THE SHARPNESS AND THE FLOW OF LIGHT

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Abstract

This paper is concerned with how perceptions of objects and surroundings are affected by the directional nature of lighting. The changing appearances of isolated objects are examined, and also how these relate to more general perceptions within a room.

The concepts of the Sharpness and the Flow of Light are proposed to describe the principal aspects of these effects, and the physical parameters to which they may be related are identified. Means of prediction and measurement are described briefly, and sources of recommendations expressed in these terms for the guidance of lighting designers are referred to.

This paper is concerned with the effects of the directional nature of lighting. Firstly, the manner in which our perceptions of objects can be influenced by directional lighting is examined, and the concepts of the Sharpness and the Flow of Light are proposed. Secondly, the physical parameters to which these concepts are related are examined.

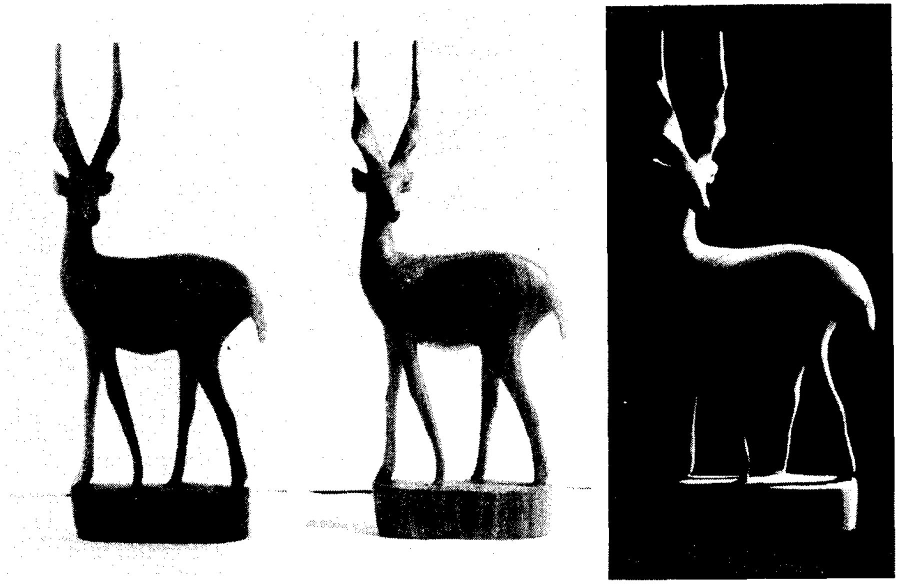
Object Appearance and Directional Lighting

Fig. 1 shows three views of the same object. In Fig. 1a the object was surrounded by a uniform white field, and the effect is dull and totally lacking of the qualities that we appreciate in good lighting. In Fig. 1b the addition of directional lighting gives a much more attractive effect. The appearance of the object is enhanced and it is more likely to be rated as a desirable or friendly object. However, the increased strength of directional lighting in Fig. 1c does not simply re-enforce this effect, but produces an effect that is quite distinctly different. The appearance of the object is dramatic, and now it is more likely to be rated as an aggressive or sinister object.

Clearly, the concept of "modelling" which has been described by Moon and Spencer (1951) and Waldram (1954) as the extent to which the three dimensional form of an object is revealed by directional lighting, is quite insufficient to describe these changes of object appearance. New concepts are required.

The basic physical characteristics of directional lighting can be more easily identified in Fig. 2. Fig. 2a shows three objects that we recognise immediately as attractive objects that give us pleasure, but the lighting does nothing to enhance their appearance. Fig. 2b is much better , with attractive patterns of light and shade created by the interaction of the object's surfaces and the directional lighting. We may feel inclined to conclude that we have achieved some sort of preferred object appearance.

In fact, this can not be so, for the three objects have responded to the directional lighting in three distinctly different ways. The matt surface of the peach shows an illumination pattern, while the shiny surface of the apple is dominated by a highlight pattern, and the coarsely textured surface and foliage of the pineapple show an intricate shadow pattern. These are the three lighting patterns; and it is the nature of their formation and the balance between them that constitute the physical characteristics of directional lighting.



(a) (b) (c)

FIGURE 1 - Lighting of Carved Wooden Figure

(a) (b)

FIGURE 2 - A Peach, an Apple, and a Pineapple

For Fig. 2 the objects were selected to separate as far as possible the three lighting patterns. In Fig. 1b they are all super-imposed on the surface of one object, but although super-imposed they are separately identifiable. In Fig. 1c the patterns have merged, and in Fig. 1a they are totally absent.

