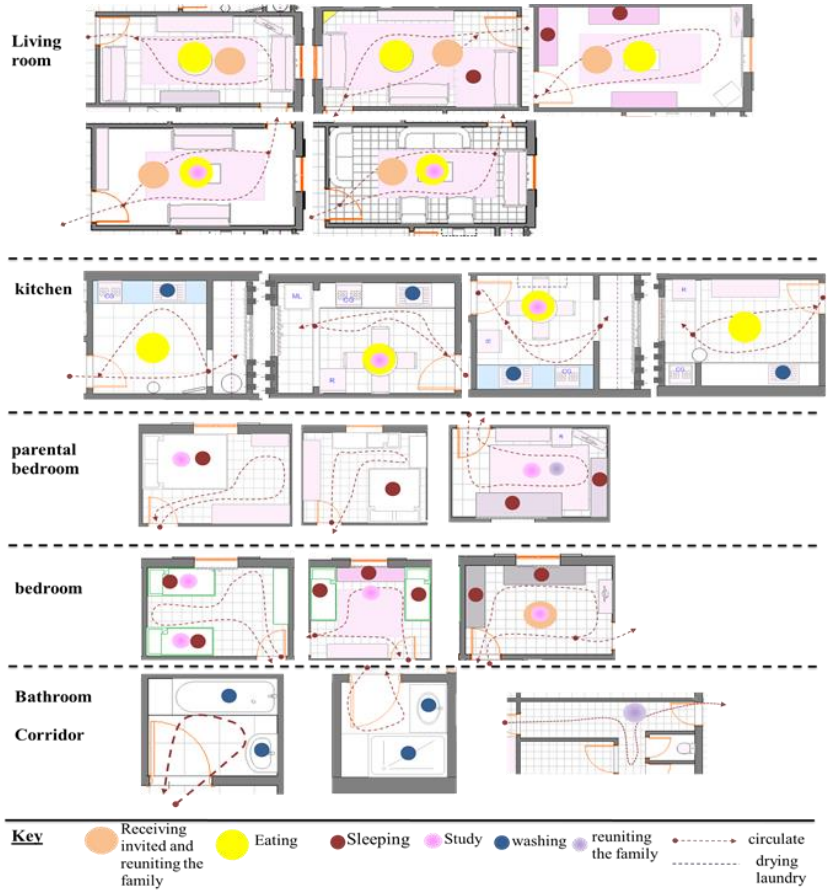

Fig. 4. Behavior card of inhabited space

Fig. 5. View of the indoor living spaces

Results and discussions

The results of this research are shown in factorial maps based on the ultimate variables of this research:

- Gender, age range of respondents.
- Daily activities
- Housing level
- External genes
- Type of lighting
- Occupant health.
- Occupant satisfaction.
- Type of lighting
- Quality of the outdoor view.

Respondent Profile

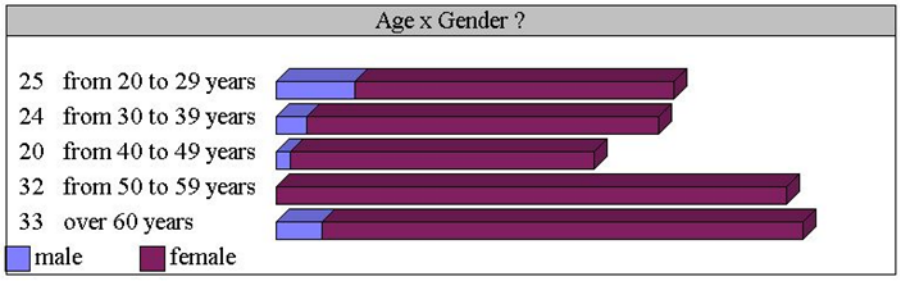

Fig. 6. The factors map of Variables:1- gender, 2- age ranges

To accurately describe the behavior of occupants, it is important to take into account the profile of the respondents, including their age and gender. The graphs show that female occupants, including housewives and elderly women, are more concentrated in the foyers. On the other hand, male residents consist of young people aged 20 to 29 and older retirees.

Inhabitants' activities

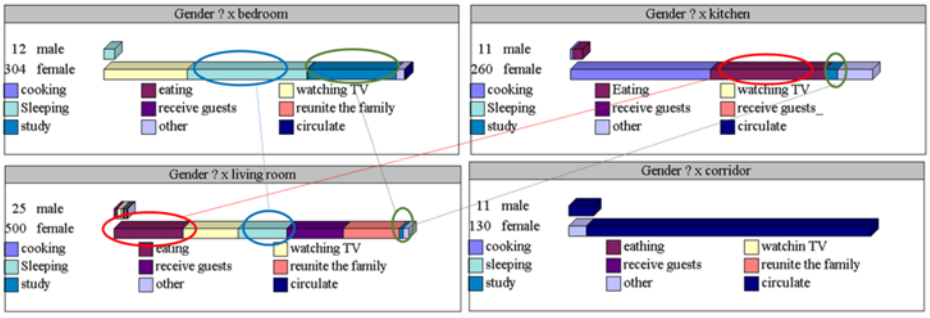

Fig. 7. The factors map of variables :1- gender, 2- daily activities

The graphs illustrate that living spaces are multifaceted, as certain rooms are used for activities beyond their intended purpose. For example, people sleep in the living room, and the bedroom, living room, and kitchen are used for studying. Additionally, people eat

in the living room, among other activities (Figure 07). Occupants indicate 'other function' for each room, indicating that these spaces can be used for various activities. This multiplicity of activities is primarily embodied by women, who spend most of their day indoors.

