MEASUREMENT AND INTERPRETATION OF LUMINOUS AMBIENCE

Ljubica MUDRI
Laboratory LAIADE,
Paris-Belleville School of Architecture, 78 rue Rébeval, Paris, France
Email: lmudri@club-internet.fr

ABSTRACT

This paper presents part of a multidisciplinary work with three teams: two laboratories of psychology and a laboratory of lighting/architecture. We concentrate here, within the project, on activities on luminous ambience and focus on the lighting/architecture part.
The problem we studied was:

- How is it possible to concisely express the variety of luminous ambience qualities on the basis of a large number of light measurements?

More precisely, in order to analyse the quantitative data collected from measurements, we intend to define interpretation models. The result of these interpretation models should be easily usable for further analysis and understandable by architects. Architects do not manipulate expressions such as luminance levels. In order to express their intentions for a luminous ambience, they use qualitative and descriptive expressions.

- On the basis on these interpretations, how can we change the existing concept of artificial lighting for a space in order to lessen energy costs, to keep a good performance of lighting and to improve the comfort and pleasantness of users?

More precisely, comfort and pleasantness are closely linked to contrasts thresholds, gradual ranges of luminance and chromaticities on the interior envelope. Artificial lighting is used by the general public and designers not only to reach a sufficient level of lighting on work surfaces, but also to increase or decrease contrasts and gradual ranges of luminance and modify the colour of the light on the interior envelope in order to reach a comfortable and pleasant ambience. In that respect, we can say that the expenditure in electric energy is also due to the fraction of artificial lighting used to create comfort and pleasantness of ambience.
To address these two questions, we have studied existing luminous ambience in two sites in Paris. The spaces under study were rest areas. We defined the method for light measurement on the opaque and glazed interior envelope (with luminancechroma and luxchroma meters) in mixed lighting (both natural and artificial). We interpret the measurements in terms adapted to architects. We defined the concepts for different luminous ambiences and built these modified ambiences in the sites themselves.

Keywords: Luminous Ambience, Daylighting, Artificial Lighting, Architecture, Interior Measurements-Interpretation, Energy savings.

1. INTRODUCTION – CONTEXT OF THE OVERALL PROJECT

In this multidisciplinary work with 3 laboratories, we propose a practical framework to study the variability of subjective responses to luminous ambiences (atmosphere).
Architects build spaces for which they define functional characteristics and an esthetical concept, while considering the quality of ambiences. The success of a building depends on the subjective perceptions and the behavioural responses of users regarding these functionalities and ambience. In most works on ambience, the user is considered as an "average user" (mister anybody). The importance and variability of the subjective

character of responses has often been mentioned. However, we still do not have effective indicators on the relationship between personalities and the sensations of comfort and pleasure in a luminous ambience. The purpose of this work is to study the relationship between the perceptivo-cognitive handling of luminance and chromaticities and the way social spaces are occupied and used depending on their luminous ambience. We study the behaviour of subjects in a laboratory and on site (in rest areas). We hope that people will choose their places essentially according to the physical characteristics of the space and, in particular, according to the luminous ambience. Moreover, in order to minimise the social constraints due to a crowded space, we perform our study during off-peak hours when the degree of freedom is greater, and at the same time, we study the luminous ambience:

- We obtain indicators on subjects: 1) by testing the dimensions of personality for 48 selected people, in order to detect high and low level sensation seekers according to their sensations of pleasure; 2) by observing the behaviour of the same subjects in rest areas and by discussing with them with a questionnaire.
- We obtain indicators on existing luminous ambiences in these areas by measuring luminance, illuminance and chromaticities on opaque and transparent envelopes.

We then modify the luminous ambiences in these areas by modifying artificial light and repeat the observations with the same kind of subjects.

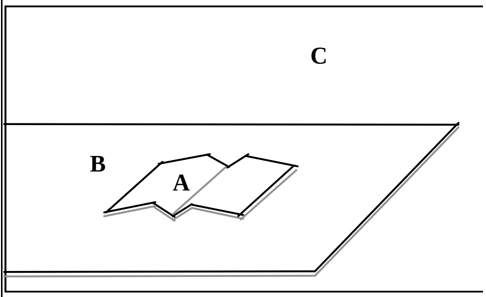
In this paper, we will present only the project part about luminous ambience.