For general lighting purposes a preferred situation is not one that produces a particular type of object appearance, but it is one that produces variety of object appearance. If the lighting is suitable, all opaque solid objects show distinct illumination patterns related to their own surface forms, but glossy objects also show highlight patterns and objects with surface concavities show shadow patterns.

The lighting of a particular object, such as a sculpture, will require appraisal of the object's surface properties and this could lead to a design objective stated in terms of the formations of the three lighting patterns, but for general purpose lighting the approach must be different. The design objective cannot be stated as a type of object appearance, but it must be stated in terms of a type of lighting.

For the physicist this creates a dilemma, for he claims that we do not see lighting but rather the light reflected from objects. The three lighting patterns are capable of photometric specifications, and as they are the physical characteristics of directional lighting, some means of specifying their formation would seem to be an essential requirement for a method of taking account of the effects of directional lighting.

However, it is apparent that we do not perceive these lighting patterns. The difference between a room illuminated by side windows and one illuminated by overhead lighting may be physically identifable in terms of the lighting patterns, but perceptually the difference is much more simple. We perceive that the lighting is different.

Two concepts are proposed to describe the perceived differences.

The Concepts

The Flow of Light describes the impression of the strength and the direction of lighting, either at a point or generally within a space. Every opaque solid object within a directional lighting field generates an illumination pattern, and it is from the appearances of these illumination patterns on all of the objects surrounding us that we develop a total perception of the varying strength and direction of lighting within a room. If an object, such as another occupant of the room, moves to a position where previously there was no object, it would be a point of perceptual confusion if either the strength or the direction of the illumination pattern generated did not confirm with our general perception of the flow of light.

The Sharpness of Light is a secondary but nonetheless important aspect of our perceptions. A single small light source causes sharply defined shadow patterns with clean cut edges and sharp, compact highlight patterns even though there may be sufficient diffuse light present for the flow of light to appear moderate or weak. Alternatively, a source of larger angular subtense may produce a similar impression of the flow of light with markedly less sharpness.

The situation is, then, that the concepts of the sharpness and the flow of light may be used to describe the principal perceived effects of directional lighting, and these may be related to the physical parameters that define the formation of the three lighting patterns.

The Physical Parameters

Although sharpness would seem to be the easier of the two concepts to relate to physical parameters, it has received little attention from the experimenters. Lighting Engineers have, of course always understood the importance of using incandescent lamps for display lighting when they want to achieve sharp highlight patterns, and many other examples could be quoted from practice, but as yet there has been no studies of how the perception of sharpness varies with the changes of the surrounding light field. However, the β/ρ concept proposed by Lynes (1971) makes a valuable contribution to the understanding of how object appearance is influenced by the nature of the highlight pattern.

The index of the strength of the flow of light is the Vector/Scalar Ratio and the perceived direction of flow corresponds with the Vector Direction. These parameters have been described in detail by Lynes et al (1966) and Cuttle (1971), and the following is a brief summary.

Vector and Scalar Quantities of Light

The three dimensional distribution of illumination about a point in space may be represented by the Illumination Solid, which has a form such that the distance from the reference point to the surface of the solid in any direction is proportional to the illuminance measured normal to that direction.

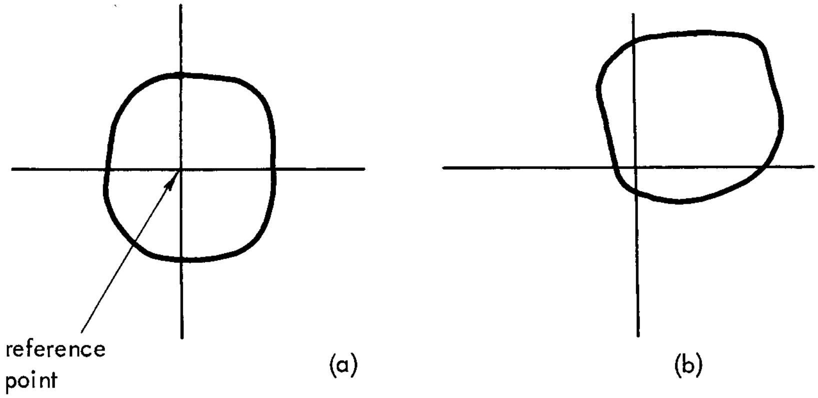


FIGURE 3 - Sections through two illumination solids

Fig. 3a shows a situation in which illuminance is almost the same in every direction, and so an object centered at the reference point will not generate an illumination pattern and there will be no perceptable flow of light. On the other hand, Fig. 3b shows an illumination solid that is highly asymmetrical about the reference point. This lighting condition will generate strong illumination patterns and the impression of a strong flow of light.