Dwelling Heights and Outdoor Annoyances

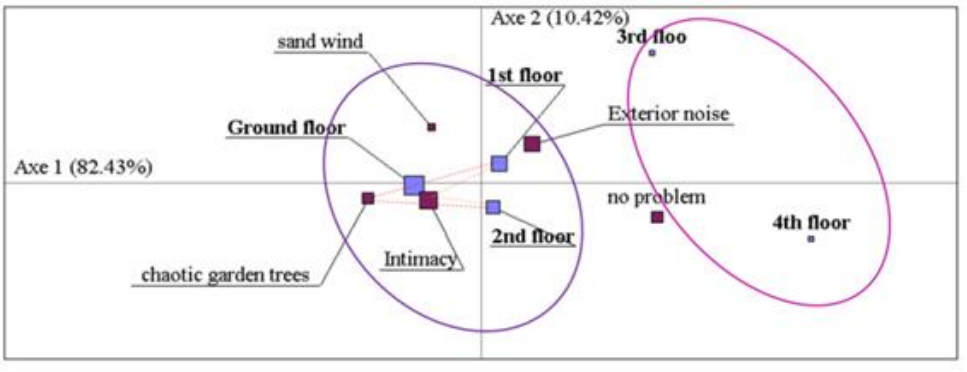

Fig. 8. The factors map of variables: 1- housing level, 2- external genes

The act of opening up to natural light is hindered by privacy concerns and overgrown trees in the garden. These factors cause discomfort for most occupants on this floor, as well as those on the floors above (1st and 2nd). External noise is the second most significant issue, particularly for residents on the first and second floors. This noise originates from various sources, including cars, children, and certain equipment. In addition, residents have reported sandy winds that make it difficult to open their windows. This issue is less noticeable on the ground floor, moderately noticeable on the first and second floors, and barely noticeable on the third floor.

The type of lighting and residents' health

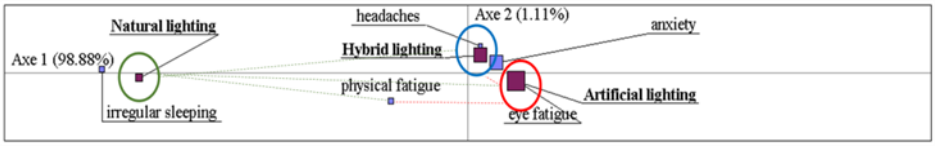

Fig. 9. The factors map of variables: 1-type of lighting, 2-health of occupants

Analysis of the graph reveals that most residents use artificial and hybrid lighting during the day, which can cause health issues such as fatigue and headaches. The study indicates a significant correlation between specific types of artificial lighting and eye strain, and a weaker correlation with feelings of anxiety. While there is a slight correlation between this lighting and headaches and fatigue, the correlation with the 'no problem' response is very weak. However, individuals who use hybrid lighting may experience more headaches and feelings of anxiety. Although hybrid lighting may have a lesser impact on eyestrain, it can affect other health issues. It is worth noting that occupants who do not report health problems are typically young and few in number. Furthermore, there seems to be little correlation between the use of daylighting and occupants reporting stress, physical fatigue, or visual fatigue indoors.

