# Daylit Spaces and Comfortable Occupants:
## A variety of luminous ambiences in support of a diversity of individuals

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*ABSTRACT: This research demonstrates that daylighting constitutes a good alternative to create comfortable spaces since it produces a diversity of luminous ambiences and address some basic human needs. It uses research methods such as: behaviour mapping, written surveys, photography and digital image analysis. These methods allow the study of the luminous conditions of a real space, the café of the School of Architecture at Laval University, and the level of comfort perceived by its occupants. The results presented in this article underline the wide variety of luminous ambiences in which occupants doing the same type of activity, including visually demanding activities, were observed. They also prove that the daylit areas were the busier in spite of the variable lighting conditions and individuals who came to the café for different reasons.*
*Keywords: Daylight, Daylighting, Luminous Ambiences, Visual Comfort, Occupant's Behaviour.*

**INTRODUCTION**

The concepts of sustainable architecture are today well established in the academic and scientific worlds. However, when it comes to the day-to-day practice, architects rarely consider the occupants' comfort and behaviour as elements in the design of a building. In the particular case of luminous ambiences of an interior space, electrical lighting systems are often preferred for their reliability and affordability [1] for their certain easiness of control and their potential to offer a constant and uniform luminous environment compared with daylight. Indeed, daylight constantly changes in colour and intensity from dawn to sunset as well as from day to day [2]. The variability and non-uniformity of the lighting conditions created have often been perceived negatively [3] since it does not comply with the most common definition of visual comfort.

Visual comfort is mostly limited to the strict satisfaction of the visual system and the absence of glare [4]. However the experience of sight separated from the other senses is purely theoretical, since comfort results in the interaction between all senses. Most people will indeed react negatively to a bad smell or a loud noise, even when standing in a space beautifully lit. In fact, several architectural and human factors [5] influence the perception of comfort in a daylit space. Some are dependent of the architects' design; for example the possibility for the occupants to access a view to the outside, the diversity of the luminous conditions offered, the degree of perceived control and the liberty of movement presented to them to avoid or limit the negative impact of an environmental stressor. Daylighting responds to our biological needs for visual information [6]. Yet, there are certain other factors such as the users' mood, preferences and aesthetic judgements [7] that influence comfort as well, but these are not direct consequences of a building design. Nonetheless as professionals, choosing daylighting for an interior space represents a sustainable decision because the diverse luminous ambiences produced naturally address the different expectations of the many individuals looking for a comfortable place in one singular space.

This paper presents the theoretical concepts, methods and results of a research developed to enquire the hypothesis that daylighting is a comfortable source of light since the diverse luminous conditions created address a wider range of criteria of comfort to be found among different occupants standing in the same room.

**RESEARCH OBJECTIVES**

Investigations were undertaken at the café of the School of Architecture at Laval University (fig. 1). It was mainly chosen because it fulfilled two requirements: the café is daylit and offers to its occupants the opportunity to exercise a certain amount of choice and control over their environment. These opportunities mainly correspond to the lighting conditions (natural and artificial), the furniture type (chair, stool or armed chair) and the view (through a window outside or towards the indoor café's

activity). The occupants constitute an homogeneous student population that regularly uses the café for several weeks during the full term typical days of October and November. Moreover, the chosen subjects were very willing *to be observed* and respond to a questionnaire. Lunch periods were excluded as all the seats were occupied during that busy time, leaving not much interpretation for user's preferences on location. Once the corpus of study was defined, data collection aimed to provide answers to the two following questions:

- Are the daylit areas the busiest?
- Do occupants performing the same type of activity choose similar lighting ambiences?

These two questions deal with the available lighting conditions for occupants sitting in the café. Daylighting is influenced by the annual sunpath, the sky conditions, several exterior elements such as the neighbouring basilica that keeps the café in the shadow during certain hours in the afternoon, and architectural features characterizing the café. As an example of such features, the café provides identified brighter zones of daylighting coming from the apertures of the inclined window wall surface. Three out of the four windows (fig. 2) face the South-East direction, the latter faces North-West. On the other hand, the areas located away from the apertures remain darker but can be artificially lit. Some spotlights are directed at the inclined roof and others at the floor, offering direct and indirect lighting conditions. The control panel is located near the entrance of the café and is accessible to all its users.

