such an extent that his total "blind area" (at an adequate distance behind the viewer) is reduced to less than 30° to either side of the mid-line back of the head. Similarly, very moderate normal movement of both the eyes (15° to right and left of mid-position) and the head (45° to the right and left of mid-position) will enable a man to scan a total surrounding with a blind area of only 25° to the right and left of the mid-line of the back of the head.[86]

Since the retina of the eye is not uniformly sensitive, when the eyes are fixed, parts of the total visual field will be sufficiently distinct to permit discrimination while other areas will be much less distinct. While the peripheral areas of the retina are not useful for distinct vision, they do serve to direct the attention of the viewer to outlying objects and enable him to fixate such objects by appropriate movements of the head or eyes.

When it is necessary to see an object distinctly, both eyes fixate on that object so that its image falls upon corresponding portions of the retinas of the two eyes simultaneously. The area that includes the widest limits of vision in all directions on which the eyes can fixate for distinct vision is called the field of fixation; it implies that the head is fixed and that the scanning or succession of fixations result from conjugate eye movements. This area is found to be very nearly circular with a diameter of about 100°. Vision downwards is somewhat over 50°, which is slightly greater than in some other directions. The emphasis on design for layout of a work space so that the operator will be provided with as wide an area of view of his displays, machinery, and surroundings as possible does not imply that he is to be immobilized during operations. He should not, however, be required to make unnecessary, extensive, and inefficient movements.

2. *Factors Affecting the Visibility of Displays and Other Objects*

Regardless of which type of display is used in the working area, its visibility as well as that of tools and materials depends upon a number of well-known considerations. The most common of these factors are size of the object, the brightness contrast between it and its immediate background, the contrast between the task area and its surroundings, the brightness of the object itself, the length of time the object is seen, and the color of the illumination. Each of these factors is discussed briefly below.

a. Size of Critical Detail. Although the normal eye can detect very small objects, no operator should be expected to see or manipulate objects close to his visual threshold. Under such conditions, considerable discomfort and fatigue would result. A margin of safety should always be allowed with regard to the size of objects that must be seen or discriminated by the eye. The safety engineer should be well aware that visual details must be made considerably larger than the just-visible size.

b. Contrast between Object and Background. The greatest contrast occurs when a jet black object is on a pure white background or vice versa. Under such

conditions of 100 per cent contrast, other things being equal, objects will be most visible.[87] Fortunately, the eye can get along comfortably with less contrast, but it is recommended that the contrast be kept at 75 to 80 per cent or higher if possible. Contrast may be used in a number of ways (either with black and white or colored paints) to augment the extent to which items will stand out from their background. Thus, frequently used tools, handles, danger areas, bins, switches, and so forth, can be made more visible by increasing their contrast.[2,24,71]

The question sometimes arises as to whether white on black or black on white is the preferable combination. Although many authorities maintain that the background should be lighter, data summarized by Fitts show that under night instrument conditions well-trained subjects read white figures on dark faster and more accurately than black figures of the same size on white. Where considerations of dark adaptation are important, instruments with white markings on black backgrounds keep the total bright area at a minimum and provide less peripheral glare when an operator is looking elsewhere. Berger has investigated number reading in daylight as well as at night, and he also found white on black superior, but numeral thickness was an added variable.[83]

Contrast between Task Area and Surround. The above principles regarding contrast may be incorrectly applied so that the working environment around the task area is much darker than the area itself. Although it may seem advantageous to have the work locus "spotlighted" in the environment, there is greater eye comfort when the general environment around the working area is illuminated to the same degree as the background area.[87,89] Visual tests have shown optimal performance when the illuminations of the background and surround areas are equal. When that of the surround is less, there is a slow falling off of visual performance; when the surround illumination is greater than the background (as occurs with glare), visual efficiency falls off rapidly.[2,71]

c. Illumination. Much has been written about illumination, and there are numerous codes for lighting practice in schools, homes, offices, and industrial situations.[40] There has been a tendency to set the level of illumination as high as possible in the belief that vision will automatically improve with the amount of light. This is not always true; however, since the production of illumination above 50 foot-candles is apt to cause glare points, specular reflections, high contrasts and shadows, and other deleterious effects in the periphery of the field of vision.[41] In some instances where the visual task involves discrimination of extremely fine

[87] P. W. Cobb and F. K. Moss, Lighting and contrast, *Trans. Illum. Eng. Soc.*, **22**, 195–201 (1927).

[40] Studies pertaining to the design of visual displays for aircraft instruments, computers, maps, charts, tables, and graphs; a review of the literature, *Tech. Rept. 5765*, Air Materiel Command, USAF, April, 1949.

[41] P. W. Cobb and F. K. Moss, Four fundamental factors in vision, *Trans. Illum. Eng. Soc.*, **23**, 496–505 (1928).

[89] American recommended practice of industrial lighting, *Illum. Eng.*, **37**, 275 (1942).