The two solids from which these sections are taken specify completely the spatial distributions of illumination about the two reference points. While some impression of the strength and direction of the flow of light can be gained from just looking at their shapes, to make objective comparisons a means of expressing numerically the essential characteristics of an illumination solid is needed.

The first characteristic of interest is the average value of the illumination solid, which is equal to the average illuminance over the whole surface of a small sphere centered at the reference point. This is termed Scalar Illuminance, as it is specified by magnitude only.

It has been shown by Cuttle et al (1967) that quantitative assessments of the illumination of a group of solid objects correlated better with measured values of Scalar illuminance than with conventional measurements of illuminance on a horizontal plane. Scalar illuminance has its own uses, but it specifically ignores all directional aspects of lighting.

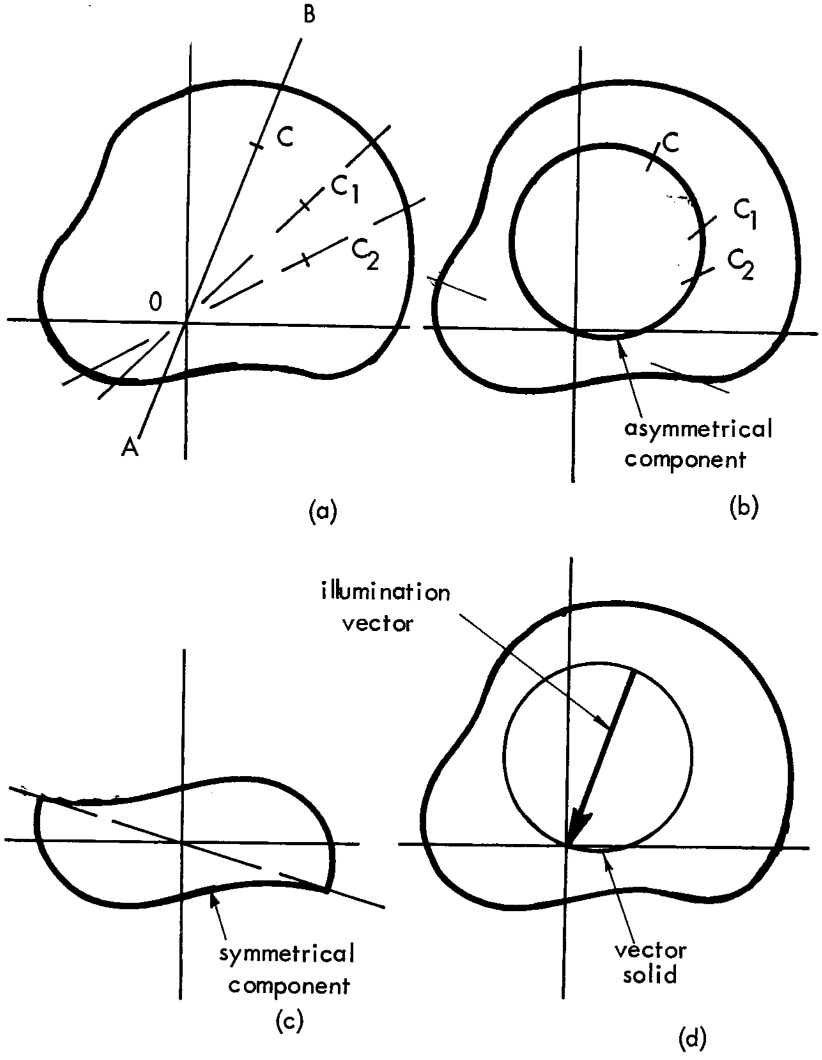


FIGURE 4 - Symmetrical and Asymmetrical Components of the Illumination Solid

It is important to realise that it is not possible to produce any form of illumination solid. The illumination solid due to a small source is a sphere tangental to the reference point, and so the illumination solid at a point in an illuminated room, or in fact any point in space that we can imagine, will always be the sum of tangent spheres due to every luminous point visible from the reference point.

Fig. 4a shows a section through an illumination solid and the line AOB passes through the reference point. It can be seen that the illuminance in the direction of B is greater than in the direction of A and the point C is placed so that OA = CB, and OC is equal to the illuminance difference in the two directions. This process is continued to place the points C_1, C_2 etc. It has been demonstrated by Cuttle (1971) that this process will always produce a circle (Fig. 4b) on a section through an illumination solid (unless it is perfectly symmetrical), or considering the situation three dimensionally, it will produce a sphere tangental to the reference point.

This sphere is the asymmetrical component of the illumination solid, for it represents for every direction through the reference point the directional illuminance difference. It follows that if this component is subtracted from the illumination solid, the remainder must be a totally symmetrical component as shown in Fig. 4c.