2. SCIENTIFIC CONTEXT AND PURPOSE

From the architectural point of view, the luminous ambience is defined as the part played by light in the way an environment influences a subject. Two notions are generally used to analyse luminous ambience: performance and comfort. *Lighting performance* indicates if there is enough light to perform an activity. European norms are defined about this [7]. However, the defined illuminance levels are not a sufficient criterion to ensure that an activity will be performed in good luminous conditions. The ambience should also be comfortable. The notion of *comfort of a luminous ambience* refers to the distribution of luminance and chromaticities on the interior envelope of a space, that is on the different fields of vision for a subject within an ambience. Luminance and chromaticities are at present seldom studied as far as comfort in buildings is concerned. The European norm [7] partially refers to this notion but only as far as the level of luminance and contrasts should not be too high to disturb the subjects' activities. However it does not define what is too high. Desirable contrasts levels are only defined via contrasts of illuminance and not of luminance and only for work surface. This is not sufficient to ensure comfort. Our work, described here, tries to specify more this question of comfort and pleasantness using the distributions of luminance contrasts on the whole opaque and glazed interior envelope.

Moreover, the European norm [7] requires the calculations of UGR which only focuses on discomfort from artificial lighting, and only in the direction of the luminaries and its background. It is also rather complicated to be used by architects during the design phase.

We based our work on the rare publications which give quantitative levels for luminance contrasts, either for the work surface, or the whole envelope.



main fields of vision

Recommendations for necessary luminance ratios in the main field of vision :
A: visual task;
B: close environment – preferably rather uniform
C: peripheral environment, also rather uniform.

A:B	= 3:1
A:C	= 10:1
Light source: adjoining field	= 20:1
Whole interior space	= 40:1

Fig. 1 Recommended contrast ratios for work space and an average subject

On Fig.1, Hopkinson defined the first two thresholds in 1963 [5], the second two were added by the European Commission in 1992 [6]. This presentation of contrast thresholds is very usable by architects thanks to its simplicity. It deals with contrasts on the entire envelope. These ratios may naturally differ if the field of vision or the room function changes. Other publications also detail luminance contrasts levels [2, 4, 1] that are coherent with these ones and which qualify other levels or other situations. As, in this paper, we are interested in rest areas, not workplaces, we use and adapt these references to define luminance contrasts classes for photopic vision in interior spaces and link them to qualitative elements (Fig.3). They are the basis of our interpretation of measurements.

Beyond comfort and discomfort, there are the notions of pleasantness or pleasure on which works are even rarer. The norm [7] only says that too low luminance or contrasts levels may result in a boring or non-stimulating work environment. There are more pragmatic habits than scientific researches. Sometimes, luminous ambience fulfils performance and comfort criteria; but these luminous ambience are not felt as pleasant but as monotonous or sad [1]: for example, in many hospitals, especially in the past decades, ambiences were designed on the basis of minimal contrasts, uniform blue colours and no psycho-physiological tension. They were comfortable but not pleasant.
In that respect, we try to answer the following question: how is it possible to express synthetically the variety of "luminous stimulation" on the interior envelope of a space? Three main points should be taken into account:

- The different *fields of vision* according to the various users' positions: there is no global luminous ambience independent from the subject, his/her position and his/her field of vision. For the data to be useful to our approach, it is necessary to study the space from several points of view. It will allow us to study the behaviours of people according to their actual field of vision.
- The influence of *daylighting variability* which implies difficulties to measure luminous flux: with lighting both natural and artificial, the luminous ambience varies with the incident fraction of the exterior light. We are developing measurement methods to take into account the quick variations of daylighting. It will also improve our existing measurement protocol [4].
- The *interpretation models* to be defined for a large number of collected data: the very large diversity of "luminous stimulation" visible on an interior envelop leads to a number of measured data far too large to handle as such. We therefore have to build interpretation and synthesis models. To define these interpretation models, we will have to refine the existing variables, contrasts and gradual ranges of luminance.

3. METHODOLOGY AND RESULTS

3.1 Fields of vision

Two sites were selected. We present one here: the café-restaurant of the new Institute of Psychology in Boulogne-Paris. Ambiences are of good quality, the luminous ambience is rather pleasant. There are 9 zones illuminated by natural light and artificial sources as complement during the day. These zones are spatial: separated by tables, luminous panels, benches, etc., but the choice and position of luminaries is identical for all zones. For daylighting, some zones are closer to openings, others are deeper in the café.

