The process of perception

The world around us is constantly changing. Autonomous events and processes produce changes in the environment over which we have no control; in addition, every time we move or act, we change the way the world around us appears. As a result, the patterns of sensory stimuli which are recorded by our senses and reported to the brain are also in a continuous state of flux.

The stimuli which bombard our organs of perception at every instant are substantially greater than can be assimilated consciously at any moment; therefore, during the process of perception the brain must actively sort, classify, and interpret the incoming flood of raw sensory data, distinguishing between those stimuli which are relevant to current needs and those which are not. Irrelevant information is shunted directly into the memory, from which it may later be recalled; this usually takes place without engaging the conscious attention of the perceiver. Relevant information, on the other hand, is incorporated immediately into the consciousness of the perceiver, where it is used to satisfy the needs which initiated the search for it.

Perception is not simply a passive recording process which receives and processes all incoming sensory stimuli indiscriminately. If this were the case, our minds would have no time at all for consciously directed activity; we would be continuously enmeshed in a wild unceasing flood of sense impressions, without hope of rest or relief. We would be unable to think, to direct our attention at will, to act usefully and meaningfully. There is simply not enough time for the conscious mind to analyze and respond to every new impression, every change in the state of the world which is registered by our sense organs. The unconscious biological mechanisms of perception handle most of this sorting and selecting automatically, although they require time and experience to learn how to do so. Visual perception is an amazingly complicated and sophisticated process, yet it functions by and large without requiring the intervention or even the attention of the conscious mind.¹

Let us trace in a somewhat idealized and simplified form what happens to a visual stimulus as it is received by the eye and converted into a perception.² A pattern of light passes through the lens of the eye, which focuses the image on the nerve cells that make up the retina. In and of itself, the pattern of light and dark and color has no inherent meaning despite the fact that it could be quantified, measured, and described—so much light of such and such wavelength here, a darker area of such and such a size there, etc. The cells of the

¹In the following discussion, we have tried wherever possible to use simple, everyday terminology rather than the often unfamiliar (but sometimes more precise) terminology from the contemporary literature of perceptual psychology. The intent of the discussion is to present the fundamentals of visual perception as they relate to the design and analysis of luminous environments, not to present an exhaustive review of the state of knowledge concerning perception. For further, more detailed analysis of the various components of perception, the reader is referred to the section “The Psychology of Perception” in the Bibliography.

²The mechanisms that determine which of the many possible stimuli is selected as the object of attention are dealt with later in this chapter in the section “What Do We Look At?”
The attributive stage of perception

During the next stage of perception the raw data from the eye are interpreted, classified, and given meaning by association. The patterns of information which have been encoded in electrical impulses, patterns which describe objects or other elements in the visual field, are sorted and classified by what we will call the experience filter: that part of the unconscious memory which stores data about all past experience. Incoming stimuli are classified according to their characteristics and associated with other, prior, analogous situations or objects which have already been filed in the experience filter. These linkages to prior experience, established by subconscious mechanism which matches or "recognizes" analogous items in the experience filter, are essential to the assignment of meaning to the incoming data.

In the terminology of perceptual psychology, this process of matching patterns and classification of stimuli is called the attributive component of perception, since it involves the attribution of meaning to the incoming stimuli. Attributive classification involves the simplification of incoming data, by classifying it according to the highest recognizable level of order which can be found in the experience filter. In Fig. 31, for instance, we see 15 dots, but we also see the circle they form, and the circle is generally perceived before the mind registers that there are in fact 15 dots. The attributive stage of perception seeks to find the general among the particulars, the highest level of organization—in this instance, the circle—which can be perceived and recognized in any given visual field.

To examine the attributive phase of perception in a little greater depth, look at the two images in Figs. 32 and 33. As each image falls on the retina, it is converted into patterns of electrical energy, as yet devoid of meaning. Because of past experience, most readers will be able unconsciously and instantaneously to classify Fig. 32 as a photograph of some vegetables, specifically, five leeks. Fig. 33, however, may prove more difficult to interpret. The average experience filter does not contain a sufficient store of analogous patterns which would permit the classification of the image. The picture is unclassifiable, and arouses curiosity.

