Daylighting museums – a case study in Lisbon

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ABSTRACT: In Portugal, daylighting solutions in Museums have been frequently put aside on behalf of all-artificial lighting solutions, simpler to apply. However, being daylight one of the key factors in environmental comfort for users in public spaces, such as in museums, the architect's role is fundamental to select and implement effective and integrated daylighting systems.
The knowledge of daylighting properties in winter and summer, specifically in the Lisbon area, is the starting point for the application of daylighting solutions that, on the one hand, illuminate the museum spaces effectively, without damaging museum objects, and on the other hand, avoid discomfort situations.
This paper presents a summary of a field study carried out in a sample of 20 museums representative of museological spaces in the Lisbon area, focusing on evaluating the advantages of daylighting applications in Museums, in order to establish a set of daylighting design strategies for those spaces.

Keywords: light, daylighting, artificial lighting, museum, conservation, Lisbon

1. INTRODUCTION

Of all issues related with comfort in buildings, the least accessible to mathematical demonstrations are those related with daylighting. Architects were once known by their capacity to create interior and exterior spaces, balancing them with harmony and environmental comfort. However, in our times of mass construction and facing the current social and economical demands, we cannot afford to rely only on talent and inspiration to conceive lighting, without also having to think about the basic concepts that provide the basis for current building practice [1].

Daylight characteristics cannot be replaced by artificial means, resulting from the human need for comfort [2].

The museum gathers several functions that may be improved by the use of daylighting. The correct use of natural light in museums is an important factor in terms of shaping the architectural space and visually enriching the displays, contributing to the interpretation of collections. Also, it is possible to create visual conditions that are comfortable, efficient and secure to the visitors of museums, while at the same time reducing to a minimum the light damage of exhibits. Moreover, a strategy sustained on the use of natural resources can contribute to the reduction of energy waste, restraining the maintenance costs with museum lighting and the negative impact associated with consumption, namely CO_2 emissions.

In a museum, spatial limitation of light and its intensity control are very important. Nevertheless, this task becomes more difficult when the lighting source is sunlight. Hence, daylight may sometimes be regarded as a hindrance for lighting museums, if we consider the combination of daily and seasonal variations of light quantity, together with other atmospheric factors.

In Portugal, the climate conditions support the need for using the available daylight, which is so abundant, to light non-residential spaces. Lisbon has privileged conditions to use daylight, with a considerable amount of annual hours of sun (between 2200 and 3000) that are not found in Northern European countries [3].

2. DAYLIGHTING MUSEUMS

2.1 Light and damage to museum exhibits

The effects of light over objects refer to their lighting, aesthetic valorisation and degradation. Light may modify and even degrade materials. If in the case of relative humidity the materials that constitute the objects tend to establish a balanced relationship with the surrounding environment, however, as far as light is concerned, that balance does not happen [4]. Light always damages, with its cumulative and irreversible action. Therefore, only some lighting levels can be applied, within strict limits [5].

The damage on the exhibits depends on the quantity and quality of radiation they are exposed to. These modifications are as high as the radiation is richer in blue, violet and ultraviolet, the exposure time is longer, the intensity of global radiation directing to the object is larger, the uniformity of light over the object is poorer and also temperature and relative humidity are higher. Light control strategies must be always based on a simple principle – the lesser the exposure, the smaller the damage [6].

On Table 1 we can observe the illuminance limits recommended for museums, according to the materials that constitute the museum exhibits.