3.2 Measurements – Variability of daylighting

For each zone, several fields of vision were selected. Fields of vision have not been taken as 120° as usual for workplaces but as 180°, because, in a café, people are less concentrated on a visual task, they move their eyes and head, contrarily to a position in a workplace. We measure luminance, illuminance and chromaticities (x and y) on opaque and glazed interior surfaces in the field of vision under mixed lighting (both natural and artificial). We present the distribution of luminance on a luminance diagram [3] for each ambience (initial and modified), for each zone in each field of vision. To ensure reliable measurements, we use and improve a protocol of measurements [4] where several problems (variability of exterior illuminance, sky types, etc.) have been studied. Among sky types, we have chosen the overcast sky (uniform and Moon and Spencer) because changes in exterior luminous flux can only induce proportional changes of the interior luminance levels, but does not modify the luminance distribution. For overcast sky, exterior illuminance changes interior luminance levels. Hence, two luminance levels, measured in two points at two different times, cannot be compared (for instance to detect a contrast), as they correspond to different exterior luminous conditions. Hence, for each point of measurement, we measure the interior luminance and the exterior illuminance on the vertical window. Then, we calibrate luminance according to a particular value of illuminance (the most frequent one). We have luminance values as if measures were taken simultaneously. To apply this calibration only on the part of the luminous flux due to natural light, we measure luminance with only artificial light, and subtract these values to the mixed lighting ones. Calibration can then be performed only on the natural part. We add this calibrated part to the artificial one to obtain a global calibrated value. A calibration is also performed for colour data (x and y). For each field of vision, we have around 200 comparable points of luminance with colour data.

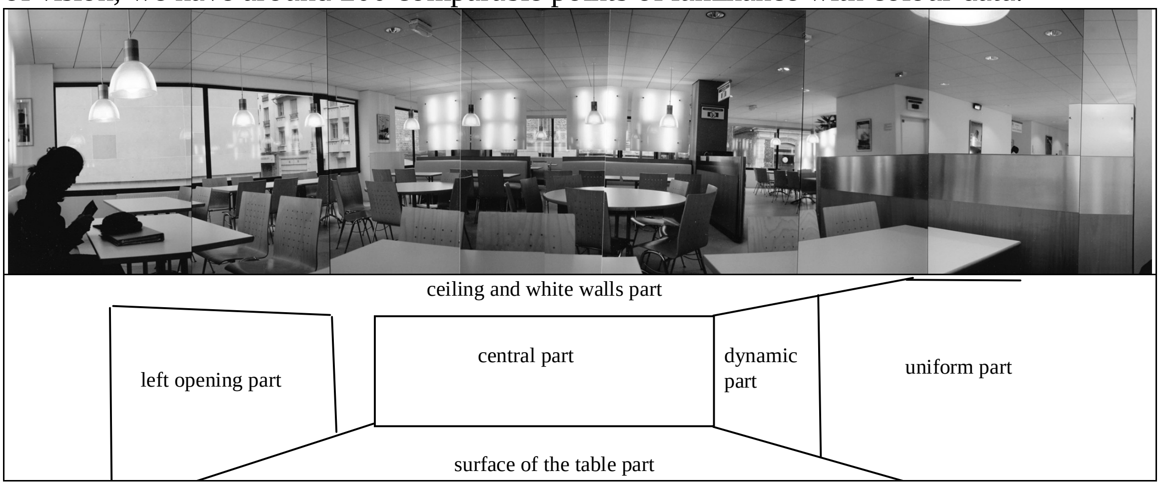


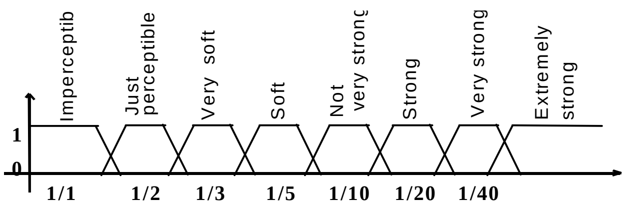
Fig. 2 Example of a zone (University Paris V) and parts of the zone