This raises a key aspect of the attributive process of classification, one which will be of considerable importance later on during the discussion of ambiguous elements in the visual field. When there is no "file" of relevant, analogous information in the visual memory to which the incoming stimulus may be successfully compared and assigned—i.e., given meaning—the attention is drawn to the unclassifiable element of the visual field. The unclassifiable is intrinsically fascinating, partly because it is unfamiliar (novelty excites curiosity) and partly because the unfamiliar may be dangerous. When one encounters the unfamiliar, biological defense mechanisms are set off which heighten awareness until the new element has been classified. An image such as Fig. 33 excites curiosity only, since we know that it cannot be dangerous. But it is important to remember that unclassifiable or ambiguous visual stimuli demand further visual attention. This explains why featureless, translucent windows...
are distracting and should be avoided.

The process of attributive classification of incoming stimuli does not depend solely on the characteristics and patterns of the individual stimulus which is the immediate object of the visual attention. All elements of the visual field are simultaneously evaluated as context, and the context plays an important role in the attribution of the stimulus to a particular “file” in the experience filter. *Meaning* is determined as much by the perceived context as by the unique, individual characteristics of the particular stimulus itself. Contextual information is an essential part of the “index” system of the experience filter.

To see the importance of context in the attributive process of classification and interpretation, turn to the next page and look at Fig. 34. You will recognize Fig. 33 as the outlined portion of Fig. 34, but now you should be able to interpret both—a blurred photograph of long grass, a pond with the reflection of a tall smokestack and several trees. Although the same information concerning the outlined area is available in both figures, with the additional information of the context in Fig. 34 you can successfully classify and interpret the outlined area (Fig. 33). This simple experiment graphically demonstrates the importance of contextual information as a factor which conditions the classification and interpretation of sensory stimuli. In a process which involves the brain as well as the eye, we see a complete visual world, and we make reference to as much of it as is required to classify any specific stimulus. In a laboratory experiment involving perception, subjects may not be able to interpret definitively what they see because they are deprived of essential context information. In real life, the context is usually available. It is often an unrealistic lack of contextual information which destroys the usefulness of a number of otherwise interesting psychological experiments as possible sources of design criteria for the luminous environment.

One aspect of the attributive process of classification deserves brief discussion in passing because it is critical to the design of the luminous environment. It might seem logical that the impact of a stimulus—attributive, expectant, and affective—would be in proportion to the absolute (measured) magnitude of the dimensions of the stimulus itself: brightness, color, size, etc. This is the tacit assumption which underlies the “more is better” approach to lighting design. However, consideration of the entire mechanism of perception reveals that the magnitude of a stimulus is not necessarily the most important factor: the immediate awareness of a stimulus is largely a function of the *associations* which can be made in the experience filter, and of the *relevance* of the stimulus to current needs for environmental information. It is the interpretation and the relevance—the *meaning* of the stimulus which determines the relative importance which it will be assigned during the process of perception, and whether it will be perceived as useful signal or as counterproductive visual noise.

Expectations in the process of perception

In our simplified model of visual perception, once the incoming data have been sorted and classified the second component of the process—*expectation*—comes into play. Whereas the attributive stage involves the classification by association of momentary stimuli, the expectant
phase establishes associations with sequences of events.

The importance of expectations in connection with the design of the luminous environment should be obvious for such mundane activities as finding one’s way around. If one is lost in a city, one expects that the streets will be arranged in some rational order and that the houses will be numbered consecutively. Prior experience tells us that signs of a certain shape located on poles of a certain height will probably be helpful directional indicators; the scanning pattern of our eyes is directed accordingly. Thus expectations are not only outputs of the process of perception, but they also influence the subsequent selection of sensory inputs by redirecting the attention, controlling eye movements and scanning patterns, and determining the attributive files in the experience filter against which the incoming data are likely to be checked in the process of attributive classification. Expectations allow us to create extensions of the visible world in our minds: we expect that a red sign inside a building which manifests the visual pattern “EXIT” indicates a means of egress in time of danger. This kind of consistently used design element plays an indispensable role in the successful satisfaction of the biological need for orientation and security in both interior and exterior environments.

