Luminous ambience, quantitative/qualitative data and subjective response

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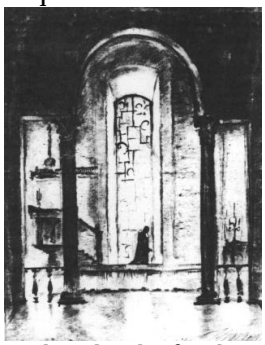
Abstract This paper presents several years of research in luminous ambience in daylighting. It began with works on the relationship between intuitive and quantitative approaches for the understanding of luminous ambience. We collected quantitative data from measurements of illuminance levels on glazed and opaque surfaces in interior spaces. From these measures we could build an interpretation related to the luminous ambience. They were compared to what was expressed by interviewed subjects in these spaces or to intentions expressed by the architect during the design when available. At the end of this work, a first issue was: how could we explain that comfort and pleasantness of an ambience may often be conflicting? We investigated this question and showed that comfort is not sufficient to express the quality of a luminous ambience and that some degree of "discomfort" may be needed by individuals to feel an ambience as pleasant. Confronted to the variety of answers given by people about luminous ambience, we tried to understand how subjective responses to a luminous ambience relate to the dimensions of personality. As this particular point of view seemed to have seldom been investigated, we decided to start a project specifically focused on this subject. The purpose of this paper is therefore to sum up this line of research, from quantitative measurements to dimensions of personality.

Keywords: Daylighting, ambience, measurement, subjective response

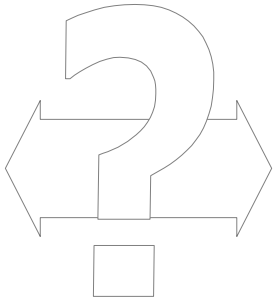
Introduction

We publish in this paper the results of several years of research in the field of luminous ambience in daylighting and/or artificial lighting as complement. This line of research has greatly evolved over the years, but the general purpose remains the same: definition of indicators useful to architects during the design phase to improve the qualities and uses of luminous ambience; development of methods to better define comfort and pleasantness of luminous ambience.

Ambience is defined here as the way the environment affects a subject. Subjects are naturally affected by a global environment (thermal, acoustic, luminous, aesthetic, etc.). As we use public spaces, we perform quasi-experimental studies. Whereas the environment is better controlled in a lab, the behaviour and emotions of people are more natural and spontaneous in quasi-experimental studies. This work started with an investigation on the relationship between intuitive/qualitative and quantitative approaches for the understanding of luminous ambience in daylighting. It was, at that time, closely linked to the work of architects and the gap students feel in the university between technical/quantitative and architectural/qualitative subjects.



A Aalto, sketch of a church



Illuminance at point M in the interior space through a window.

$$E_M = L \int_{\theta_1}^{\theta_2} \int_{\varphi_1}^{\varphi_2} \sin\theta . \cos\theta . d\theta d\varphi$$

$$\frac{L(\zeta,\alpha)}{L_z} = \frac{f(\gamma).\Phi(\zeta)}{f(Z_0).\Phi(0)}$$

Radiation theory formulas

Fig. 1 Illustration of what we mean by intuitive and scientific approaches for luminous ambience

In the sketch phase (the early phase of design), architects proceed, indeed, in an intuitive manner (using imagination, descriptive ways, words, sketches, etc.) regarding the repartition of luminous flux and the feelings of the future users (future subjective response to the luminous ambience). The scientific approach is integrated (as far as architects are concerned) in computer-aided design tools specialised in natural and artificial lighting which perform evaluation of ambience during the project. The use of these tools in the sketch phase raises several issues:

- Architects do not use the scientific/quantitative tools during the design, as it appears far too time-consuming in the quickly evolving sketch phase.
- Evaluations of luminous ambience in daylighting by sophisticated computer tools require a well-defined morphology and data which are not available during the sketch phase.
- This evaluation is still rare and rather expensive and only accessible to large public projects.

Moreover, it is in this sketch phase that fundamental choices on the project, such as the general morphology, the openings and their orientations, are defined. The scientific tools which can only be used at the end of the design when the project is precise cannot therefore be of great help in the design of the project (even if they were easily available to architects).

In order to help and enrich architects' intuitions regarding luminous ambience we proposed to compare qualitative expressions from subjects (what they felt like calm, soft, dynamic, tense, etc. ambience) with measured illuminance levels in these ambience. The purpose is to describe, for example, a calm ambience using technical and quantitative characteristics (contrast levels, gradual range of luminance, etc.). We believe this would create a better understanding of ambience by architects, help ambience classification, and facilitate the discussions between architects and engineers. This method, we will detail in the first part of this paper, is currently applied in our university.