Table 1: Maximum values of illuminance recommended for museum objects and total illuminance limits of exposure recommended per hour per year, corresponding to 54 lux * 8h/day * 125 days [5]

Objects	Maximum value recommended	Lux-hour per year
Metal; Stone; Glass; Ceramic; Jewellery	No limit (or 300 lux)	Depends of exposure conditions
Oil painting; Tempera; Unpainted Leather; Ivory; Bone; Wood; Lacquered (Oriental and European)	150/200 lux	500.000
Textile; Clothing; Water-colour; Carpet; Stamps; Drawings; Manuscripts; Tempera painting; Wall paper; Tainted leather; Natural history and ethnology exhibits	50 lux	54.000

2.2 Daylight *versus* artificial light

At present, a considerable number of Museum directors, curators, architects and engineers specialized in lighting argue that artificial light is preferable for museums' lighting. There are two main schools of thought concerning museum lighting: the first defending an exclusive use of artificial lighting for museums; and the second the use of daylight complemented with artificial light [7].

Both schools present understandable arguments. On the one hand, the daylight defendants argue that most artworks were created with natural lighting conditions, and were also, during centuries, still exposed to them; opting for exclusive artificial lighting would result on visitor deprivation from observing the artworks subtlest qualities. On the other hand, daylight, with its variation and possibility for outside views, is more suitable to entertain the visitor than an artificial light system, which is more stable and monotonous. Furthermore, one must consider the inherent costs of using artificial light, which in some countries has to be imported. And finally, artificial lighting consumes electricity, which production has a negative environmental impact, with CO_2 releases to the atmosphere [3].

Artificial light defendants reply that daylight is the most damaging agent to pigments, textiles and other delicate art pieces. Also, that daylight is too variable, if compared with the constant and predictable artificial light; that artificial light is softer; that "white" artificial light can mimic the characteristics of daylight; that installing a daylight system adequate to climate conditions is considerably more expensive than an equivalent artificial lighting system; and finally, that windows suppression easily solves the issue of dust infiltration inside the buildings [8].

Nonetheless, it is a fact that daylight is more difficult to control than artificial light, and it also carries a level of UV radiation that is difficult to eliminate. Moreover, the love for sunlight is also more evident in countries where it is scarce. In countries with a great presence of natural light, its absence can sometimes be considered relaxing [6]. Therefore, we must consider the need to apply adequate daylighting systems to the place where the museum is located, in geographic and cultural terms, in order to achieve maximum comfort for the visitor.

3. THE CASE STUDIES

3.1 Objectives

The objective of the field research was, among other issues, to collect and analyse data about daylighting solutions of Museums in Lisbon, using physical and subjective criteria, in order to contribute to specify a set of design strategies for lighting museums, specific for this region, while focusing on user satisfaction. The field study was part of the research developed for an MSc dissertation [9].

3.2 Methodology

The field-work involved 20 museums existing in Lisbon, which were chosen to be representative of building characteristics and type of exhibit's materials. The data were collected during the winter and summer of 2004 (between January and February, and June and July).

In order to make a quantitative analysis of lighting conditions, some illuminance measurements (both horizontal – at eye level plane, and vertical – over the artworks) were carried out. These measurements were collected around winter and summer solstice periods, using a luxmeter. To analyse extreme conditions, in only overcast sky was considered in the winter, and only clear sky in summer. Simultaneously, throughout each day, measurements also carried out in three distinct periods – opening time (10 am), solar midday and closing time (5 pm). After gathering the data, the values were displayed in a plan, deducting the same illuminance spots with the help of a common chromatic scale for all museums studied. This type of representation allowed for quick comparisons between different space illuminaces, according to different times and seasons. Thus, we could compare the data gathered from these measurements with the users' sensations.

Complementarily, a questionnaire about the quality of light in museums was elaborated and then delivered directly to a random visitor's sample, in the solstice's periods. The adjectives chosen had as a reference the Parpairi's study [10], adapted to the Portuguese cultural context.

To present some examples of the most significant case studies of museums within the sample of this study, three art museums were chosen: Museu de Arte Antiga (Ancient Art Museum), Museu do Chiado (Chiado Museum) and Museu Gulbenkian (Gulbenkian Museum). The above cases were selected because they presented different daylighting systems, allowing for comparison between top lit, side lit with views and side lit without views daylighting systems. All of them have the same light level demand, the same sort of museum exhibits (artworks) but different daylighting solutions.

