

# Visual Appearance of Office Lighting

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## ABSTRACT

THE VISUAL ENVIRONMENT OF A simulated office in a laboratory has been evaluated by 21 observers through semantic differential and preference scales. The lighting provided by luminaires equipped with 36 fluorescent daylight lamps, were adjusted at three levels above three desks with different orientations. The horizontal and cylindrical illuminance and the task luminance were recorded for each lighting situation and they varied between:  $E_h=240-1300$  lx,  $E_c=7-38$  lx,  $L_t=32-225$  cd/m<sup>2</sup>.

The ANOVA test showed that 6 adjectives were more powerful in order to distinguish the three lighting levels: attractive, dark, stimulating, bright, soporific and warm.

Most of the assessments concentrates around illuminance levels of 400-550 lx. Those levels correspond to hardly and moderate on the assessment scale. For those levels the electrical lighting power load of the room is around 20W/m<sup>2</sup>. On the other hand, the higher the illuminance levels, the more discriminating the adjectives. For 1200 lx, the illuminance level selected as optimum, the power load is around 35W/m<sup>2</sup>. From 500 lx a region is limited by bright and dark. The same tendency is shown for levels lower than 500 lx but with opposite sign.

## INTRODUCTION

Office lighting has important consequences in terms of energy consumption and economic impact. The electrical energy consumption destined to lit offices amounts to between 25% and 50% of the total electrical energy demand of such buildings<sup>1</sup>.

An accepted reference to evaluate the energy demand and the rationality of office lighting in terms of users needs are the illuminance level recommendations. The techno-

logical and social development have had strong impacts on recommended illuminance levels. The extensive introduction of computers in offices has not only added a variety of visual tasks but also created new demands of work organization<sup>2</sup>). Such development and the availability of more efficient lamps and luminaires have been followed by a continuous increase in recommended illuminance levels. In USA, for example, the amount of light recommended to perform a task like reading in offices has varied between 1910 and 1959 from 20 to 750 lux<sup>3</sup>). The last value is still recommended.

These figures could vary depending on the conceptual framework selected to determine the amount of light needed in offices. The balance between office workers productivity and energy consumption has been interpreted mainly in terms of visual performance. One milestone of this approach since the 40's are the work of Weston<sup>4</sup>) where the visual performance is defined in terms of the efficiency and speed with which the visual task is performed.

Another aspect is the comfort or satisfaction that the office lighting generates for the users. When observers are asked to assess office illuminance levels as too dark, satisfactory or too bright, 80% of them select 2000 lux as satisfactory<sup>5</sup>). Other studies show that in terms of assessing office illuminance levels as low, correct and high, around 90% of the office workers chooses between 600 to 1000 lux as correct<sup>6</sup>).

The CIE recommendations for office lighting includes illuminance levels between 500 and 750 lux<sup>7</sup>). These levels are mainly based on visual performance oriented studies.