At the end of this work, a rather surprising issue was raised: Using the quantitative measurements we had, we could easily determine if a luminous ambience was comfortable or not. It was quite interesting to notice that subjects often declared that an ambience considered as comfortable was not pleasant and vice-versa. This observation was repeated on several subjects randomly selected in several different spaces. This pointed out that the notion of comfort may not be sufficient for the study and design of ambience.

Comfort explicitly excludes tension and psycho-physiological disturbance on subjects. On the contrary, one way to define a pleasant ambience especially includes the notion of tension on subjects affected by an ambience. Natural lighting and passive ventilation are generally considered as more pleasant than artificial lighting and ventilation, even if the latter can lead to a much better controlled ambience. We believe that this question is of particular interest nowadays as we considerably developed technical control systems for ambience but which do not ensure pleasantness. We therefore decided to study specifically this issue, as this is very important to be able to define the quality of an ambience. We think that a very global view on ambience is now needed as we detail in the second part of this paper.

Through these two projects, but in particular in the second one, it became obvious that the notion of pleasantness is extremely subjective. Some individuals may feel an ambience as pleasant whereas others may feel it as very unpleasant. Some find a calm ambience as pleasant, others look for dynamic ambience, etc. In order to further enrich our understanding of pleasantness as compared to comfort and quantitative notions (such as measurements and norms), we decided to investigate the diversity of subjective responses to luminous ambience. This work took the shape of a multidisciplinary project with three laboratories. In this research we focus on 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. Part three of this paper details the approach and the project.

1. Relationship between quantitative and qualitative data for luminous ambience

The field of luminous ambience in daylighting is a very interesting one as it strongly appeals to architects' feelings and works. There are also solid and rather complicated scientific research and methods to tackle the question of daylighting. However, very few links seem to exist as if these were two separate fields. The aim of this study was therefore to provide links and, in the long run, to help and enrich architects' intuitions regarding luminous ambiences and to prepare criteria for the classification of luminous ambiences.

1.1. Method

After having chosen buildings particularly interesting for their luminous ambience, we measured luminance and illuminance levels on glazed and opaque surfaces in interior spaces. The measurements helped us build a synthetic scheme of these levels. We compare the analysis of quantitative measurements to the subjective expressions given to us by interviewed people (students, professors, users and workers in these spaces) or to compare to the architectural intentions as expressed by the architects who designed the buildings. We present here the case of the National Superior Academy of Music and Dance of Paris for which the architect' s point of view has been published [1]. For this work, we defined a protocol of measurement to ensure the validity of results. We will detail this in the next subsection. Once we had the measurements, we interpreted the measures using methods defined in published scientific works. Finally we compared the architect's intentions which were published with our interpretation of the quantitative measurements.

If we look in a dictionary (freely translated from Le Petit Robert, Paris, 1970.), we can find:
Quantitative: which belongs to the field of quantity and numerical values.
Quantity: property of a measurable grandeur; the thing itself which can be measured.
Qualitative: which belongs to quality (and not to measurable things)
Quality: Way of being, sensitive and not measurable characteristics of things.

Qualitative data may be expressed with words, descriptions, drawings, sketches, paintings, etc. We focus here on expressions (using words) from subjects raised from luminous ambience in interior spaces. These qualitative data are hence subjective as dependent on the subject's emotions. Quantitative data are light measures we take. As measured, these data are considered as objective.

1.1.1. Protocol of measurements

In order to ensure the validity of our measurements, it has been essential to define a method of measurements. It is particularly true with daylighting. Natural light varies from one moment to another, in particular its spectral composition and the distribution of illuminance. It therefore changes in the interior spaces. The protocol of measurements, see [2] for details, helps us collect reliable, significant and comparable data. We had to define the proper moments for measurements and several complementary information. These complementary data were:
- Geographic location of the site and date and exact time.
- Sky type (clear, intermediate clear, intermediate clear, intermediate overcast, overcast) ([3] [4]).
- Interior vertical illuminance in front of windows and, if possible, exterior horizontal illuminance.
- The standpoint on the plan of the building (to take pictures and measures from the same place).
- Luminance measurements on glazed and opaque surfaces and indication of measured points later indicated on the pictures that are taken at the time and from the point of measurements.

1.1.2. Interpretation of measures according to previously published scientific works

We use the notion of contrast (C) as the ratio of luminance between two surfaces (L_0 and L_1) of an interior space, i.e. $C=L_0/L_1$ as defined in [5,6]. Contrast is widely used to analyse work ambience in scientific works about discomfort and glare or response to contrasts. Table 1 shows contrast (luminance ratio) levels for workplaces recommended by the European Commission ([5, 6]):

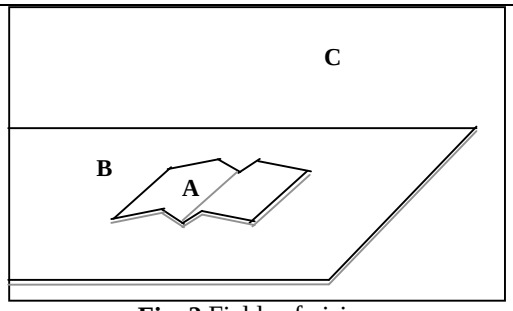


Fig. 2 Fields of vision

Table 1 Recommendations for necessary luminance ratios in the main field of vision :
A: background of visual task;
B: environment – preferably rather uniform;
C: peripheral field – preferably rather uniform.