3.3 Museum de Arte Antiga

This museum has one of the most ancient and important art collections in the country, including artworks from the 14th century until the 1920's.

Figure 1: Museum de Arte Antiga – Left: Paintings Room; Right: another example of a top-lit room.

In the paintings room, where the measurements and surveys were developed, daylight comes from skylights and a diffuser ceiling made of acrylic. This room presents no views.

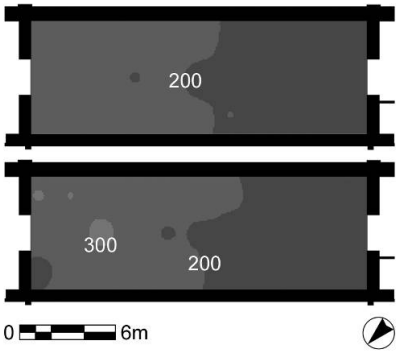

Figure 2: Museum de Arte Antiga – Illuminance measurements in the winter and summer, at 13:00.

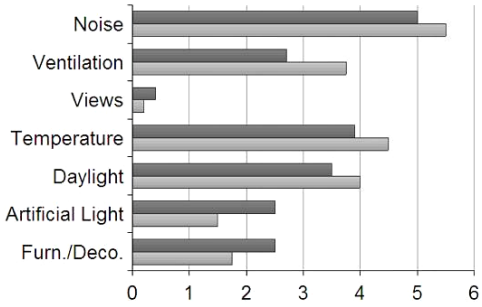

Figure 3: Preference factors in the winter and summer.

As we can observe from the plans in Figure 2, in the winter the illuminance levels were very low, and daylight was complemented with fluorescent lamps placed inside the daylighting system. In the summer, the daylighting system presented considerably higher illuminance levels, also resulting in some thermal discomfort in the afternoon, caused by overheating.

According to the surveys, the preference factor in the winter and summer was the noise level, followed by temperature, and only then by daylight.

In terms of daylight and artificial light qualification, we can see from Table 2 that in winter daylight was considered more unpleasant and unsatisfactory than artificial light, although it was also considered more relaxing.

Table 2: Average values for each qualification scale, according to the light type and season.

	Winter		Summer	
	DL	AL	DL	AL
(1) Pleasant – Unpleasant (5)	2,50	2,30	2,50	2,50
(1) Relaxing – Tense (5)	1,80	2,20	2,75	2,25
(1)Satisfactory-Unsatisf. (5)	2,30	2,10	3,00	3,00
(1) Light – Dark (5)	3,30	2,60	3,00	2,50
(1) Clear – Foggy (5)	2,90	1,70	2,75	2,50
(1) Warm – Cold (5)	2,90	2,70	2,00	1,50
(1) Uniform – Non-Unif. (5)	2,40	2,20	2,75	2,50
(1) Glary – Non-Glary (5)	3,50	3,10	3,75	3,25
(1) Bright – Dim (5)	3,70	3,00	3,50	2,50
(1) Direct – Diffuse (5)	3,10	2,10	3,50	3,50
(1) Strong – Weak (5)	3,40	2,60	3,50	2,75
(1) Sharp – Soft (5)	4,20	3,70	3,75	3,25
(1) Gloomy – Cheerful (5)	3,30	3,80	4,00	3,75

This can result from the lower levels of daylight in this season, which gave the visitors the impression of a dimmer environment. In the summer, on the other hand, we have an overall neutral opinion about both daylight and artificial light, although with daylight being considered more cheerful than artificial light.

In general terms, we can gather from the observations and measurements made that daylighting and artificial lighting systems are accurate in this museum and the illuminance levels are completely fulfilled. Nevertheless, the thermal discomfort in the summer could be considered a disadvantage of the skylighting system available.

3.4 Museum do Chiado

The Museum do Chiado – national museum for contemporary art, is located at the historic centre of Lisbon, and presents a large collection of Portuguese art from the 1850's until nowadays.