The affective component of perception

The third fundamental component of the perception process is called the affective because it is concerned with how each stimulus affects our emotional or evaluative responses to stimuli. The attributive classification to which a stimulus is assigned and the expectations which are activated by that classification trigger emotional responses which in the aggregate determine how we feel in a given situation or environment. This in turn influences the amount of attention which is paid to any element of the visual field: an interesting or pleasurable stimulus may be made the focus of visual attention and examined in great detail, while an uninteresting or irrelevant stimulus may be passed over and filed without further ado in the visual memory. The affective response generated by a stimulus also determines to some extent where in the memory—in which attributive “files” in the experience filter—the incoming stimuli will eventually be filed.

When the environment appears and behaves as expected, i.e., when the luminance levels, gradients, patterns, and colors in the visual field are relevant to needs and are as expected, the associative links established by prior experience in the experience filter are confirmed. This generally produces a positive emotional response in the perceiver (assuming of course that the expectation was for a pleasurable, comfortable environment).

All three aspects of perception—the attributive, the expectant, and the affective—are inextricably interwoven in real life. We have pulled them apart for purposes of analysis, yet in fact they are so intimately interrelated that they cannot really be separated. The attributive establishes links to prior experience, activating expectations and provoking emotional responses. Expectations in turn influence what will be chosen as the next object of sensory attention, and can trigger any emotion from joy to fear to apathy depending on the nature of the anticipated developments. The affective qualities of a perception determine the importance which we give it, which in turn influences what impact it has in terms of recalibrating the experience.
The entire, complex mechanism of the experience filter is constantly being updated as new stimuli are classified, activate expectations and emotions, suggest new foci for the attention, and are finally filed in the visual memory. If the environment behaves as expected, the web of associative relationships which constitute the experience filter will remain essentially unchanged; the relevant associations will merely be strengthened by confirmation, and will be correspondingly stronger the next time they are called into play. If, however, the world behaves in some unexpected way, the validity of established associations is called into question, and the inferential relationships which underlay the initial set of expectations will be reevaluated. The experience filter is modified in the process; subsequently, an identical stimulus may call forth a different set of expectations and emotional responses.

Suppose, for example, that I see my best friend, and without warning he punches me in the nose. The next time I see him, I will be much more cautious and suspicious. My experience filter—specifically, my image of my friend—has been drastically modified by my recent experience. From now on, I will respond differently to the sight of his approach!

If, on the other hand, my friend behaves as expected and greets me warmly, it will be a pleasant encounter and I will look forward to our next meeting.

Likewise, an environment in which there is a good match between positive expectations and the perceived reality of the situation will evoke a positive affective response. The environment will seem friendly, attractive, appropriate, and pleasant and I will feel good about it. But if the environment contradicts my positive expectations or confirms my negative expectations, it will provoke a negative affective response. I may perceive it as unfriendly, ugly, inappropriate, or unpleasant, depending on the nature of the contradiction or confirmation.

We always have conscious and unconscious expectations about the nature of the immediate environment, and designers must realize that the success of an environment is directly dependent on how well they anticipate and then consistently confirm the positive expectations of the user. Evaluation is always dependent on expectations.

Summary

Seeing is not a passive response to patterns of light; rather, it is an active information-seeking process directed and interpreted by the brain. Visual sensory data are coordinated with incoming contextual information from the other senses related to past experiences of a comparable nature, and given attention or not depending on whether the incoming stimulus is classified as signal or noise. It is the information content and context of a stimulus, not its absolute magnitude, which generally determines its relevance and, finally, its importance. This in turn largely determines what we look at and what we perceive.

What do we look at?

Close your eyes for a minute. When you open them again, look around the room. Note carefully the first thing you look at in the
visual field, then the second, etc. Unless you were looking for something specific, it is very likely that the first thing to attract your undirected visual attention was either bright, fast moving, strongly colored, of high contrast, strongly patterned, or a combination of two or more of these characteristics. Some unusual quality caused it to contrast with its visual context, making it a figure. The eye searches the visual environment automatically for signals which supply information relevant to the satisfaction of activity or biological needs, and “figure” objects with these characteristics tend to attract the visual attention automatically.