Recommended contrast ratios for work surface	
A:B	= 3:1
A:C	= 10:1
Light source: adjoining field	= 20:1
Interior in general	= 40:1

These ratios may differ as the situation changes. However, nearly all studies deal with workplaces and we have also used these ratios as a basis.

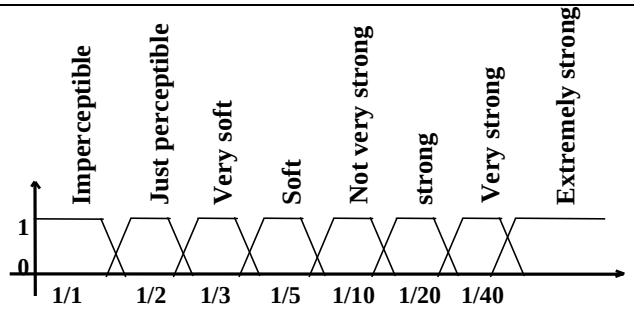


Fig. 3 First step to a link between qualitative/quantitative data

To take into account the lack of precision of the limits, Fig. 3 present a classification of the ratios presented as fuzzy sets of the set of imperceptible contrasts (improved from [7]).

A field of vision of someone in a working position in an office is called the main field of vision (Figure 2). It is made up of the background of visual task (A), the environment (B) and the peripheral field (C). We call secondary field of vision what may be found from the working position when moving the head [LAIADE internal document].

In this paper, we also use the expression gradual range of luminance: For a given surface, if luminance levels increase or decrease continuously for contiguous points, we can speak of a gradual range of luminance. In our work, if luminance levels decrease or increase so that limits between clear and dark cannot be precisely defined, we speak of soft gradual range of luminance. On the contrary, if such limits are clearly defined, we speak of strong or very strong gradual range of luminance. [8]

1.1.3. Expression of an intuitive representative response despite its subjectivity

In the case of the National Superior Academy of Music and Dance of Paris, the subjective intentions of the architect Christian de Portzamparc have been published [1]. We have chosen a space called "chapel" because of its peculiar ambience. It is not a classroom. It is a complex space for spontaneous work and coffee-breaks, not quite closed, but sheltered, with a spiritual side like in a temple but also where any event is possible. Henceforth, we shall refer to this place as the café. Considering luminous ambience of the chapel, he stated that: "Some students prefer a padded, soft and dark ambience […] the more exuberant are in front of the light, in the café which is noisier."

1.2 Results

Conditions for measurements: Intermediate overcast sky (hidden sun). 10th October 1998, 4 p.m. Point B where the above picture was taken. Vertical interior illuminance: 400lux at point B towards the glazed surface. Points in table 2 are on figure 4. Point 6 is on the white frame of the window.

The café has been studied under two points of view and two different skies. Here, a short abstract of the results for point of view B for one sky is presented, ([2] for more):
Right-hand side surface, black marble, covered, against the light, the back of the café
- Maximum contrast on the opaque surface 3:1 (points 10 to 14 and 22, 23). The contrasts which are from just perceptible to very soft and spread over a large surface lead to very soft gradual range of contrast on this surface. Luminance levels are rather low.

- Maximum contrast with the glazed surface 50:1 (points 1, 2, 3 and 23). It is a strong contrast. However, the whole line of high luminance of the glazed surfaces is aligned at a great height and the luminous flux from these openings does not reach students in the café but stays higher. It reaches the opposite interior surface which reflect it. Students are psychologically protected from this flux. The flux and contrast belong to the gangway which is higher. This flux delimits the height of the café.