Recently it has been suggested that the office lighting

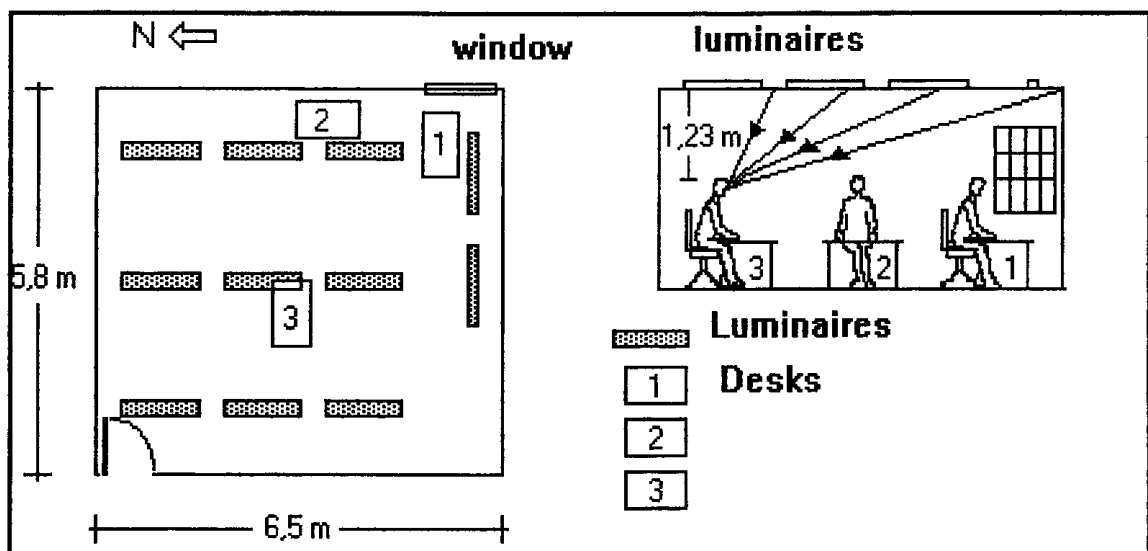


Figure 1 shows a plant and sectional view of the room with the distribution of the luminaries and the position of the 3 desks from where the observers evaluated the room.

levels needed by the users vary during the working day. The levels adjusted by the office workers are between 1000 and 2500 lux depending on the season and the daylight contribution<sup>8)</sup>.

The increasing evidence obtained from investigations on the influence of lighting on users behaviour considering no visual effects of light on human being, indicates that both the recommended levels and energy demand<sup>9)</sup> could vary dramatically.

This paper resumes results obtained at a laboratory simulated office where a group of observers assessed the desk lighting on the task area in terms of perception of the environment and preferences. The methods used to gather data included semantic differentials as an instrument for subjective evaluations in lighting research<sup>10)</sup>, psychological architecture studies<sup>11)</sup> and surveys of preference opinions.

The values of lighting levels for office lighting, deducted from the semantic differential analysis, can be compared with the values adopted in different countries when the frame work is either visual performance based methods or preference studies. The analysis of the data and the conclusions derived are included in the above mentioned situation about office lighting levels. This review does not intent to include all the main contributions on this subject, but to serve as a frame for the analysis of the data - that were generated during this research project - on Subjective Evaluation of Office Lighting<sup>12) 13)</sup>

#### EXPERIMENTAL ASPECTS

##### TEST ROOM

The office was simulated in a room of 6,50 m x 5,80 m with an aluminium blinded window towards the East, reflectance 66%, panel ceiling with three lines of recessed luminaries with louver, each one equipped with four fluorescent lamps of 36W daylight (5000 K.). The illumination of the room was completed with wallwashes on the southern wall made by two luminaries with diffuse plastic cano-

pies, each one with a 36W daylight fluorescent tube. Three illuminance levels were provided on the desks. The circuits allowed to switch on one lamp at a time by each ceiling luminaire.

#### OBSERVERS

A group of 21 persons participated: 11 females and 10 males, between 22 and 38 years old. They were students of psychology and electric engineering and staffmembers of the institute, with normal vision and without previous knowledge of this kind of test.

#### PROCEDURES

A completely randomised model was used for the experiment. The 21 observers entered the office three at a time for each lighting level, placing themselves each time at a different desk, on which typical office elements were placed

The experiment does not pretend to evaluate visual performance, the observers should merely judge the visual environment as a whole, using a form with semantic differentials, followed by marking their illumination level preference (three selections) for which the grade of difficulty that they had reading the adjectives form could be taken as a reference.

Each observer took approximately 25 minutes to do all the tests.

#### VISUAL ENVIRONMENT EVALUATION TECHNIQUES

##### SEMANTIC DIFFERENTIALS

The observers were given a list of 18 adjectives which intended to describe different perceptual dimensions of the lit room. The persons indicated to which level each adjective described their sensation by marking: nothing - hardly - moderately - totally - extremely.

