

LIGHTING QUALITY AND LUMINANCE DISTRIBUTION: WHERE IS THE IMPORTANT PART OF FIELD OF VIEW?

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INTRODUCTION

There have been different approaches to the definition as well as the measurement of lighting quality. However, a definitive definition eludes us and a metric of lighting quality seems remote. In this paper, the original theoretical consideration and suggestion on the framework of lighting quality are proposed. After these consideration, it is felt that the most useful road of development is the gross luminance pattern and its subjective assessment. This paper therefore takes the original work of Loe et al.(1) and performs some further analysis on the dataset.

THEORETICAL CONSIDERATION

Three factors contributing to visual comfort in the environment

In his classic paper, Waldram(2) explores the mechanism of interior lighting and in a flow chart defines three aspects of interior lighting: Adaptation, Revealing of Form and Texture, and Emphasis. In this diagram he considers three detail luminance patterns: texture pattern, shadow pattern and modelling pattern. Cuttle(3) has subsequently extended the modelling concept and introduces a term “preferred appearance” related to the flow of light.

However, the factors contributing to visual comfort in the environment are thought to be more extensive. In order to construct a comprehensive explanation for visual comfort, three factors contributing to visual comfort are proposed by the author. The first factor is the physiological and psychological condition of the visual system. This includes not only adaptation state but also visual stress, visual fatigue, concentration or mood, etc. which are correlated with the other two factors below. The second factor is the visibility for object discrimination related to the nature of the visual task, safety issues and security issues (feeling secure). The third factor is the meaning of the environment. The meaning of the environment means not only the understanding of the environment but also environmental conditions favourable for survival and well-being as well as some kind of effect of “lifting the spirits”(4). The meaning of the environment from the visual information presented can be categorized into two groups: (i) the lighting condition and (ii) the feature of the surroundings, such as their shapes, spatial arrangements and other attributes. Of three factors contributing visual comfort, this paper only considers the lighting condition.

General hypothesis behind lighting quality studies

The General hypothesis in this paper is that our objective as a human being is to live, not only to exist, therefore all psychophysical (or psychophysiological) responses must contribute to this objective without exception. This idea can be found to some extent in neurological research and is also found in early research work in landscape and lighting quality. For example, Zeki(5) states that the brain seeks stability in the face of the continually changing environment. This mechanism seems to be suitable to acquire information useful to biological needs/survival. Appleton(6) proposed that aesthetic satisfaction stems from the spontaneous perception of landscape features which act as sign-stimuli indicative of environmental conditions favourable to survival and called it habitat theory. Corth(7) re-interprets and synthesizes ecological and biological data into a new concept: it is likely that Homo sapiens as well as its visual system evolved in a forest habitat. Eventually he concludes that “Natural light, whatever it may be, is certainly not sunlight in an open sky; only the filtered light under a forest canopy might reasonably claim that designation”. Heerwagen(8) argues that for most organisms, being in “the right place” is an important determinant of survival and well-being, therefore, there is no reason why this should be different for humans.

Information from the environment is judged whether it is favourable or not through ancestral memories and experiences. In respect of the ancestral memories concept, Appleton(6) argues that humans have an evolved preference for environments that enable one to see the surrounding environment (prospect) from a protected location (refuge) because of the memories of hunting. Appleton's prospect-refuge theory was developed with reference to the natural landscape, and it must be the only environment where these ancestral memories were built up. Accordingly, the context in which psychophysical responses operate is that of the natural environment which is familiar to our psychophysical system.

Objectives of the analysis

A positive feeling like brightness or interest from the environment might be achieved if the built environment had similar characteristics to those of the favourable natural environment. Which qualities of the built environment need to be defined to match that of the natural environment? Where is the important part of field of view? This paper concentrate on the perspective of gross luminance pattern, especially on boundary surfaces.

EARLY WORKS AND THE DATASET

Reconsider The original work of Loe et al (1994)

The experiment in the original work of Loe et al.(1) whose data is analyzed in this paper is mainly designed to investigate the third factor contributing to visual comfort mentioned earlier in the introduction. The subjects had no problem about the first factor. Concerning the second factor, the subjects were in the conference room and the visual task is not difficult. They were not concerned about safety issues either.