*Figure 1: Photography of the student café of the School of Architecture at Laval University.*

## METHODOLOGY

Due to the fact that the research had to consider certain human, architectural and physical parameters, several tools and methods were incorporated into the experimental protocol. Behaviour mapping [8] was integrated because its graphical format allows to gather information about the occupants' location and activities during specific periods of time [9] while observing in parallel the architecture and the ongoing lighting conditions. Five activity type were identified: reading and writing, team work, discussion, meal and rest. Observations were recorded at regular intervals of 15 minutes due to the intense activity of the café. Typical stays lasted from a five minute visit to get a coffee and socialise to longer periods lasting more than an hour. The latter were especially relevant to the research as position of the observers becomes a key factor in the evaluation of user's satisfaction and comfort.

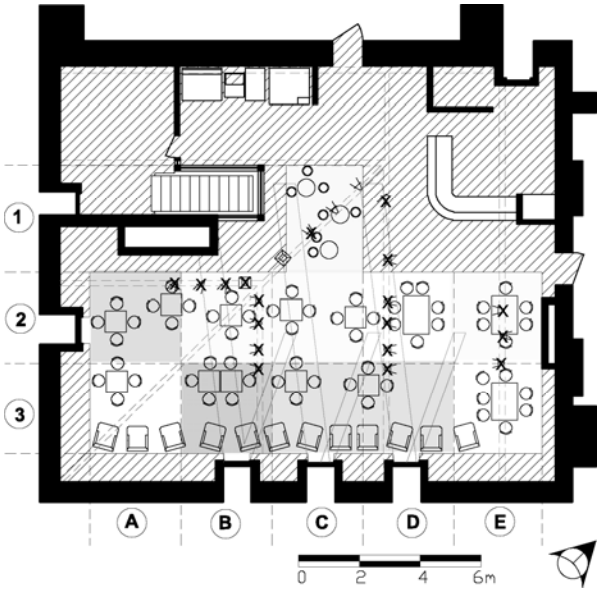



*Figure 2: Example of a behaviour mapping plan completed during the investigations.*

The plans were drawn while making the observations and aimed to locate the occupants, identifying their activity, their field of view and the furniture that they used by means of a designated graphic code. For instance, figure 2 illustrates that the areas (dark squares) located next to the windows (A2, B3, C3, D3) were occupied at the time when the observations were made.

A concise written questionnaire was distributed to all occupants to minimize the risk of faulty interpretations of the observed preferences and actions. The six questions were mainly meant to ensure that the respondents had freely chosen their location and that the observations gathered through behaviour mapping regarding their activity type were accurate. Questions also aimed at precisely identifying the occupant's motivations for choosing a particular seat and to determine whether daylighting was the most important factor affecting their decision or if other environmental factors such as the

preference for a view to the outside, the type of furniture that was available, the proximity to other occupants as well as the diversity of the offered thermal conditions, had been more influent.

Photography was also used as a complement to the "on-site" observations of behaviour mapping. The various lighting ambiences found over the entire studied environment were captured into a mirror ball every fifteen minutes (fig. 3). Several pictures of occupants (fig. 4) were also taken to provide a visual record of the observations and to constitute additional data required by the qualitative [3] and quantitative image analysis [10].

*Figure 3: Global lighting ambiences (November 1st 12:45).*

The qualitative analysis combines many of the information gathered during the investigations to study each photograph of the occupants. It is inspired of the work undertaken by Flynn [3] who highlighted the three following luminous qualities:

- The character of the source (natural or artificial)
- The quality of the source (direct or diffuse)
- The localization of the occupant in relation to the source (clear or dark lit area).

The additional photographs taken with a mirror ball (fig. 3) ensure that the lighting ambiences shown on the occupants' photographs are realistic in relation to the overall lighting ambience since some images appeared darker due to back lighting. It also provides information relating to the diverse sky conditions. Figure 4 corresponds to the activity type "reading and writing". The character of the source is natural, its quality is diffuse and the two encircled occupants are located within the brighter and daylit areas of the café. These lighting conditions are also illustrated in figure 3 in which the location of the occupants is highlighted.