The Temporary Display room, which was evaluated for this study, had a wide display in the winter, with direct daylight coming through lateral windows and without a shadow or diffuser device applied, with views through one of the windows. Artificial light was the result of a series of projectors. In the second temporary exhibitions room the daylight entered through vertical, narrow windows, with grey canvases and with an UV radiations filter. These

windows extended to the ceiling, and the direct artificial light came from supports placed on it.

Figure 4: Museum do Chiado – Temporary display rooms in the winter.

In the summer new displays spawned new lighting strategies. In the first Temporary Display room the windows were completely covered except the window with a view to the garden, where a shadow canvas was applied. The only daylight available came through this window. Nevertheless, the variation of illuminance levels was still evident in this room.

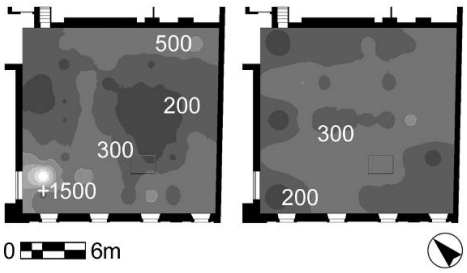

Figure 5: Museu do Chiado – Illuminance measurements in the winter and summer, at 13:00.

In terms of survey results, we can see from the graph in Figure 6 that in the winter and summer the preferred factor was daylight.

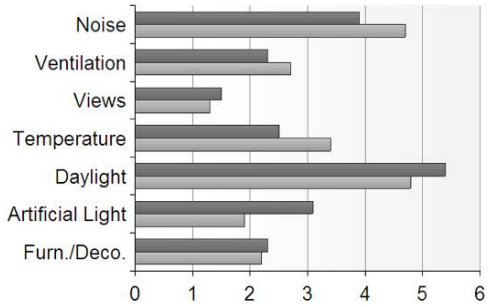

Figure 6: User preferences in the winter and summer.

According to Table 3, daylight was considered more pleasant and relaxing than artificial light, for both seasons. Generally, it had better results in users' opinions than electric light.

Table 3: Average values for each qualification scale, according to the light type and season.

	Winter		Summer	
	DL	AL	DL	AL
(1) Pleasant – Unpleasant (5)	1,40	1,70	1,10	1,80
(1) Relaxing – Tense (5)	1,20	2,20	1,60	2,50
(1)Satisfactory-Unsatisf. (5)	1,50	1,30	1,30	2,20
(1) Light – Dark (5)	1,60	1,90	2,40	2,00
(1) Clear – Foggy (5)	1,40	1,60	1,90	2,20
(1) Warm – Cold (5)	2,70	2,70	3,30	2,60
(1) Uniform – Non-Unif. (5)	2,30	2,70	3,00	3,00
(1) Glary – Non-Glary (5)	3,20	2,70	2,90	2,70
(1) Bright – Dim (5)	3,80	3,20	4,20	3,20
(1) Direct – Diffuse (5)	3,80	2,60	4,10	1,60
(1) Strong – Weak (5)	2,80	2,80	2,80	2,50
(1) Sharp – Soft (5)	4,30	3,70	3,70	3,40
(1) Gloomy – Cheerful (5)	4,60	4,10	4,10	3,50

Despite the different displays in the winter and summer, we cannot see a correspondence in change of user's opinions about daylight. However, artificial light reaches lower values, probably because it becomes more evident by the lack of daylight.

In general, the daylight and artificial lighting systems are satisfactory and adequate. Nevertheless, this museum presents architectural conditions for a greater and better use of daylight, which would improve the lighting of the display area.

3.5 Museum Gulbenkian

Located in Santa Gertrudes park, the museum building is a reference of Portuguese museum architecture, with several openings to the exterior, allowing the visitor a constant dialogue between nature and art. The Museum Calouste Gulbenkian, presents a collection from Ancient Oriental Ages to Contemporary European Art from the beginning of the 20th century.