Point	*Luminance*	*Point*	*Luminance*
N°	*Cd/m²*	*n°*	*cd/m²*
1	15	*13*	9
2	531	*14*	5
3	39	*15*	222
4	4	*16*	17
5	25	*17*	21
5'	22	*18*	11
5''	21	*19*	54
5'''	20	*20*	176
6	444	*21*	23
7	4	*22*	8
8	66	*23*	11
8'	62	*24*	153
8''	60	*25*	37
8'''	58	*26*	44
9	131	*a*	34
9'	5	*b*	60
10	11	*c*	96
11	13	*d*	125
12	9	*e*	165

Table 2 Measurements in the points

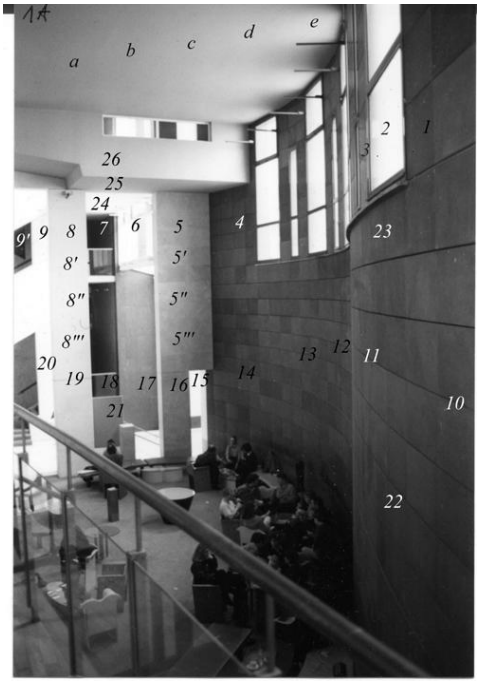


Fig.4 Points measured in the Chapel (café), synthetic scheme of luminance

From these data we build a first relationship between the intuitive approach and the quantitative measured data. Christian de Portzamparc said it well: Some students […] are in front of the light". It does not mean that they receive the direct light on the face. Indeed, no portion of the sky (or exterior reflections) is visible from the café. However, there is an opposition between low contrast (3:1), soft gradual range of luminance and rather dark illuminance on one side (9cd/m², on the right) and, on the other side, strong contrast (50:1), no gradual range and much higher levels of illuminance at the exterior limit of the café (back of the picture). This opposition is very specific to this space. Students are sheltered in a rather dark and soft space. They feel protected, and they can see a luminous flux as an exterior limit, but it does not reach them. Hence, the measurements performed in the café on the right-hand side surface (dark) and on the close side (underneath the photographer) have low levels of luminance, soft gradual range of luminance and rather low illuminance levels. On the contrary, the noisier side (back of the picture and the left hand side, not visible on the picture), as named by Christian de Portzamparc, is very well illustrated by the measurements when we consider the whole composite opposite surface with rather strong and varied contrasts, no gradual range of luminance and changing levels of illuminance with large surfaces having high illuminance levels. The opposition between calm and noisy is very characteristic for this complex space and very well shown on the measures (table 3) and it is very coherent with the intentions expressed by Christian de Portzamparc.

We have then determined 6 logical zones, see [2], on the surfaces of the café. Each zone contains 5 points of measurements. In table 3, the points belonging to a zone and the corresponding luminance are in the left-hand side of the table (points are in brackets: point 11 has 13 cd/m²). These data are identical to those of table 2, but per zone. On the right-hand side of the table, each zone is ranked with respect to the intervals of figure 2. It is worth noticing that the above-mentioned opposition clearly appears on the table: Contrasts per zone are just perceptible, very soft or extremely strong.

	Initial data												
	Cd/m^2	cd/m^2	cd/m^2	cd/m^2	cd/m^2	Contrasts							D.
Zone	(point)	(point)	(point)	(point)	(point)	Im	Jp	vso	so	Nvst	Rst	Vst	est	
1	13 (11)	9 (12)	9 (13)	5 (14)	11 (10)			+						+
2	15 (1)	531 (2)	39 (3)	4 (4)	11 (23)								+	
3	25 (5)	22 (5')	21(5'')	20 (5''')	17 (16)		+							+
4	66 (8)	62 (8')	60 (8'')	58 (8''')	54 (19)		+							+
5	4 (7)	444 (6)	23 (21)	66 (15)	131 (9)								+	
6	34 (a)	60 (b)	96 (c)	125 (d)	165 (e)				+					+

Table 3 Points measured and grouped first in zones then in classes

Classes : im, jp, vso, so, nvst, rst, vst, and est, correspond to classes on figure 2 ; D. is for gradual range of luminance.

Some classes are then defined. Let us focus on classes for qualitative expressions such as relaxed, tense calm, etc. From contrasts and gradual range, we (us and architects) classify the ambience. About 15 tables (as table 2) and their associated classifications have been used to calibrate neural nets. Then, neural nets have been capable of associating images, i.e. contrast and gradual range of luminance with the existing classification.

In this work, we showed that it is quite possible and interesting to build efficient links between quantitative/technical techniques (i.e. measurements, formulas) and expressed feelings. We now use these links in our teaching on ambience. We used the qualitative expressions given by the architect. We also collected qualitative expressions given by users of the space. It was quite noticeable that, in some cases, a technically comfortable ambience was not felt as pleasant. These people did not know about norms and recommendations (which define comfort); they did not measure natural light. They just felt or not a well being in given spaces, theses spaces being comfortable or not. As this observation could be repeated with many subjects in different spaces, it appeared to be an important issue in the characterisation of ambience. We therefore started to investigate this issue.