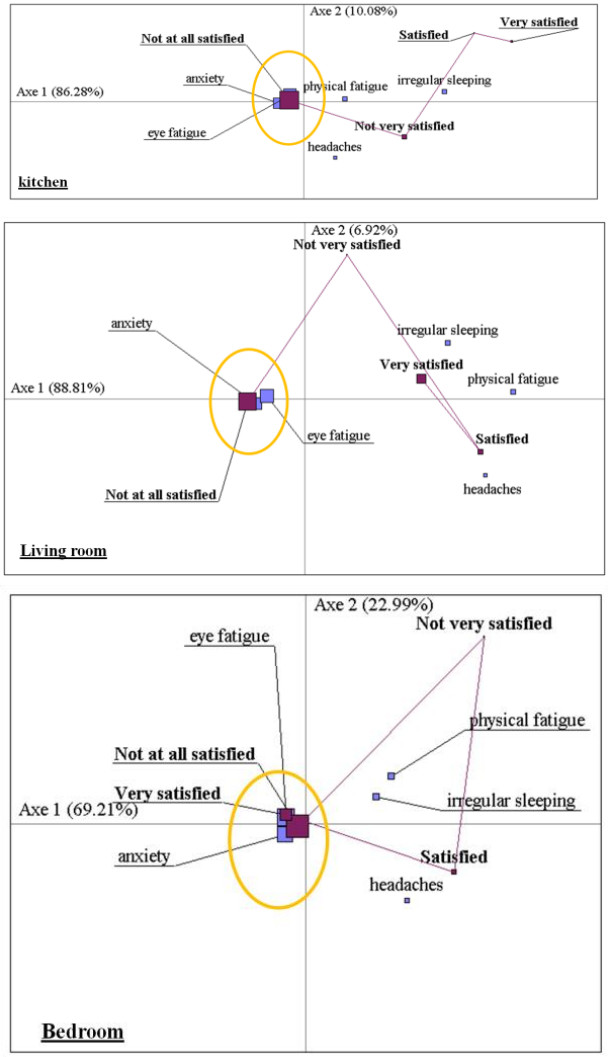

Fig. 10. The factors map of variables: 1- occupants health, 2- occupants' satisfaction with their lighting environment

The graphs demonstrate the impact of the lack of natural light in indoor areas on the mental and physical health of inhabitants. Dissatisfaction with daylighting in these areas moderately correlates with feelings of anxiety and eyestrain. The survey results indicate that occupants are generally dissatisfied with the lighting in their bedrooms and living rooms, while they are more satisfied with the lighting in their kitchens. Occupants who are dissatisfied with their bedroom lighting may experience anxiety, eyestrain, and sleep disturbances. Similarly, individuals who are dissatisfied with their kitchen lighting may experience headaches, fatigue, and weakness. While occupants generally express satisfaction with their living room and bedroom lighting, they still experience anxiety, eye strain,

and sleep disturbances. There are also some reports of headaches, fatigue, and weakness. The lighting ambience is rated as somewhat dissatisfying, as well as somewhat satisfying.

The type of lighting and the quality of the exterior view

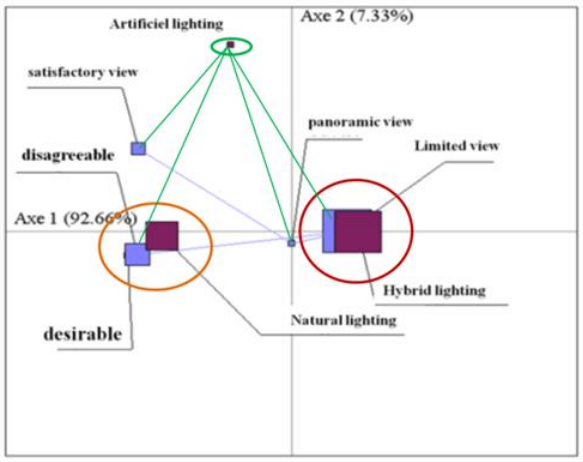

Fig. 11. The factors map of variables: 1-type of lighting, 2-quality of view to the outside

The text states that occupants of a building typically have limited views from their windows. However, those residing on upper floors often desire views, with the view quality being primarily related to the room's height. Upper floors provide unobstructed views, which can create a sense of freedom. Additionally, the text suggests a strong correlation between the 'hybrid lighting mode' and the 'limited view' modality, indicating that residents in areas with limited views rely on artificial lighting. There is a weak relationship between the 'natural lighting mode' and both the 'unpleasant view' and 'desirable view' modalities, as well as with 'satisfactory lighting'. The use of 'artificial lighting' also has a weak relationship with the other modes, indicating that occupants may rely on artificial lighting in their living spaces and may not benefit from other lighting sources to illuminate their living spaces, which may limit their exposure to other lighting sources.

Conclusion

A post-occupancy evaluation was conducted to assess the impact of daylighting and human behavior on the natural luminous ambience of residential buildings in the Oued el-Fourcha estate in Annaba. The analysis of the data revealed the following.

The surface area is considered limited in relation to family size. The dwellings are occupied by multiple households, with 17.9% being four-person, 30.6% being five-person, and 35.10% being occupied by more than five people. The presence of a mother in one of these spaces adds complexity to the interior.

The windows are smaller, and the view of the outside world is less significant. In an attempt to protect themselves from external annoyances, inhabitants often isolate themselves from the outside world. Unfortunately, this can negatively impact the luminous ambiance of inhabited spaces.

The satisfaction with daylighting is influenced by external factors such as privacy, security, external noise, and chaotic planting, as well as internal issues related to limited space and multifaceted room usage. However, the use of windows in the inhabited spaces on higher floors varies depending on the floor level. The height of the floor is a crucial factor in the window's potential to open away from sources of nuisance.

Additionally, the need for natural light in women's living spaces differs from that of men. Specifically, 90% of women who occupy their homes during the day are housewives or elderly women.

Prolonged use of artificial lighting during the day indicates insufficient natural lighting and reduced lighting comfort. This inadequacy directly affects the health of occupants, leading to various health problems. These include psychological issues such as anxiety, as well as physical symptoms such as eye fatigue and vitamin D deficiency, which can result in headaches and physical fatigue.

Conflicts of Interest: The authors declare no conflict of interest.

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