##### ILLUMINATION LEVEL PREFERENCES.

Three illumination levels were selected. Calculating the

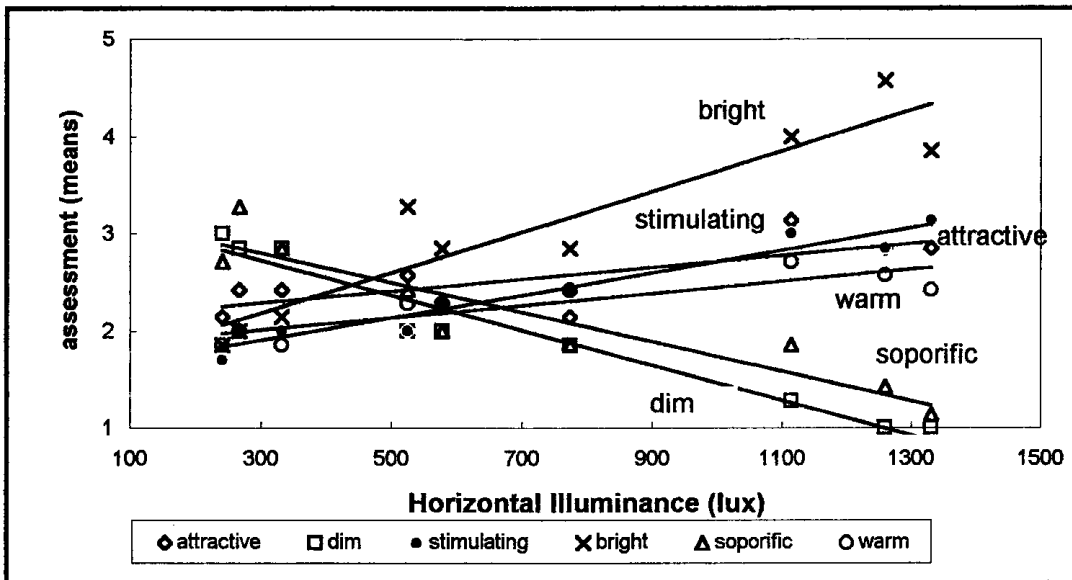


Figure 2 a

Figure 2 b

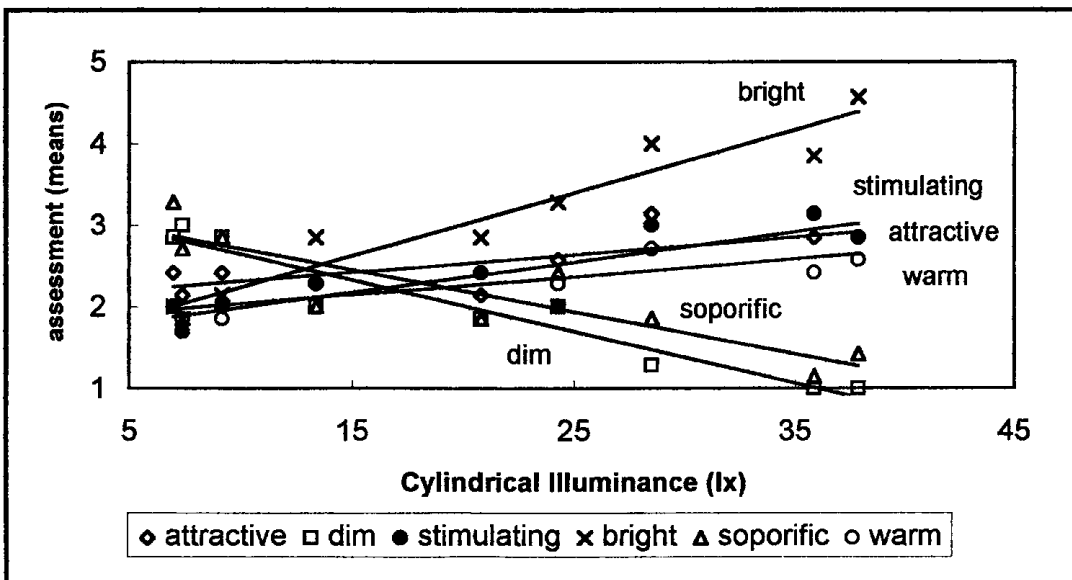


Figure 2- Subjective assessments vs. Photometric values. Average values of Eh, Ec and Lt for the task adjusted illumination levels and average subjective assessments of the magnitudes by the adjectives attractive, dark, stimulating, light, soporific and warm.