2. Comfort, Pleasantness and psychological tensions

Taking our dictionary again, we can find:
Comfort: what contributes to the well being, to the convenience of material life,
Well-being: given by the fulfilment of physical needs, absence of psychological tensions,
Convenient: easily (free of trouble or difficulty) accessible and well adapted to some purpose.

Therefore, the word comfortable implies the elimination of all constraints, which may rouse a psychological tension, whatever level this tension may have. Moreover, the notion of comfort appears in the definition of ergonomics which is defined as "the body of knowledge relative to human beings and necessary to design tools which could be used with maximum comfort, security and efficiency"[10]. Hence, there are hospitals with a uniform blue colour inside because it has been proved that blue gives a feeling of comfort and relaxation [11]. In these hospitals, there is no visual tension (with chromaticity or with luminance), the luminous ambience is comfortable. However, such ambience is often considered as monotonous, even dull. It is not pleasant.

A comfortable ambience may not be pleasant.

We can also find in the dictionary that:
Pleasantness: characteristic of someone or something that makes it/him/her pleasant.
Pleasant: pleasing the mind, feelings or senses.

Even if we do not try to define the word pleasure, we look for a possible insight about what pleases a subject (affected by an interior space, his/her environment). For pleasantness, psychological tensions are not mentioned in the definitions. The first lead one may follow is to think that the notion of pleasantness is equivalent to comfort, that it just goes further in the elimination of psychological stress, that pleasantness is simply quantitatively greater comfort. Our belief is that pleasantness and comfort are essentially different. Pleasantness implies the presence of an attention, a psychological tension. It is contrary to comfort and its complete absence of stress.

Let us take a well-known example: the famous house on the cascade by Franck Lloyd Wright is surrounded by a noise coming from the outside, whose level is above all norms. Therefore we cannot consider the ambience of this house as comfortable. It is not comfortable (or ergonomic) because a subject feels a psychological tension in this space. However, this house is famous for its pleasant ambience. It may be for several reasons, but, in particular, for its acoustic ambience. The tension, the noise from the cascade, is considered as pleasant.

A pleasant ambience may not be comfortable.

The nature and level of a psychological tension due to an inconvenience in the ambience is important to characterise an ambience in terms of comfort or pleasantness. The absence of tension classifies an ambience as comfortable, but not as pleasant as the existence of a tension can contribute to pleasantness. The question of limits is rather delicate and, in a specific sociocultural environment, depends on subjects' sensitiveness and on the space functions. Norms generally focus on performance of lighting (levels of illuminance, see [12] for an example in France). A few recommendations focus on comfort, that is on the elimination of possible inconvenience, usually due to strong contrasts, which may lead to tension. This normative point of view is comfort-oriented and does not take pleasantness into account. On the contrary, we show that architects often focus on pleasantness, to the prejudice of comfort. To illustrate this point, we concentrate on daylighting.

2.1. Choice (voluntary or not) between comfortable and pleasant

The renewed awareness of the fact that the human body takes pleasure in natural light radiation, the interest in energy savings constraints and, finally, the fashion in transparent envelope, have raised several questions on the choice between the comfortable and/or pleasant sides of luminous ambience in daylighting. For this research, we have studied several buildings from the point of view of daylighting. In this paper, we present our study on recently built French National Library by architect Dominique Perrault. In this case study, we did not look for architects' intentions, we only concentrated on users' responses. People could express themselves freely. We added semi-directed questions about ambience pleasantness. Measurements were performed to conclude on comfort.

2.2. Results : The French National Library, reading room G

2.2.1. Subjective/qualitative expressions for two situations

Under an overcast sky, the ambience is pleasant, intimate and warm. Under a clear sky (with penetration of direct sunlight), it is felt as irritating, not adapted to concentration, like outside, not pleasant.

2.2.2. Measured/objective data and comparative analysis

Under an overcast sky: illuminance on work surfaces is around 500 lux. Gradual range of luminance on the walls. The major part of the interior envelope has just perceptible (1:2) or very soft (1:3) contrasts even in the main field of vision. However, the glazed surface (light source) which is, for some readers, in the secondary field of vision and, for others, in the main field of vision, leads to rather strong (1:18) and strong (1:24) contrasts. Colours are warm (red carpets and reddish exotic woods).