Figure 7: Museum Gulbenkian – Rooms where the measurements and surveys were taken.

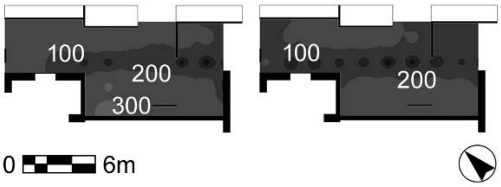

Figure 8: Museum Gulbenkian – Illuminance measurements in the winter and summer, at 13:00.

The daylighting system applied in this museum consists of lateral daylight coming from large clear glass windows, shaded with grey canvas or mechanical louvers, which allows for the maintenance of outside views. Artificial light is mainly diffused, and it is located over the ceiling. The direct artificial light comes from spotlights directed to the artworks. The walls are made of soft textured and clear coloured canvas or textured clear stone, which enhances the exhibits displayed.

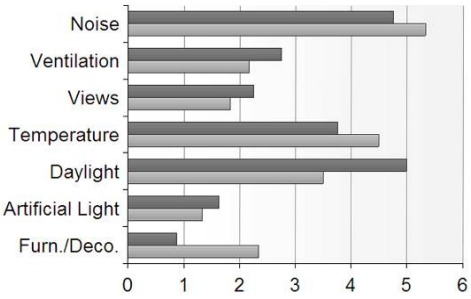

Figure 9: User preferences in the winter and summer.

Table 4: Average values for each qualification scale, according to the light type and season.

	Winter		Summer	
	DL	AL	DL	AL
(1) Pleasant – Unpleasant (5)	1,88	2,50	1,00	1,83
(1) Relaxing – Tense (5)	2,38	2,63	1,00	1,67
(1)Satisfactory-Unsatisf. (5)	3,13	2,88	1,67	1,50
(1) Light – Dark (5)	3,63	2,63	2,67	2,17
(1) Clear – Foggy (5)	3,13	2,13	1,33	2,00
(1) Warm – Cold (5)	3,13	2,00	3,33	3,17
(1) Uniform – Non-Unif. (5)	2,75	2,88	1,50	2,33
(1) Glary – Non-Glary (5)	4,38	2,63	3,17	2,33
(1) Bright – Dim (5)	3,88	2,75	3,83	2,83
(1) Direct – Diffuse (5)	4,13	1,88	3,17	2,17
(1) Strong – Weak (5)	4,00	2,50	3,67	2,67
(1) Sharp – Soft (5)	4,13	3,25	3,83	3,50
(1) Gloomy – Cheerful (5)	2,63	3,13	4,33	4,00

As we can see in Figure 8, the illuminance levels remained almost steady between both seasons. This results from the fact that the excess of light is controlled by means of canvas and louvers, which secures the protection of art works.

On Figure 9, we observe that the most important factor for visitors was daylight in the winter and noise level in the summer.

From Table 4 we can clearly see that daylight was considered significantly more pleasant and relaxing than artificial light, in both seasons. Nevertheless, it was also considered more unsatisfactory than daylight.

A possible explanation for this is that visitors felt the strict control of daylight as an undesired solution, as the views allowed to see all the beauty outside, filtered by the grey canvas for illuminance reduction.

This museum uses the great potentialities of its building in its relation with the exterior environment and the presence of daylight and views. However, the side-lit system of daylighting causes some glare that needs to be controlled by shading devices, but is noticed by users as a lack of light.

3.6 Summary of the field work's analysis

Generally, we could observe that the issues related with illuminance control, in terms of object preservation, were dominated in all of these museums. The gaps and mistakes observed were related with a lack of maintenance or financial problems to update the lighting systems.

Nevertheless, we can realise, after interviewing directors and curators, that even in museums where daylight is not correctly explored, there is the notion of its importance in terms of quality for colour restitution and visitors time orientation, with direct implications in their comfort.

