3

Light and Color

Light and Color

Light and color play an important role in the design of interior environments. To use them effectively, the designer must have a working knowledge of the science of light and color and how they work together. This chapter discusses light and color terminology in order to give a better understanding of how to use them to their fullest potential.

Introduction to the Science of Light and Color

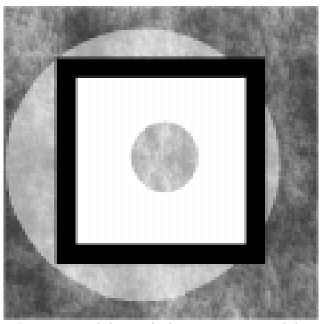

Fig. 1 White light on a white board with a hole.

Visual perception requires the interaction of a light source, an object, the eye, and the brain. Light energy is the medium of communication between the object and the eye. We may observe energy radiating directly from a source (such as the sun), or only that which is reflected from some object in the path of the light.

When light strikes an object, some of its energy is absorbed; we see only that light which is reflected back from the object. The light-reflective property inherent in an object that determines its color is its **pigmentation**. Commonly we refer to the pigmentation of an object as its color. A white board in space with a hole in the middle of it reflects back all light incident upon it, and thus appears white (Fig. 1). The hole "absorbs" all light incident upon it, and thus appears black.

Quantity of light is the amount of light energy present in an environment. It is described in terms of energy incident per unit area, and is quantified in footcandles or lumens. Quality of light is most often described in terms of color temperature, quantified in degrees Kelvin. The temperature referred to is that of a "blackbody radiator," one which is black when cool, but heats to red-orange, yellow, and eventually blue-white. The color change is due to the increased energy output of the heated body and the shift in wavelength of the light energy being produced. Our eyes interpret the various wavelengths of light as color.

White light contains the full spectrum of visible light. Objects perceived as white are those which reflect all colors (Fig. 2). An object may be perceived as red for one of two very different reasons. The light source may be white, while the object reflects only red (Fig. 3); or the object may be white, but be illuminated only by red light (Fig. 4). The result is the same: we see a red object.

An object's apparent color is dependent upon both the pigmentation of the object and the color of the light shining upon it.

Perceived color is also dependent upon the ability of the receiver to distinguish between wavelengths of light. Red-green color blindness is a relatively common malady which limits the ability of the subject to perceive the difference between red and green. Similarly, a black and white television receives the same information as a color television; but is unable to process it, and thus produces a different image.

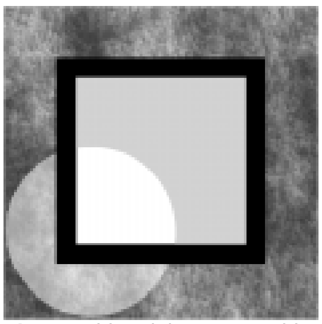

Fig. 2 White light on a white board.

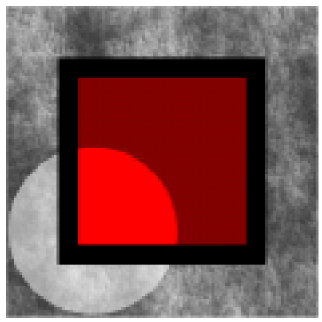

Fig. 3 White light on a red board.

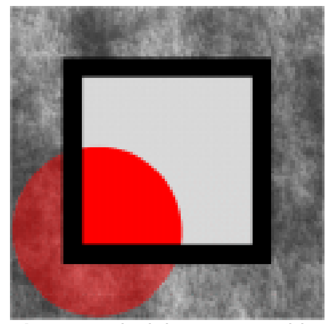

Fig. 4 Red light on a white board.

Spatial Perception and Definition

Distance is a critical factor in one's perception of space. **Perspective** describes our perception of objects over a distance, and is defined in part by the clarity, quantity, and intensity of light received from an object. Because light emanates radially from any given source, and its total energy remains constant; the farther we are from an object, the less light we receive from it. Through experience we are conditioned to perceive dimmer objects as farther away and brighter objects as closer.

Darker colors tend to recede from view (Fig. 5), lighter to encroach (Fig. 6). Similarly, when colors are placed closer to the viewer, they appear more brilliant, more intense than the same colors placed at a greater distance.

Our perception of space is also affected by shading, the way that light is captured or reflected by an object. At a distance, or when lit from behind, a sphere and a disk may appear to be identical (Fig. 7); however, when nearby and illuminated by a direct source from any direction other than behind, the way light reflects off of the object gives us additional information about its true shape (Fig. 8).