From these subjective and objective data we can say for comfort under an overcast sky that contrasts, luminance and illuminance levels are within the limits set by norms and recommendations, with only small excesses. Excesses are as follows: first, contrasts between the glazed surface (considered as a large light source) and its contiguous parts are a little bit higher than those recommended (by 25%). It can be regarded as very small excess. Second, because this glazed surface (naturally rather bright) is within the main field of vision for some readers (surface C on figure 1, the ratio A:C = 10:1 is not respected, it is around 5:1). The fact that, for some readers, the peripheral field is brighter changes the equilibrium of recommended contrasts. The ratio A:C is therefore twice lower than recommended, however stable for this type of sky. This situation has not been detected as annoying by users themselves. However we could not study the influence of this excess on visual weariness after a long time of exposure. Therefore, the ambience is comfortable for

most users, apart for a few of them who are exposed to the contrast A:C that is twice lower than recommended. This particular situation would have deserved in itself an experimental study: can the change in the equilibrium be compensated by a nice view through the glazed surface which shows a calm and stable image (a garden and an equilibrated surface)? For pleasantness, the interviewed readers have felt the ambience, as a whole, as pleasant, intimate and warm.

We can say that existing contrasts, even those above or under recommended limits, help to avoid uniform, monotonous or dull ambience. The distribution of contrasts in particular introduces a dynamic aspect: for example, contrasts on the ceiling are very soft. However, they very a largely and randomly vary (the ceiling is made of reflecting sheets of stainless steel). This soft but dynamic play with contrasts is pleasant -the surface of the ceiling is very large and a uniform one would have been dull. The warm colours have given an intimate aspect and also participate in pleasantness. The limit between pleasantness and discomfort is well defined.

Subjective answer: pleasant ambience
Measured comfort: twice two much (greater than recommended)

Under a clear sky:

The situation is more complicated than under a uniform sky. Pictures 5 and 6 present luminance and contrast distribution in more details. On figure 5, we see that a rather large surface of the window is exposed to sun and sky. It allows penetration of direct sunrays on 75% of the table surfaces in this room (see figure 6). In Paris, there is 50% of time with clear sky. Let us recall the qualitative-subjective responses under a clear sky (with penetration of direct sunlight into the room): irritating ambience, not adapted to concentration, like outside. The quantitative/objective data under a clear sky show that illuminance on work surfaces is well above 500 lux. Luminance measurements, without a white paper on the table should show imperceptible contrasts. Results show that the ratio between point 4 and 5 is around 1:4 (figure 6). Curiously it may reach 1:30 with natural or mixed light (artificial and natural) on different tables.

This variation from 1:4 to 1:30 on tables comes from the natural varying colour of the wood and from the type of polish used.

Considering comfort under a clear sky, illuminance on work surfaces is correct. On the contrary, contrasts are too high, from 4 to 30 times above recommendations. In this situation, apart from the fact that solar rays may enter the users' eyes, there are too many solar spots. Moreover the spots move and that creates a strong dynamics just where a uniform and stable surface is required. The work surface is very important in a library and one may consider that the ambience under a clear sky is not comfortable for an average user. The limit between pleasantness and discomfort is not well defined.

Subjective answer : not pleasant ambience
Measured comfort: 10 to 30 times too much

Fig. 5. The part of sky and sun visible through the transparent surface in a reading room Southwest oriented.

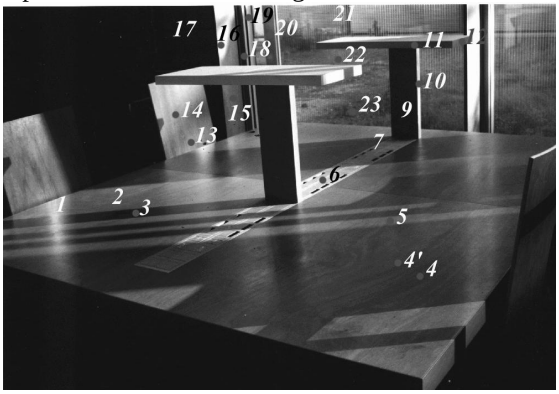


Fig 6. Contrasts due to direct sun on the reading surface.

The work therefore showed that comfort is not sufficient to ensure the quality of the ambience, that pleasantness may be in conflict with the comfort. Through these two projects and the numerous interviews we performed, it became obvious that subjective feelings greatly vary from one subject to another and that it strongly interferes with the notions of pleasantness and comfort. In order to further investigate this, we started a new project entirely devoted to the study of the impact of personality in the responses to luminous ambience.

3. Dimensions of personality in the responses to luminous ambience

In the first and second phases of this work, the population consisted in professors, students (mainly from our school, accustomed to the library) and librarians. We have not studied them in order to know if they were, for example, anhedonic or anxious etc, nor did we interviewed people who did not like to come. We have considered them as average. This is one of the weakness of these works. Answers have been interpreted as if people were all psychologically equivalent or average (without defining this average). To collect reliable results and analysis related to luminous ambience, we started to search for methods within a multidisciplinary project. The results of the first year of the project, our methods to take into account dimensions of personality in the study of luminous ambience, are presented here. These methods are currently used in the second part of the project which will be finished in eighteen months.