**The focus selector**

Through what we will call a focus selector, the brain dictates the scanning pattern of the eye. Whenever the eye is not under conscious control, it monitors the general luminous environment, checking that no significant changes have occurred which would require conscious attention. During this scanning, undirected by the conscious mind, the focus selector is likely to pick out stimuli which relate to William James’s “normal congenital impulses” — i.e., to biological needs for information.

As noted in the previous section, both the experience filter and current expectations play important roles in dictating the pattern of eye movements. The choice of specific elements in the visual field by the focus selector is influenced by various aspects of the experience filter including (1) stored past information in the form of attributive files; (2) personal habits and expectations; and (3) the current state of the perceiver — rushed or at leisure, happy or depressed, friendly or irritable, sick or well. The nature of the activities in which the perceiver is currently engaged also affects the operation of the focus selector in proportion to the amount of uninterrupted attention required by the task at hand.

**Central versus peripheral vision**

When open, our eyes produce two different kinds of stimuli, due to the physical construction of the eye itself. Visual acuity is highest in a very small area of the retina, called the fovea. Under normal conditions, patterns of light falling on the fovea are reported to the brain in much finer detail than the visual information falling on other parts of the retina. This innate differentiation of the visual receptor itself produces a functional differentiation between central and peripheral vision. In effect, the central vision (generated by the fovea) scans the luminous environment, gathering detailed information about elements of the visual field to which it is directed by the focus selector; simultaneously, the peripheral vision (produced by the rest of the retina) monitors the remainder of the environment for changes which might be of sufficient biological significance to warrant the attention of the central vision.

Routine control of eye movements by the conscious brain is sometimes interrupted by seemingly involuntary movements of the eye toward stimuli which the peripheral vision has detected and which the focus selector, in conjunction with the experience filter, has determined to be of relevance to biological needs.

*Visual acuity refers to the sharpness of vision, in terms of the size of detail which can be detected by the eye at a given distance. The standard alphabetical optometrist's chart is one method of measuring acuity.*
The role of the experience filter

Although it is inherently phototropic (i.e., attracted to light), the focus selector is profoundly influenced by the relevance assigned to incoming stimuli by the experience filter. Irrelevant or undesirable signals (visual noise) are rejected as possible centers of visual attention in favor of signals related to what we want or need to see, even if what we want or need to see is not the brightest element in the visual field. As pointed out in the last section, the absolute luminance of a stimulus is not as important as its information content from the point of view of the focus selector. For instance, if we are looking for a friend in Fig. 35, the bright landscape is perceived as a background, and the focus selector directs the visual attention to the silhouetted figure, despite the fact that the landscape is hundreds of times brighter than the figure. On the other hand, if we are only concerned about walking down the stairs, the focus selector concentrates on gathering information required for physical orientation: the railing, the height of the stair risers, the landing, the horizon line, the people in the distance, the weather, and so forth (Fig. 36).

Even if the person is the object of focus, however, the peripheral vision still registers useful facts about the background, partly to provide contextual information for attributive classification (identification) of the oncoming figure, and partly to satisfy the continuous biological need for orientation information. In addition, the high luminance (brightness) of the background tends to dominate the visual field, causing the eye to reduce the amount of light which it lets fall onto the retina, thus interfering with the perception of the person.

Ferris wheels, fire engines, neon signs, and traffic signals all owe their success as attractors of the visual attention to the fact that they take full advantage of the innate phototropic tendencies of the focus selector (tendencies which derive directly from biological needs) while providing useful or pleasurable visual information which makes them desirable foci in the luminous environment.

Distraction

When the focus selector interrupts the normal sequence of consciously directed eye movements, we say we have been distracted. The new stimulus is processed through the experience filter, which decides whether the new information is of sufficient importance to call for a redirection of the conscious attention. If it is not, the focus selector returns to the initial focus, unless the distracting stimulus is so close to the initial focus and so overwhelming in luminance or strength of pattern that the mind’s eye cannot ignore it.