Dark colors recede while lighter colors encroach; thus, the box on the left appears deeper than the one of the right.

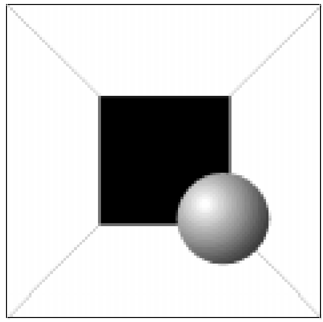

Fig. 5 Dark surfaces recede.

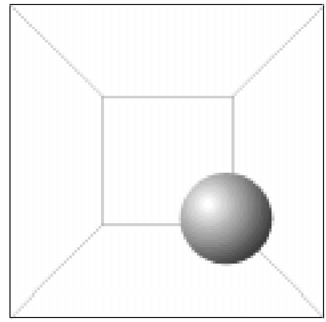

Fig. 6 Light surfaces encroach.

Lighting location may dramatically affect perception of an object or space.

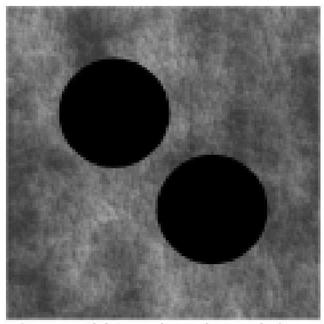

Fig. 7 Objects illuminated from the rear.

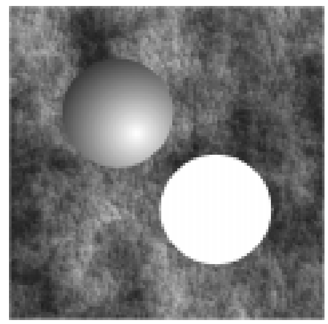

Fig. 8 Objects illuminated from the front.

The Luminous Environment

The quality of an illuminated environment is established through the manipulation of light to communicate specific information. In achieving a design which responds meaningfully to aspects of human behavior, designers must recognize that light affects how well work tasks can be seen (visibility), and subsequently how well they are performed (productivity). Of equal or even greater importance is how light affects visual quality and the sense of well-being experienced by users of a space.

In any given environment, the user should be able to see easily, comfortably and accurately. The illumination level required to achieve these results will vary based on a number of factors related to the user and the given activity taking place. The illumination level required for most spaces and environments is a function of the following:

• the type of activity,

• the characteristics of the visual task (importance, difficulty), and

• the age of the user (as the eye ages, it requires more light for visual tasks).

The Illuminating Engineering Society of North America (IESNA) has developed recommended ranges of lighting levels needed for many visual tasks, activities, and the general illumination of spaces. A sample schedule of ranges is given in Chapter 5. For a more complete understanding of this subject, please refer to the *Lighting Handbook, Reference & Application* by the IESNA.

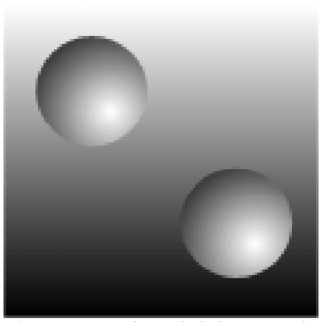

Fig. 9 Relative brightness is dependent upon context.

Quality and Quantity

In order to understand how visual quality and quantity of light affect the experience of users of a space, one must first understand the concepts of brightness and reflectance.

Brightness refers to how much light energy is *reflected by a surface*. The degree of brightness of an object depends upon the color value and texture of its surface. Brightness can be relative or measured. When a gray object is viewed first on a black background and then on a white background, the brightness level appears different (Fig. 9). However, the measured brightness, or luminance, of the object would be equal.

Reflectance is defined as the *ratio of light incident upon a surface* to that reflected. Reflectance of major surfaces in a space is critical to achieving intended brightness ratios.

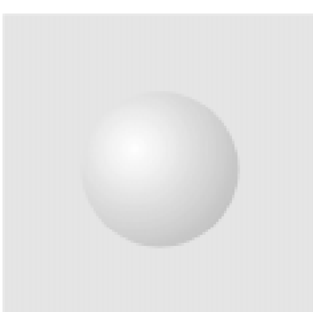

Fig. 10 Low-contrast figure.