3.1. Objective

The research performed in the past few years led us to study the links between the perceptivo-cognitive handling of luminance and chromaticity and the ways social spaces are used according to their luminous ambience. It will help us better understand subjects' responses to luminous ambience and to identify characteristics of comfort and pleasantness. This knowledge should, in our opinion, allow improving the design of interior spaces.

3.2. Methodology

3 linked approaches are used: we test subjects in laboratories and select some of them according to their psychological profile. We measure specific luminous ambience in the chosen space and observe the behaviour of selected subjects in these spaces. We modify the luminous ambience of these spaces and then study the behaviour of similar (same psychological type) subjects in these modified spaces.

3.2.1. Selected sites

Two sites have been selected for our experiments: the café of the Grand Palais Museum in Paris and the café of the new institute of psychology in Boulogne. The selected spaces have been designed for rest where of comfort and pleasure are essential. The interior design and the lighting system are modern. Therefore, the results will interest professional people having to design rest spaces. The ambiences of the selected spaces are already of good quality and the luminous ambiences rather pleasant. They are not monotonous or uniform throughout the whole space. There are two or three zones with different luminous ambiences in each space. They are illuminated by both natural light and artificial sources as complement. We hope that people will choose their places essentially according to the space characteristics and, in particular, according to the luminous ambience. To minimise the constraints due to a crowded space, we perform our study during off-peak hours when the degree of freedom is greater.

After the studies described in this paper on the actual ambience in these spaces, we will design a second luminous ambience (called modified ambience) for each space. This modified ambience will be based on the definition of a new architectural concept of the ambience. We will also use the behavioural data we will have collected from the study in the sites with the initial ambience. The modified ambience will be designed using partial protections from natural light and carefully chosen artificial lights we will add. We will be particularly careful with the type of lights to add and their positions.

We will transform the contrasts and the gradual ranges of luminance. We may, for example, transform an existing monotonous zone, with no personality, into a calm, soft, little lighted zone with soft gradual ranges of luminance, very soft contrasts. Another zone can be transformed into a rather dynamic and animated one with strong contrasts, etc. Quantitative values for contrasts and gradual ranges of luminance for the initial ambience are measured and those for the modified ambience will be studied theoretically and built in the sites. The influence of contrasts and gradual ranges of luminance on comfort and pleasantness of the luminous ambience will be validated by the modification of the users' behaviours we will observe.

3.2.2. Measurements

We will measure luminance levels, illuminance and chromaticities on opaque and glazed interior surfaces in the selected spaces with lux-chromameter and luminance-chromameter. We will present the distribution of luminance on a luminance diagram for each ambience (initial and modified), for each zone and each field of vision. We will use a defined protocol of measurements where several problems (variability of exterior luminance, sky types, chromaticity of light, etc.) have been studied. Among the five sky types we have chosen the overcast sky because changes in the exterior luminous flux can only induce proportional changes of the interior luminance levels, but not of modify the luminance distribution. Therefore, within limits, variations in the exterior lighting will not prevent the continuation of the study.

3.2.3. Interpretation of measured data and links with qualitative expressions

These measured data will be interpreted and analysed to determine contrasts, gradual ranges of luminance and the main chromaticity. These results will be used by the study of people's behaviour. Secondly, we will look for the opinions of populations on the sites about their fields of vision. It will be used to find links between the qualitative expressions and the quantitative measured data.

3.2.4. Electrophysiological approach in laboratory

We have 48 wealthy subjects -16 reducing anhedonic, 16 augmenting anhedonic and 16 non-anhedonic (control group) subjects detected by a questionnaire. The recording of Event Related Potentials is performed in a room with a complete acoustic insulation. Subjects are installed in a comfortable and adjustable armchair. The brain activity is recorded on the surface of the head by 31 electrodes according to the international configuration of the 10-20 system. ([13] [14])

The stimuli are based on contrasts. The subjects have in front of them a screen on which 50 images will be displayed in a specific order. These fifty images represent 10 scenes with 5 different contrast levels and we record their reactions to contrasts. Hence, we measure the pleasure the subjects feel depending on the level of contrasts. Then one half of these subjects, whose personality' s dimensions are now well known, will go to the sites where the initial ambience has been studied. The second half will go to the sites when the modified ambience is applied. Their behaviour will be studied using the psycho-environmental methods.

3.2.5. Collected data during on site experiments

The analysis of behaviours will detect three types of information, the exact position chosen by people, the body orientation of people in the space and the collective or individual use of the space.

In a first phase, videos will be recorded to observe the behaviour of people (the 3 groups previously studied in the laboratory and the general population) in the spaces. During this phase, the observation grid and the categories for the coding of questions will be designed and validated. The observation methods in situ and the method of experimental mapping, to build density maps and occupation modes of a space, have been largely validated ([15] [16]).