*Figure 4: Occupants reading and writing next to a window (November 1st, 12:45).*

*Figure 5: An occupant is reading and writing within the space that is located away from the windows (October 21st, 14:45).*

The quantitative image analysis [10] requires that the digital photographs be simplified into five levels of gray values (fig.4-5) to obtain their histograms. An histogram presents two data related to the amount and the dispersion of the grey pixels found in each image. The standard deviation provides an indicator for *global contrast* [11]. The percentage of brightness, obtained through the division of the mean data by the total amount of pixels, defines the indicator of lightness as opposed to darkness. Photographs belonging to the same activity type are presented on a comprehensive graph (fig. 6) to identify the diverse lighting ambiences according to brightness and contrast. The parabolic curve of figure 6 identifies the boundary of the area where photographies will theoretically occur in the graph. Figure 6 stands for the quantitative analysis of the activity type "reading and writing". Most of the pictures are dark since the brightness values ranges from 10 % to 25%. They also show a medium level of *global* contrast with values ranging from 50 to 75. These data correspond to a dark

space with moderate to low contrast values, a result generated by the four small apertures of the café, the only sources of daylighting in the space. Conversely, some pictures distinguish themselves from the average values (refer to figure 7 located at the bottom left of figure 6). A closer look at this photograph reveals that the occupant has chosen an electrical source of low lighting level, away from the windows, which could explain the dark and poorly contrasted luminous conditions. This occupant (in fig.7) may not be representative of the majority of readers and writers, but the fact that he actually chose that particular ambience over other available seating options, justifies the need to provide a variety of ambiences within a space.

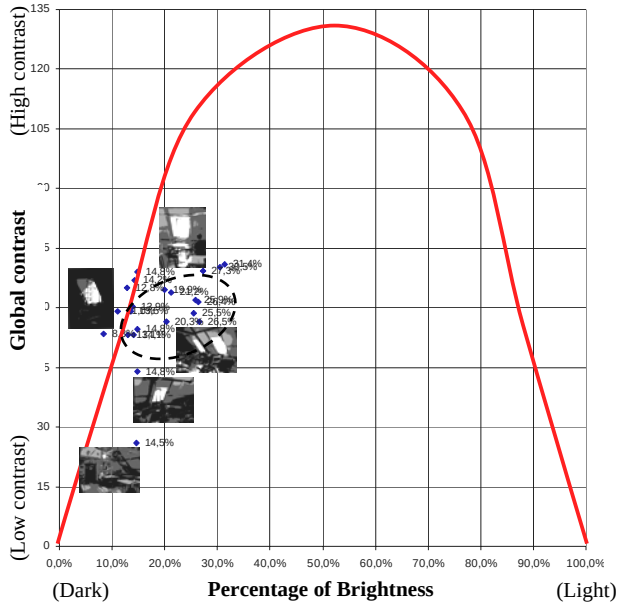



*Figure 6: Quantitative image analysis for the activity type "reading and writing".*

*Figure 7: Occupant reading and writing using the electrical lighting system (November 3rd, 14:45).*