Brightness ratios are critical to the understanding of the visual field required for a specific task. Brightness is of significant benefit to the viewer, as ability to distinguish fine detail increases with object brightness. Of equal importance is relative brightness between objects being viewed and their surroundings. Some degree of contrast in brightness is required. For example, it is very difficult to see any object against a similarly colored background (Fig. 10).

A maximum brightness ratio of 3:1 between the task surface and background is recommended by the IESNA.

Between the task area and darkest part of the surrounding space, the brightness ratio should not exceed 5:1. Brightness ratios higher than these values can lead to glare, visual fatigue, and loss of performance.

Contrast between objects and their background is especially critical for visual tasks that require discrimination of shape and contour. This need is easily understood on the printed page where dark letters can best be read when printed on light paper. For visual tasks requiring that one see surface texture and detail, less contrast between the surface and its background is desirable because the eye will adjust automatically to the average brightness of a scene. A brightly illuminated background serves to silhouette any object seen against it. **Glare** is the result of too much contrast between objects within the field of vision.

Undesirable glare-producing conditions include two types: direct and reflecting. **Direct glare** (Fig. 11) is caused by the brightness of light sources within the normal field of vision. **Reflecting glare** (Fig. 12) may be caused by the same source as direct glare, but results from light reflecting off the task surface. The term **veiling reflection** is sometimes used to describe this type of glare because the reflection of the light on the surface veils the task and obscures the image. Reflecting glare is most severe when the task or viewing surface is shiny—has a high specular reflectance value.

A single source may cause glare in different ways.

Fig. 11 Direct glare.

Fig. 12 Reflecting glare.

Light in Relation to Surface

The surface texture of an object will affect the distribution of light reflected from that object. Surface textures can be classified into one of three categories: specular, semi-specular and matte. **Specular** (mirror) **reflection** (Fig. 13) redirects light without diffusing it—the angle of reflection equals the angle of incidence. **Semi-specular reflection** (Fig. 14) diffuses light but still maintains the cohesiveness of the light pattern, thus maintaining the general direction but "spreading" the light a little. **Matte reflection** (Fig. 15) diffuses a light beam, causing the incident light to be reflected in all directions.

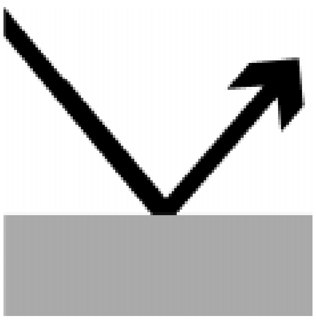

Fig. 13 Specular reflection

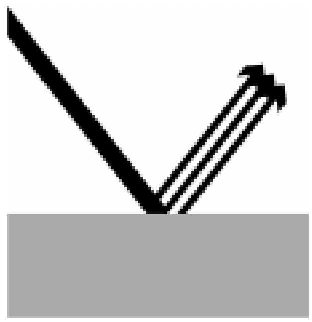

Fig.14 Semi-specular reflection

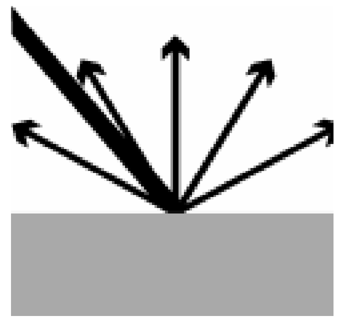

Fig. 15 Matte reflection

Specular, semi-specular and matte surfaces differ in the way they reflect light.

The color of objects often appears to change with surface finish. Specular reflections from glossy surfaces may increase the saturation and darkness of colors at one angle while obscuring colors and causing glare at others. Matte finishes of highly diffusing materials (such as velvet and deep pile carpeting) cause shadows within the surface that make the materials appear darker than smooth surface materials (such as satin, silk and plastic laminates) of the same color.

The Nature of Color

When discussing color, the three qualities of hue, value and chroma need to be defined. Hue, value and chroma together form a complete description of any color. **Hue** (Fig. 16) relates to the distinctive characteristics of a color as described by a basic color name or a particular position in the spectrum. **Value** (Fig. 17) is the relative lightness or darkness of a hue in relation to a scale of grays ranging from black to white. Light values are called **tints**, dark values are **shades. Chroma** (Fig. 18)