Secondly, a semi-directed interview will be proposed to every subject in the space to collect their preferences about spaces for rest and their perception of the architectural quality of the site and of the luminous ambience. These interviews will also be used to collect the reasons people will give to explain the places they choose in the space and how they characterise it.

Finally, questionnaires corresponding to the scales for sensation seeking and anhedony will be given to the general population (who was not tested in our laboratory) who participated in the interviews in order to get information about their psychological attitude towards pleasure (hedony, anhedony, etc.). It is a less detailed method than ERP tests in a laboratory, but it still enables us to get some information about the psychological profile of people.

4. Conclusion

This paper briefly presents several projects undertaken in the past few years. This line of research is aimed at providing architects help to design comfortable and pleasant luminous ambience. Some specific parts of this paper have been published separately over the years. The overall research is presented here with perspective on future work.

This work began with an analysis of quantitative and qualitative data regarding luminous ambience. We have defined a protocol of luminance measurements for interior spaces for the overall interior surfaces and not only for working spots. This protocol (necessary because of the variability of natural light) helps to define extreme situations. It allows us to have comparable data and to rebuild intermediate cases if necessary. We have recorded and compared measures and qualitative (subjective) expressions for several spaces. This comparison was our basis to build definitions, founded on measured data, for qualitative expressions on luminous ambiences. It can also be used to enrich the language on luminous ambience and be of great help on the classification of luminous ambiences. We use this comparative approach in teaching in our school of architecture. We built a method to help structuring luminous ambience in natural lighting and develop a first implementation in neural nets. During this project, it appeared that people do not necessarily associate comfort and pleasantness. As this seemed to be generalised, we investigated this issue.

The possible conflict between comfortable and pleasant is a frequent issue in existing ambiences. We have tried to put forward some elements to answer this question using measured data. We showed that a luminous ambience may be comfortable but not pleasant, or pleasant but not comfortable. Comfort and pleasantness are two theoretically opposed notions: absence of psychological tensions for comfort, existence for pleasantness. However, we showed that they are not antagonistic when one is trying to build a good luminous ambience. A certain amount of discomfort may give some spice to a possibly dull situation, hence bring some pleasantness. The delicate question of these limits remains open. It is not our purpose to remind people that they should respect or not respect norms. But we showed tensions may be necessary for pleasantness.

The examples we presented show that even in renowned buildings, too uncomfortable situations may arise. Why is that? Do architects think that recommendations are useless, do they build their own criteria? Do they not know recommendations, or are they not even aware of the problem? As we have tried to show, the ignorance of recommendations may lead to unpleasant and not liveable ambiences and the strict respect of norms is not a goal in itself which may guaranty a good luminous ambience.

In fact, norms and recommendations in daylighting are rather general. Even if they are necessary, they are insufficient to design a pleasant luminous ambience. With his/her ability and creativity, architects should integrate existing recommendations in the design, but also adapt them to new situations while avoiding unpleasant ambiences. Of course, it requires a deep understanding of these phenomena and more than a superficial knowledge of norms and techniques. It requires a genuine culture of ambience which one should begin to acquire during his/her study in architecture.

This work on pleasantness based on interviewed subjects showed us that individual perceptions greatly differ from on subjects to another. In order to verify the validity of our results and to improve our understanding our luminous ambience, we started a project focused on the importance of the dimensions of personality in the subjective responses to luminous ambience.

We expect to better understand reactions to luminous ambience by individuals having different perceptive sensitivity. It will allow to better defining the notions of comfort and pleasantness for

luminous ambience in rest spaces. In architectural design, professionals use qualitative expressions. Our results will allow to better link this qualitative approach to quantitative and experimental data. This link will greatly facilitate the integration of the results of this study by the professionals.

Several results are expected from this work, the main ones are:

- Identify contrast thresholds and levels for gradual range of luminance which are comfortable and pleasant for people with known sensitivity (extreme or not). It will help to advance this current debate in architecture. Moreover, as artificial lighting is used by architects and users to change contrasts and gradual ranges of luminance to obtain a pleasant ambience, these thresholds will help control and optimise the expenditure of energy.
- Understand the adjustment behaviour of people having a hyper or hyposensitivity.
- Identify the criteria expressed by users in the choice of a place in a café and determine, among all given criteria, the ones linked to luminous ambience.
- Improve the analysis and interpretation models to define luminous ambiences and link them to qualitative expressions in order, for example, to develop simulation tools for luminous ambience.
- Improve measurement protocols in artificial/natural lighting mainly with chromaticity integration.
- Offer a better understanding of the use of rest spaces by linking the behaviour of people and the given reasons, that is between the representations of individual motivations and actual behaviours.

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