average from the three desks, level 1 was **280 lx**, level 2 **625 lx** and level 3 **1235 lx**. The observers should indicate their preference for these levels on a five point scale: excessive - optimal - sufficient- hardly sufficient- insufficient.

#### PHOTOMETRIC SURVEY

The luminance was measured in different areas of the room from the direction of the eyes of the sitting observers (see Figure 1). Besides, the luminance, the horizontal and cylindrical illuminances of the task were registered. All the measurements were carried out with a luxmeter equipped with accessories to measure cylindrical illumi-

nance and luminance. In this last case, the measuring field covered by the equipment was 30°.

#### RESULTS

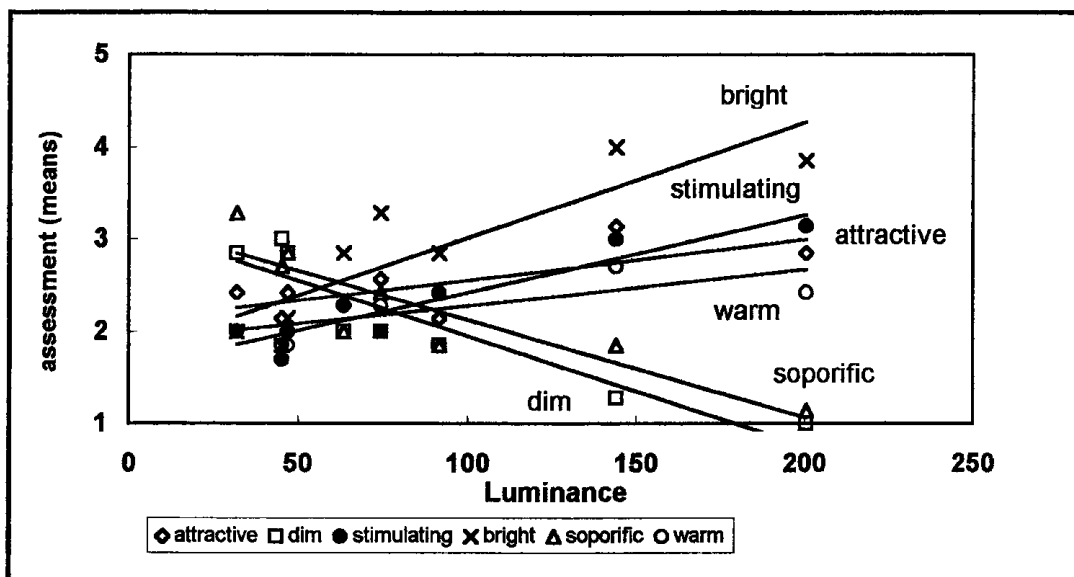
##### SEMANTIC DIFFERENTIALS

The data obtained with the semantic differentials were processed by three statistical methods:

##### *Factor Analysis:*

18 five-graded scales answered by the subjects in the three situations (lighting levels) were factor-analyzed, and five different factors were obtained. These are shown below,

Figure 2 c



described by the most powerful scales in each factor and also by the proportion of total variance explained by it in % (V P).

1. *Evaluation*: attractive, appropriate, dynamic, sociable, harmonic, stimulating, comfortable, small. VP=31.
2. *Visual Clarity*: dark, bright, soporific, confusing. VP=24.
3. *Sociological Characteristics*: modern, original, warm. VP=15
4. *Adequacy*: impersonal. VP=15.
5. *Spaciousness*: cold, closed. VP=13.