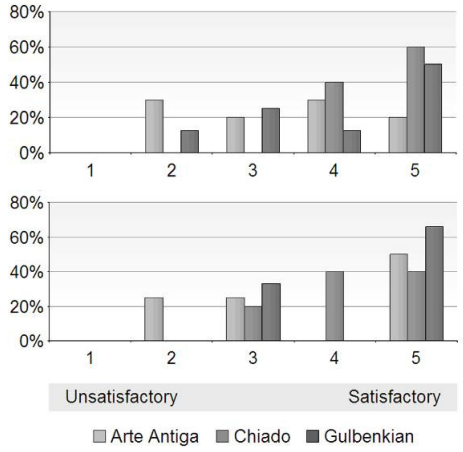

Figure 10: Exterior views values for the three museum examples, in the winter and summer.

Considering the relative importance of the different factors of comfort in buildings, and analysing the frequency of each answer, there are some appointments that can be underlined:

First, we must stand out the fact that noise level almost always appeared as one of the most important factor for comfort in museums. This result may show that a museum was considered by the majority of visitors a space for silence, where unwanted noise is received negatively.

Second, we can observe from the surveys' results that exterior views were considered the least important factor in Museums. However, in museums where the views were privileged, visitors referred to the need of a relationship with the exterior, which did not happen when this factor was not present.

Other interesting feature is that temperature rose to the second place for user preferences in the summer. This could reveal that most of the museums do not apply a proper cooling system (or do it insufficiently), causing thermal discomfort to users.

When considering the values of the semantic differential rates, in terms of relationship between daylight and artificial light, the former comes always detached in comparison to the latter. This may demonstrate the preference of users by its application in museums.

The qualification of daylight and artificial light in these museums was developed with the pursuit of characterizing each space individually. These data analysis fundaments the lighting design strategies outlined for museums in Lisbon.

4. DAYLIGHTING DESIGN STRATEGIES

The research conducted may contribute for a series of design strategies for Museums in the Lisbon:

First, in terms of adaptation to light levels, it was generally observed that the greatest transition occurred between the exterior and the interior of the buildings. Therefore, visitors should be able to walk between transitional spaces with different lighting levels, in order to help the eye to adapt to display levels, before entering the exhibition space.

From the conclusions of the surveys, we can say that in a museum lighting project it is also important to consider the natural light experience, often referred as more satisfactory than artificial light. Therefore, we should aim for a proper balance between soft and directional light, both in isolated objects and in the common space. An overall diffuse light with directly lit pieces would probably produce the most satisfactory effect. On the other hand, since the eye is naturally attracted to the brightest point in its field of vision, the object should be brighter than the wall, the supporting area brighter than upper and lower surfaces, and also the supporting surface lighter than the floor.

Considering the fact that temperature was referred as an important issue in the summer, and in order to avoid high levels of daylighting or solar gains, natural light use should be applied with special care. On above-lit galleries, sun light could be controlled with passive shading techniques and ventilation, instead of blinds and shades, benefiting from lower installation and maintenance costs in the long run. Moreover, instead of trying a fixed illuminance, one could opt to work with an annual amount or the equivalent exposure, to establish a link between exterior weather and the museum interior conditions.

Finally, in museums with abundant views, which usually present lateral windows, it is necessary to reduce the illuminance levels in order to avoid glare. With this purpose, different protection systems should be provided between the upper and lower areas of windows, allowing at the same time outside views and an even distribution of light.

5. CONCLUSION

The objectives of this dissertation consisted of studying the lighting conditions most appropriated to the museum space, in order to define a set of design strategies for museums in Lisbon.

The fieldwork conducted over 20 museums in Lisbon allowed the analysis of the current state of application of those systems and to observe general mistakes and lacunas. It also returned some conclusions about the importance of daylight in museums lighting, and the need for a careful application, adapted to the climatic conditions of Lisbon, in order to guarantee the user's comfort, as a key element of architecture.

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