Distractions may relate either to activities or to biological needs. Activity-related distractions can be very useful; they bring to our attention changes in our activities which are likely to make them more productive or satisfying. For example, suppose that while hammering a nail you suddenly notice that the board is too short or cracked or discolored. This functional distraction will bring the hammering to a halt if you care about the appearance of the finished product. To give another example: if my peripheral vision registers a sparkling stimulus on the pavement as I walk down the street, the distraction causes me to pause and reorient my attention, since the signal might indicate a
dangerous piece of broken glass—or a silver dollar!

The last example can also be considered a distraction of biological importance, since it is relevant to the protection of the body. Distractions of biological importance may be due to potential danger, an undesirable or repulsive situation, or an ambiguous stimulus in the visual field. An unusually dark shadow at night or a sparkling object on the ground may indicate danger, causing the focus selector to redirect the attention in order to evaluate the situation. A dirty windshield illuminated by oncoming headlights causes undesirable distractions, interfering with our ability to perceive necessary information about the environment. Ambiguous signals often distract us for longer periods of time. Due to our inability to classify them attributively, we are unsure of their functional implications. In the discussion of biological needs, it was pointed out that glazed surfaces can be somewhat ambiguous if nothing recognizable can be seen through them. Windows are more comfortable to look at and less distracting if familiar elements—clouds, trees, buildings, etc.—are visible on the far side. In a tall building, where the ground plane may be well below the field of view, the presence of some structural element such as a window reveal or a roof overhang beyond the glazing plane reduces the irritating ambiguity which can be distracting on overcast days. The most ambiguous and unpleasant type of window is one glazed with white translucent patternless glass, since it is very difficult for the experience filter to differentiate such glazing from a uniformly overcast sky.

**Distraction caused by luminance dominance**

When distraction is caused by an extremely bright source (dominance of luminance), the eye responds by constricting the iris, reducing the amount of light which falls on the retina. This simultaneously reduces the visibility of other objects in the visual field, which can be dangerous under some circumstances—the difficulty of driving into the setting sun will be familiar to most readers. Anyone who has been blinded by oncoming headlights when driving at night is familiar with a classic example of dangerous visual noise, but few people realize that the same phenomenon occurs to a lesser degree each time they look up in the typical office or classroom, and their eyes are assaulted by glaring light fixtures. Direct light sources, which typically have a high surface luminance, produce a defensive response on the part of the eye. If the light sources themselves are of no inherent interest, and serve no useful function in terms of satisfying biological needs, the mind usually evaluates them as glaring and unpleasant regardless of their actual luminance.

Unexpected bright elements in the visual field, particularly if they are distorted, demand the attention of the focus selector, causing distraction. The uneven illumination of the planar structural surfaces in Fig. 37 distorts their apparent form, commanding attention and forcing viewers to make sure that the structure is not in fact the irregular shape which the patterns and gradients of incident illumination seem to suggest it is. This sort of distracting distortion is annoying and should be avoided whenever possible.

Despite its tremendously high luminance, the sun is not distracting, unless it lies close to our line of sight, because we expect it to be in the sky. We know what it is, it always behaves consistently.
with our expectations, and the highlights and shadows which it causes give us continuous orientation to its location. There is no confusion or distortion in the scene in Fig. 38, although the brightness ratios between the sunlit surfaces and those in shadow are on the order of several hundred to one, and the luminance of the pavement is probably several thousand footlamberts. On the other hand, the lens of a fluorescent fixture of comparable luminance is perceived as ambiguous, unnatural, and unpleasant, and the focus selector is drawn to it again and again to investigate it further. This is tiring and annoying for the viewer, even though it may proceed at a totally unconscious level.

**Distraction caused by pattern dominance**

Strong patterns of visual information can also dominate the visual field, demanding the attention of the focus selector. The problems of visual noise at the Houston Astrodome can be traced directly to this type of distraction. The strong pattern of the structure completely drowned out the relatively weak signal of the ball. But it is important to realize that the same phenomenon is at work in every office with a regular grid of high-brightness fluorescent troffers: this type of lighting produces an identical form of distraction, due to the strength of the inherently arbitrary and therefore meaningless pattern of fixtures in the visual field. This problem can be eliminated by the use of indirect lighting systems, which deliver light to the room by reflection from room surfaces, which are intrinsically interesting to look at. These bright room surfaces satisfy biological needs for structural clarity and for a bright, cheerful environment. Compare the offices in Figs. 28 and 30; the photographic medium cannot capture the real brightness relationships of the actual environments, but the difference should be quite obvious.