*Comparison of Photometric Values and Adjectives. Variance Analysis.*

Through this analysis the semantic rating scales that differentiate the three experimental situations (three illumination levels) were identified: attractive, dark, stimulating, bright, soporific and warm. The average scores were graphically displayed in terms of the photometric parameters measured. The data were adjusted through least square linear regressions: **Eh, horizontal desk illuminance**, from 240 to 1300 lx, **Ec, cylindrical illuminance**, 7 to 30 lx and **Lt, task's luminance**, 32 to 225 cd/m<sup>2</sup>. (See Figure 2.). The correlation coefficients, obtained for the six adjectives and the three photometric parameters are high, being the highest for horizontal illumination.

*Stepwise Discriminant Analysis*

This analysis was applied to classifying scales obtained through the former analysis, the major discriminative power of the three situations is reduced to adjective "bright".

PREFERENCES

The results of the illuminance level preferences survey are depicted in Figure 3. Around 50% of the opinions agree that 625lux are sufficient while 70% of the observes determined that the optimum preferred illuminance level is 1.200lx.

DISCUSSION

The results obtained with the semantic differentials, particularly for those adjectives related to visual appearance of the room, can be adjusted by linear regression. The lines shown in Figure 2, describes the variation of the subjective assessments with the lighting parameters. The lines meet in a zone which corresponds to the mid point of the subjective scale. This means that the six selected adjectives are assessed as moderately for illuminance levels between 500 and 600 lux. For lower illuminance levels, the lines diverge, entering for all adjectives in the classification zone between hardly and nothing, thus in the area where the illumination level is insufficient. As the illumination level increases, the observers differentiates more precisely between the environment's character and the effects of the illumination.

The distribution of the evaluation lines defines an area limited by **bright** and **dark**, besides including an intermediate discrimination zone with **attractive** and **stimulating**, which are adjusted by lines with similar slopes and limited by **soporific** and **dark**, also described by similar negative slopes.

These results can be interpreted as if the subjective evaluation of the illumination of the room is summarized in three adjectives, one linked to the sensation of brightness evoked by direct and reflected light of the environment and its opposite linked with the perceived grade of darkness. In the middle an adjective related to the character of the environment (attractive) and its effect on the observer's state of mind (stimulating).

This is a result that coincides with the factor analysis that was done to the 18 adjectives, which shows that the factors with the greatest percentage of data variance are referring to evaluative and visual brightness impressions.

Among them the adjective bright was the one with the greatest discrimination power in the three experimental situations.