3.3 Interpretation models - Interpretation of measured data and links with qualitative expressions

Measured data are interpreted and analysed to determine contrasts, gradual ranges of luminance and the main chromaticity. We do not look for an average luminance for the field of vision or other average values. We split a field of vision into parts to find the characteristics of each part and the relations between parts. The field of vision is split according to the architectural and lighting homogeneity. Fig.2 shows parts in the café of the University Paris V. For each part we have contrast and gradual range of luminance:

- maximal contrast, if points for it are contiguous, close, rather distant or very distant.
- contrast between close points: just perceptible, very soft, soft, etc., see Fig.3.
- contrasts punctual vs. linear.
- gradual ranges of luminance: soft, medium or strong.
- gradual ranges of luminance: ordered vs. unordered.
- characteristics of the frontiers between parts: well-defined or fuzzy.

This allows us to build links between quantitative data and qualitative expressions. The first step of this linkage is given on Fig.3. Naturally, these thresholds are different for very high luminance levels (rare in interior spaces) and very low ones (mesopic or night vision).



To take into account the lack of precision of the limits, Fig. 3 presents a classification of the ratios as fuzzy sets (improved from [4]).
It is designed for photopic vision in an interior space.

Fig. 3 Definition of classes/thresholds for luminance contrasts

3.4 Concepts for modified ambiences

We then design a second luminous ambience (modified) for 5 zones for Paris V. The modified ambiences were designed using carefully chosen artificial lights. The design of the modified ambience was founded on interpretations of initial ambience, the detected drawbacks and possible energy savings. On Fig.2, for the central part, the analysis of the initial ambience showed: monotony due to the repetition of identical luminous panels; a weariness of eyes due to the fuzziness on the whole panels surface. The eye tries continuously to adjust but does not find a precise shape to use it as a reference. Contrasts are also strong (1/20) due to the suspended luminaries. We therefore decided to eliminate the monotony and the weariness of the eyes by working on the panels, to have a softer ambience by decreasing the contrasts and to allow the visitors to act upon their luminous environment.

Fig. 4 Example of modified ambience (see Fig.2 for the initial ambience)

These changes consist in: addition of colour filters in the panels higher part, introduction of precise shapes on the panels lower part, new suspended luminaries (Fig. 4). After this, we perform new measurements using the same protocol as for initial ambience.

The measures show for the central part that:

- For panels higher part, max. linear contrast decreases: 1/8, not very strong, to 1/4, soft.
- Between higher and lower parts, max. contrast from 1/8, not very strong, to 1/6, soft.
- In the lower part, from 1/8 linear to 1/6 linear and punctual 1/8.5.
- The maximum contrast 1/20 (strong) disappear thanks to the change in luminaries.
- Between the facade and the side of the panels, contrasts decrease from 1/3 to 1/2.4.
- Each user may change the height of the new suspended luminaries and hence decrease the contrast from extremely strong (that were intentionally introduced) to very soft.
- Introduction of precise shapes in the panels lower parts allows the eye to adjust.
- Changes in chromaticities and introduction of precise shapes to suppress monotony.
- 25% energy savings but new luminaries are more expensive.
- As the coloured filters introduced in the panels are simple and inexpensive, they can be easily changed from time to time to introduce a new dynamics and change the luminous ambience.

4. CONCLUSION

In this project, we worked on the analysis of luminous ambience. We improved the protocol of measurements and enriched the possibilities of interpretation.

In order to do this, we adapted the protocol of measurements to mixed lighting: To handle the problem of variability of daylighting, we separate the data about daylighting and about artificial lighting. We calibrate the daylighting part with respect to exterior illuminance and chromaticities. Then, we develop interpretation models able to handle the large number of data we collect: We split the fields of vision in zones and study contrasts, gradual ranges of luminance and chromaticities within the zones and, after for the whole field of vision. This results in a concise description of a luminous ambience which can then be easily used. These descriptions also provide qualitative expressions, issued from quantitative data, which are closer to architects' way of working. We used these results to design a new luminous ambience.

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PARTICIPATING TEAMS

MUDRI L., BERNSTEIN D., Laboratoire LAIADE, Ecole d'Architecture Paris-Belleville, Paris, France
LEGENDRE A., Laboratoire de Psychologie Environnementale, Université Paris V, Paris, France
PIERSON A., Laboratoire Personnalité et Conduites Adaptatives, Hôpital La Salpêtrière, Paris, France

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