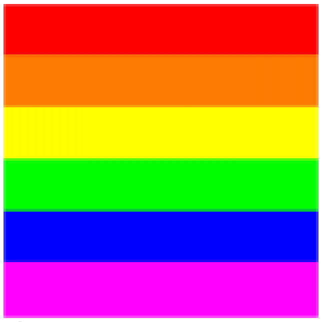

Fig. 16 Hue

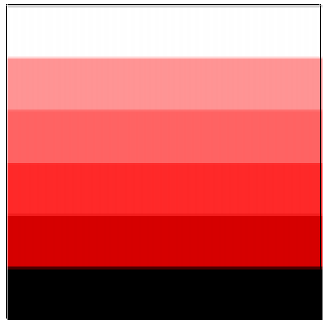

Fig. 17 Value

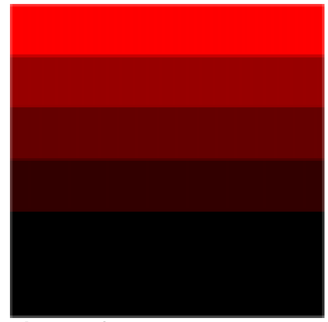

Fig. 18 Chroma

refers to a hue's purity or saturation. Adding a color's complement, decreases its chroma, as the purity of the original color is diminished.

The **color wheel** (Fig. 19) is a circular representation of hues arranged according to their relative position when a beam of light passes through a prism. The color spectrum is organized first by the three **primary colors** —red, yellow, and blue—located equidistant from each other on the color wheel (Fig. 20). Between the three pure hues fall the **secondary colors** (Fig. 21). Green,

Fig. 19 Color wheel

violet, and orange are each created by the combination of two primaries. The **tertiary colors** (Fig. 22) are created

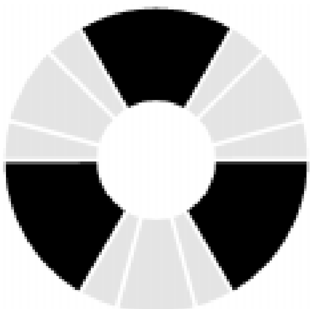

Fig. 20 Primaries

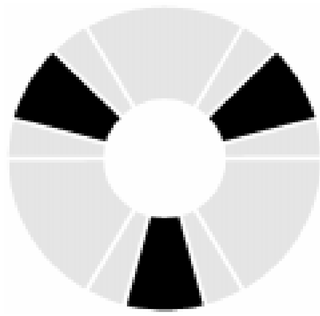

Fig. 21 Secondaries

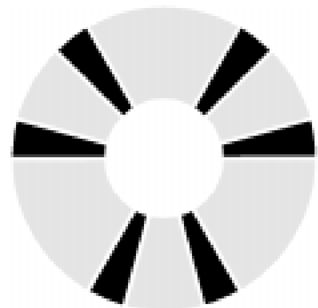

Fig. 22 Tertiaries

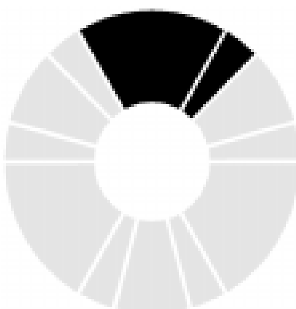

Fig. 23 Analogous

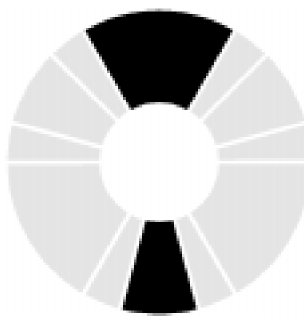

Fig. 24 Complementary

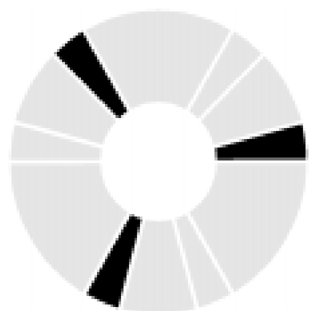

Fig. 25 Triad

The color wheel may be used to show color families and relationships.

when a primary and related secondary combine. Yellow-green, blue-green, blue- violet, red-violet, red-orange, and yellow-orange constitute the tertiary hues.

The hues of the color wheel can be discussed in terms of their relationships to one another. **Analogous colors** (Fig. 23) are those adjacent on the color wheel. **Complementary colors** (Fig. 24) are two colors located opposite one another on the color wheel. A **color triad** (Fig. 25) consists of three colors spaced equidistant from each other on the color wheel.

An understanding of the theories of light and color is essential to our ability to work with these most important components of design. In Chapters 4 and 5 we continue our discussion of light and color from the perspectives of conceptual application, and the technical means of achieving the desired affects.