## RESULTS

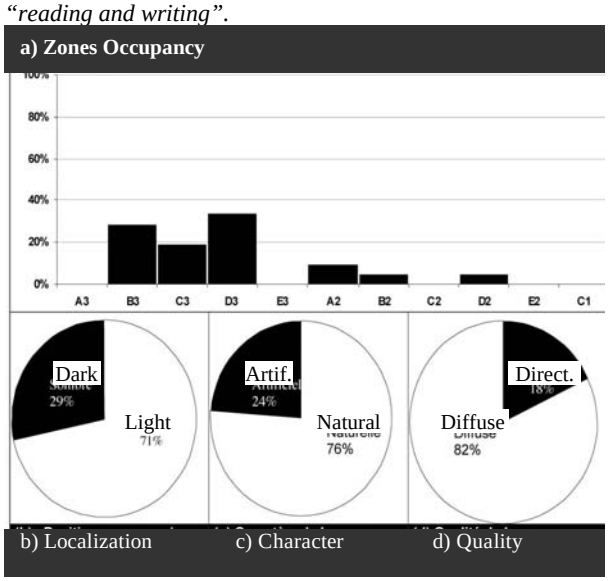
The results presented in this section correspond to the questions addressed earlier in the research objectives. The analysis of the occupancy of the café, based on the behaviour mapping [8] plans, drawn every 15 minutes during 2 weeks, revealed that the zones located near the windows were noticeably preferred for most activities in spite of the risks for highly variable daylighting conditions. In fact, 61% of occupants chose those areas representing only 36% of the entire potentially usable surface of the café. Meanwhile, the answers to the written survey confirmed that light (20%) had been the most influent factor for the selection of a location. Yet, certain architectural and human factors [10] seemed to matter as well; namely the potential to view outside (14%), the diverse thermal ambiences (16%), the type of furniture available (14%) and the distance with the other users of the café (15%). These results also confirm that architects should not strictly think in terms of visual comfort when it comes to daylighting given that there are so many other factors involved in the feeling of comfort.

The qualitative analysis has demonstrated that occupants performing the same type of activity, but at different times of the investigation, were exposed to highly diverse luminous ambiences. Occupants also seemed to be comfortable in locations that were not corresponding to the IES recommended values [12]. In particular, activities that required higher visual acuity such as reading and writing were often performed in rather dark conditions. Indeed, the average illumination levels measured in the café during the investigations were mostly fluctuating between 60 lux and 400 lux, which means that the minimum of 500 lux, required by the IES, was rarely encountered. The fact that occupants came freely to the café, knowing that other places in the school were designed to provide higher illumination levels and a more uniform lighting, is significant. Occupants seem to have been more sensitive to the qualities of light [3] than to its measurable quantities.

Table 1 exposes the three graphs (b, c, d) that summarize the qualitative analysis made on photographs belonging to the activity type "reading and writing". The upper part of table 1 (graphic a) provides the distribution of the occupants in relation to the various locations in the café. The "readers and writers" are concentrated around three of the four apertures (B3, C3, D3, as shown on fig.2), suggesting a preference for daylight and confirmed by the three graphs located in the lower part of table 1. The "readers" and "writers" were mostly positioned within a bright (71% of cases) and daylit (76%) environment, characterized by a diffuse source of light (82%). These luminous ambiances are illustrated in figure 1, 4 and 5. Yet, as illustrated in figure 7, some occupants chose different scenarios, preferring to sit in a bright area under an electrical and direct source of light.

The results of the quantitative image analysis (figure 6) discussed earlier, confirm that some lighting ambiences, in terms of brightness and global contrast, were more frequently encountered than others. However discrepancies did exist and they were most likely caused by physical and human factors as identified previously through the analysis of the written survey.

*Table 1: Results of the qualitative analysis for the activity type "reading and writing".*




## CONCLUSION

This paper presented parts of the analysis developed for a research striving to demonstrate that daylighting is indeed a comfortable source of light for interior spaces even if it does not often comply with the actual definition of visual comfort. The research however presents an expanded view of visual comfort in which human, biological and architectural variables were also determinants in the occupant's preferences. Recognizing the inherent subjectivity of individual perceptions, it appeared that a diversity of luminous ambiences would most likely correspond to comfortable locations and please a greater number of people. Daylighting creates these different lighting conditions due to its great variability in addition to respond to human biological needs.

The results exposed in this paper illustrated that the daylit areas of the café were invariably the most occupied, although adjustable electrical lighting was always available. They also highlighted that the various luminous ambiences offered a comfortable environment since individuals performing the same type of activity did not choose systematically identical lighting patterns and positions but rather explored different alternatives that suited their mood or habits. Those results are however representative of a particular space, and future investigations studying a broader range of interior spaces will most certainly assess the importance of the diversity of daylit ambiences over comfort.

In a such a context where sustainable design is determinant of the architectural profession, it appears necessary that practitioners not only acknowledge the importance of daylight as a source of energy but also as a response to the diversity of luminous ambiences that supports the different demands and expectations of the many individuals using the same space.

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