The illuminance level of 600 lx., which is usually includ-

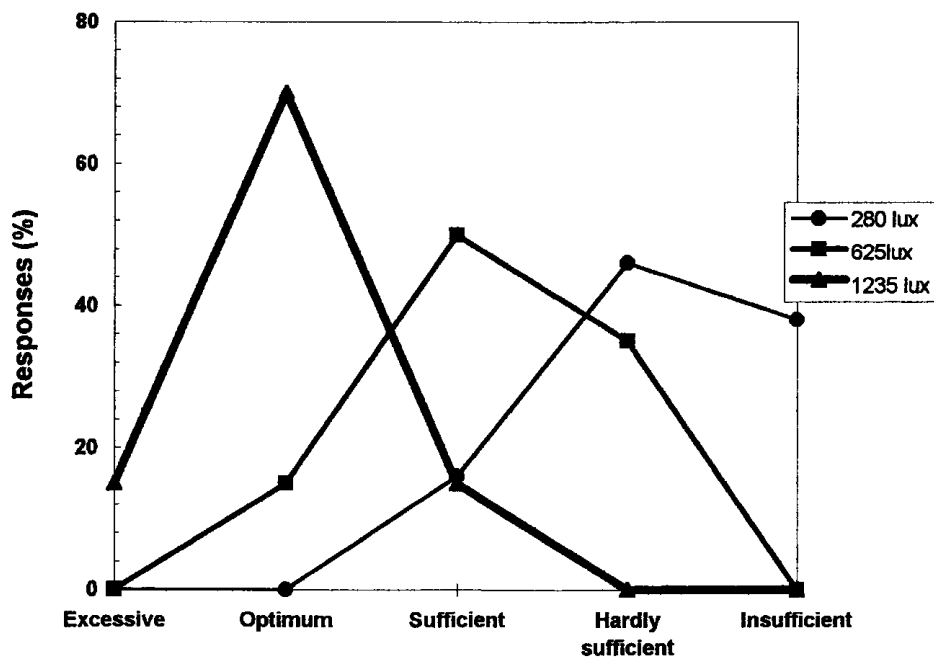


Figure 3

ed in the lighting recommendations for offices, was judged as sufficient and 70 % of the observers classified the level 1200 lx. as optimal.

#### CONCLUSIONS

For simulated office room under the following conditions:

- bright walls
- low glare luminaries equipped with fluorescent day-light lamps
- illumination levels between 500 and 600 lux on the desks
- energy load of approximately 20 W/m<sup>2</sup>.

the present study shows a *moderately bright, attractive and stimulating* appearance to observers aged between 22 and 38 years.

Increasing the illumination level on the working places to twice as much, around 1.200 lux, which implies an energy load of approximately 43 W/m<sup>2</sup>, the room's appearance is evaluated as *totally bright, moderately attractive, stimulating and warm*.

The adjective bright is the one which, with major intensity, registers the observers evaluations of the visual appearance of the room. Referring to the adjective warm, the variation of the evaluation between 500 and 1.200 lx. is between *hardly* and *moderately*, indicating a strong influence of the daylight colour of the lamps.

#### AKNOWLEDGEMENTS

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#### REFERENCES

- 1) United States Department of Energy, *Overview of Building Energy Use and Report Analysis - 1985*, Office of Buildings and Community Systems, Washington DC, October 1985.
- 2) Organización Internacional del Trabajo (OIT), *Las repercusiones socioeconómicas de las nuevas tecnologías*, Comisión Consultiva sobre Tecnología, ACT/1/1985/II
- 3) Collins B., Fischer S., Gillete G., Marans R., *Evaluating Office Lighting Environments: Second Level Analysis*, Department of Commerce, United States of America, NISTIR 89'4069, April 1989
- 4) Weston H, C., *The relation between illuminance and visual performance*, Industrial Health Research Board, Report N° 87, HMSO, London, 1945.
- 5) Fischer D., *Optimale Beleuchtungsniveaus in Arbeitsräumen*, Lichttechnik, Band 22, S. 61-103, 1970
- 6) Vanlerlan J.F.A, *Two thousands Dutch office workers evaluate lighting*. Publication N° 283, Institute for Environmental Hygiene, TNO, Delft, Holland, 1967. Quoted by P. Boyce in "Human Factors in Lighting: Designing for people", Lighting in Australia, vol.2, December 1982.
- 7) CIE- Publication 29, Guide on interior lighting, 1986
- 8) Begemann S H A, van den Beld G J, Tenner A D, *Daylight, Artificial Light and People, Part 2*, Proc. 23rd Session of CIE, vol 1, 148-151, 1995
- 9) Brainard G C, *Effects of light on physiology and behavior*, Proc. 23rd Session of CIE, vol 2, 1995
- 10) Flynn J, Hendrick C, Spencer T, Martyniuk O, *A guide to methodology procedures for measuring subjective impressions in lighting*, Journal of IES, January 1979
- 11) Küller R, *Beyond Semantic Measurements. Architectural Psychology*. Proc. of the Lund Conference, Studentlitteratur, University of Lund, 1973

12) Tonello G, *Evaluación Fotométrica y Subjetiva de una oficina simulada en laboratorio*, Actas de LUX AMERICA 92, San Pablo, Brasil, 54-57, Agosto 1992.

13) Tonello G, Kirschbaum C, *Evaluación Fotométrica y Subjetiva de una oficina simulada en laboratorio, Parte 2*, Actas de LUX AMERICA 93, Buenos Aires, Argentina, 1994.