This work proposed the concept of "horizontal degree band" as the important part of field of view. The horizontal degree band concept of field of view is shown in Figure 1. Since Loe et al. gave little interest to the meaning of the horizontal degree band, further consideration and definition are thought to be required. Human beings have relatively wide visual field, but focal vision and peripheral vision work differently. Although we can quite easily look around wherever we want, there might still be the difference in importance between the wall in front and the ceiling overhead when we feel the atmosphere of the room. The main results of this work were as follows:

2 factors were extracted: Brightness and Interest, which are the main factors of lighting quality or preference. The work suggests that individual semantic differential scales may now be used to make initial indications of the values of luminance

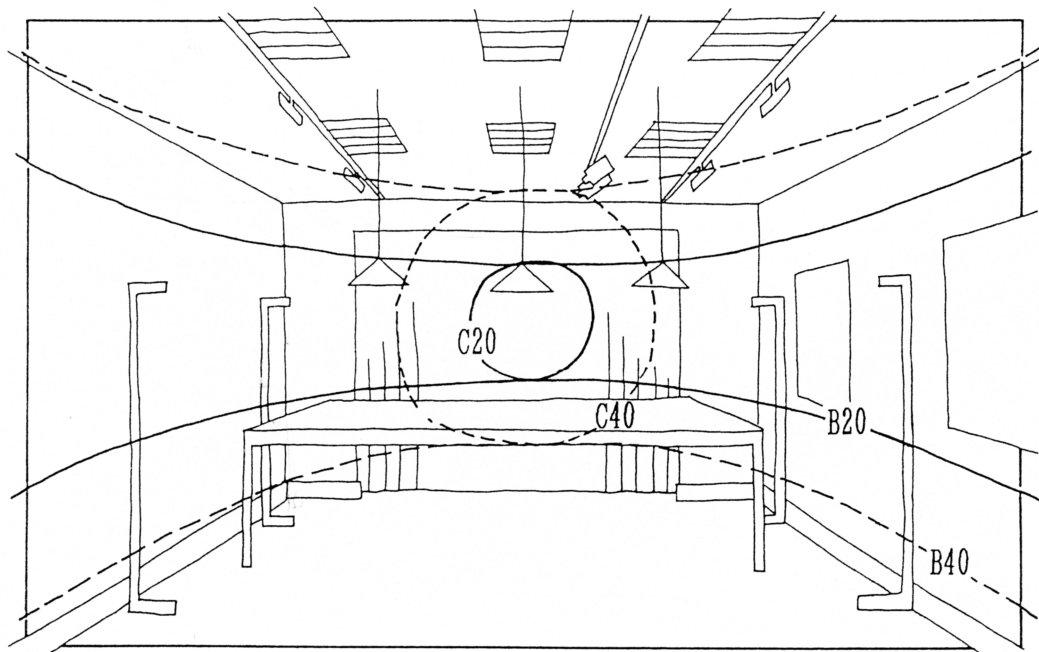


Figure 1 Figure of the room and the concept of horizontal bands(1).
Dotted lines do not indicate the boundary on the surfaces.

parameters within a lit environment to achieve specific subjective assessments:

(A) By inspecting the bright - dim scale at the point at which it is assessed from being generally dim to generally bright, a value of 30 cd/m² for the average of luminance within the horizontal 40degree band is noted.

(B) Similarly, for a lit environment to be assessed at the point at which it turns from being generally uninteresting to generally interesting, a value of approximately 13 on the maximum/minimum of luminance within horizontal 40degree band is found.

Dataset of subjective assessment and luminance parameters

The same sets of subjective assessment and luminance distribution data are used as the original work of Loe et al.(1). This paper should be referred to if full details of the experiment are required. The abstract of experimental arrangement and procedures are quoted below.

The experimental room is situated within an existing room space and it was furnished as a small conference room. Lighting patterns are comprised of 18 conditions from uniform lighting to concentrated lighting. Luminance was measured with the instrumentation which comprised a luminance-measuring head mounted in a cradle which was powered by two stepper motors. The measured values are stored on a computer disk, weighed and analyzed. Each of the lighting conditions was assessed by a group of 12 observers from a position at the side of the room using traditional semantic differential scale techniques. All the observers were members of the staff of The Bartlett, University College London. The order of presentation of the different lighting conditions to each observer was varied to minimise any order effects. Care was taken to ensure that there was a short adaptation time of a few minutes by the observer to each condition before assessment commenced.