The asymmetrical component is termed the Vector Solid, and in Fig. 4d the Illumination Vector is indicated as a diameter of the vector solid terminating at the reference point. The precise specification of the vector solid requires only the magnitude of the illumination vector in lux and the angles of altitude and azimuth to identify the vector direction. It has been demonstrated by Lynes et al (1966) that the illumination vector conforms with the conventional laws of vector addition.

As the magnitude of the illumination vector indicates the size of the asymmetrical component, its ratio to the average value of the illumination solid offers simple and convenient way of indicating the extent of asymmetry of the illumination solid. This is the Vector/Scalar Ratio, which provides an index of the perceived strength of the flow of light.

In Fig. 5 a disc of radius r centred at P is arranged so that its surface is normal to the direction of light source S from which it receives an illuminance E_n. If a sphere of radius r is substituted for the disc, the quantity of light intercepted will be the same, but the average illuminance will be reduced as the surface area of the sphere is four times that of the disc. As Scalar illuminance is equivalent to mean spherical illuminance, it follows that Scalar illuminance $Es = E_n/4$.

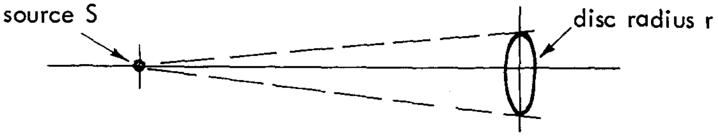


FIGURE 5 - Illuminated disc

The resultant scalar illuminance at a point in a complex light field is the arithmetical sum of the scalar illuminances due to each luminous element visible from the point. The resultant illumination vector is the vectorial sum of the corresponding normal illuminances, so that elements which appear close together from the reference point re-enforce each other and elements on opposite sides of the reference point tend to cancel each other. Point - by - point techniques of this sort can be tedious to apply in practice, but simplified design data for use with the British Zonal Method have been published by Pilkington, Turner (1973).

Special equipment is not essential for the measurement of vector and scalar lighting quantities. A simple approach is to centre a cube of convenient size at the measurement point with its upper surface horizontal and its vertical surfaces parallel to the walls. The illuminance on each of the six faces measured with a conventional light meter, provides the necessary information. The arithmetic mean of the six readings gives the approximate value of scalar illuminance (for very directional lighting the potential error is significant, but this is unlikely to be the case for normal indoor lighting) and the three illuminance differences on opposite pairs of sides of the cube give the vertical and horizontal components of the illumination vector. The resultant may be found by constructing two parallelograms of vectors.

The measurement procedure can be simplified if a suitable instrument is constructed. It has been shown by Cuttle (1971) that if a photocell that responds to mean hemispherical illuminance is rotated about a point to seek the direction in which maximum illuminance occurs (this will coincide with the Vector direction), and is then rotated through 180° to obtain a minimum reading, the required information can be obtained from only these two readings. Their sum is equal to twice the scalar illuminance, and their difference is half the illumination vector. A suitable photocell could be made by cementing half a table tennis ball to a selenium disc and adding selective masking on a trial and error basis.

Cuttle (1967) has described an experimental programme in which observers faced the experimenter and adjusted the lighting to achieve certain criteria. The results were expressed in terms of vector/scalar ratio and vector direction, and have been the basis of recent recommendations to the designers of indoor lighting installations published by The Illuminating Engineering Society (1973). These have included a table relating Vector/Scalar Ratios to assessments of directional qualities of lighting and showing a range of photographs of a model head to convey to lighting designers how appearance of the human features varies with the strength and direction of the flow of light.

Final Remarks

This paper has dealt with the influence of one particular aspect of the physical environment upon perception. It must be admitted that the selection of the aspect to be studied followed from work of Lynes (1966) in developing the physical concepts originally proposed by Gershun (1935), rather than from identification of the needs of building occupants or designers, and furthermore that a selective study of this sort does little to enlarge our understanding of perception.

However, the incorporation of vector/scalar ratio recommendations into the 1973 IES code suggests a willingness on the part of lighting engineers to accept recommendations that go beyond the traditionally ergonomic interests of illuminating engineering, although it remains to be seen where this enlarged interest will lead.

An office worker's appreciation of his desk or his telephone is unlikely to be influenced to any extent by the value of the vector/scalar ratio, but his interactions with other people certainly are susceptible to this influence. From the "soft lights" of the intimate night club to the harsh glare of the interrogation situation, there is a rich variety of ways of manipulating the flow of light to influence inter-personal communication. Perhaps this is a step towards illuminating engineering becoming recognised as an aspect of social psychology.

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