SUBJECTIVE ASSESSMENT AND LUMINANCE PARAMETERS

Important visual field for Brightness factor

As Loe et al. suggested, it is possible that in some circumstances the use of individual scales would be more straightforward and advantageous, giving a clearer picture. Therefore, the measure of association between the luminance parameters and 2 individual scales “bright - dim” and “interesting - uninteresting” were tested in this investigation.

In the previous investigation of correlation between average luminance of different parts of the field of view and the Brightness factor, the logarithm of average luminance of horizontal band width 40 degrees had the highest correlation and was considered the most logical and influential because it encompasses the main area viewed when a person looks around a space. For further investigation, other band widths were tested in a similar way. The corresponding correlation coefficients for the bright-dim scale are given in Table 1. This table includes the whole measurement area and central circles for comparison. It is clear that the correlation coefficients for central circles are relatively low. The correlation coefficients for horizontal bands are generally similar. This demonstrates that the choice of band width is not too sensitive but the horizontal band concept still has some advantage over the whole measurement area and certainly over the central circle area.

Important visual field for Interest factor

With regard to the Interest factor, the correlation between the ratio of the maximum luminance to the minimum luminance (max/min ratio) of different parts of the field of view was tested in the previous investigation and the logarithm of this ratio of horizontal band width 40 degrees had the highest correlation. However, since the minimum values of luminance are

Table 1 Correlation between logarithm of average luminance of different parts of field of view and bright-dim scale.

| Area of field of view | Correlation coefficient |
|--|-------------------------|
| Whole measurement area (W) | 0.91 |
| Central circle angular subtense 40deg(C40) | 0.84 |
| Horizontal band width 30deg(B30) | 0.91 |
| Horizontal band width 40deg(B40) | 0.93 |
| Horizontal band width 50deg(B50) | 0.94 |
| Horizontal band width 60deg(B60) | 0.94 |

Table 2 Correlation between various luminance ratios in different parts of field of view and interesting-uninteresting scale.

| Area of field of view | Correlation coefficient |
|------------------------------------|-------------------------|
| C40max/C40 average | 0.14 |
| log C40 max/C40 average | 0.05 |
| C40 max/B40 average | 0.45 |
| log C40max/B40 average | 0.34 |
| C40 average/peripheral average | 0.46 |
| log C40 average/peripheral average | 0.55 |
| C40 average/W average | 0.49 |
| log C40 average/W average | 0.55 |

Table 3 Correlation between logarithm of ratio maximum luminance/average luminance in different parts of field of view and interesting-uninteresting scale.

| Area of field of view | Correlation coefficient |
|--|-------------------------|
| Whole measurement area (W) | 0.42 |
| Central circle angular subtense 40deg(C40) | 0.05 |
| Horizontal band width 30deg(B30) | 0.58 |
| Horizontal band width 40deg(B40) | 0.68 |
| Horizontal band width 50deg(B50) | 0.60 |

considerably low, if there were some error, it could obviously influence this ratio. Therefore a more robust parameter is required.

The ratio of the maximum luminance to the average luminance (max/av ratio) could be considered as the parameter that represents the degree of luminance non-uniformity as well as the max/min ratio. The association between the max/av ratio of various areas of the field of view and the interesting-uninteresting scale was tested. The corresponding correlation coefficients are given in Table 2 and 3. Correlation coefficients with ratios related to the central circle shown in Table 2 are relatively lower than those with ratios within the horizontal band shown in Table 3. As for band widths, 40 degrees has the highest correlation of 0.68, which is nearly equal to the value from the maximum to minimum ratio used in the previous investigation. Therefore, the logarithm of ratio maximum luminance to average luminance within the horizontal band width 40 degrees is proposed as a robust parameter of visual interest.

DISCUSSION

The extended analysis confirms that the concept of horizontal bands is one of the key definition of lighting quality within a room. As for the band width, 40degree would be the most important part of view, though wider band width could be appropriate for Brightness. Is there a plausible explanation why the horizontal band width 40 degrees is the most useful measure? Note the fact that subjective scales are correlated with the luminance of horizontal bands and not with central circles showing the way people look around the environment. In the original experiment observers were encouraged to look around the room. That is to say people scan almost horizontally and usually do not look up or down unless it is necessary.

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