When glass planes are incorporated into interior partitions above eye height in such a way that they reflect patterns of direct fixtures, still another distracting form of visual noise is introduced into the luminous environment which further compounds the undesirable qualities of this type of lighting (see Fig. 39). When the glass runs at an angle to the lines of fixtures, the reflections are even more confusing. A similar unpleasant effect is usually produced when mirrored glass is used in exterior windows: during the day, the glass reflects patterns of interior fixtures, overlaying them on the view outside, confusing the mind’s eye and distracting the focus selector. The negative emotional response generated by this kind of visual noise is intensified if the patterns of glaring fixtures seem to show no relation whatsoever to the activity patterns within the space. Irrelevance intensifies annoyance.

**Summary**

We look at what we want or need to see, unless our visual attention is redirected by the focus selector to a distracting stimulus in the visual field. Such a stimulus need not be the brightest thing in view: the information content of the stimulus is also important in determining its relevance and consequently its inherent attractiveness to the mind’s eye. When brightly illuminated elements of the visual field are unrelated to our needs, they distract us from our conscious activities, which can be both annoying and dangerous. When driving at night,
for example, we may hit another car or drive off the road, not because we were unable to see the other car or the edges of the road, but because we were momentarily distracted by the brightness of oncoming headlights or misguided by a pattern of poorly placed street lights. We are comfortable when we are free to look at what we want or need to see, and uncomfortable when the luminous environment itself interferes with our freedom to do so.

Attributive classification of visual stimuli: assignment of meaning

We know now that our visual system is far more than an assembly of passive gauges, capable only of measuring and recording luminance levels, visual size, and spectral color. We do not “see” the separate attributes of shape, color, or brightness as abstract, independent qualities: the synthesizing function of the perceptual system delivers complete perceptions to the conscious mind—we see a ball in flight, a man walking, a rose in bloom, and so forth. Each set of stimuli can only be given one holistic interpretation at a given moment; consider for example the classic ambiguous drawing in Fig. 40 by the Danish psychologist Rubins. We perceive either two faces silhouetted against a white background, or a vase against a black background. Each perception is a whole and independent of the other; in fact, it is impossible to perceive both vase and faces simultaneously, because the conscious mind cannot simultaneously assign two distinct and unrelated interpretations to the same stimulus. In viewing the Rubins figure, we do not perceive a series of curves and lines, and then add these up laboriously in the conscious mind to create meaningful combinations, unless we are consciously trying to follow and analyze the perception process itself. Normally, the synthesis of related stimuli into holistic, meaningful images is performed unconsciously by the apparatus of perception itself.

In the same way, we perceive objects and their individual attributes in context—in relation to their use, feel, odor, intent, etc. Precise measurements of only one aspect of an object, such as its color or luminance, cannot yield a meaningful or accurate index of how that object will be perceived by an observer. In and of itself, the measured surface luminance of an object does not determine per se how bright the object will appear as perceived by the conscious mind. That perception, like any other, is influenced by a host of related factors, all of which combine to determine the perceived brightness of the object. This is why the specification of single-valued numerical criteria for the luminous environment, such as minimum footcandle levels, gives no guarantee whatsoever that the resulting environment will be perceived as bright or cheerful, pleasant or appropriate. All such judgments are based on holistic, complete perceptions involving the entire visual field, as well as expectations and prior experience.

The unconscious search for order in the visual field

During the attributive phase of perception, the unconscious mind seeks to classify what we see according to the highest level of recognizable organization. Thus in Fig. 31 we saw a circle before we were aware of the 15 individual dots. Since the mind can only formulate one complete perception at a time from a given set of
stimuli (remember the Rubins drawing, Fig. 40), this quality of
classification according to the highest perceptible form of organization
allows us to comprehend several objects simultaneously when all are
clearly interrelated and form a single message or gestalt. We perceive a
circle instead of 15 dots, a colonnade instead of a number of columns,
etc. Very complex visual environments are easily comprehended if all
the available information is interrelated and clearly synthesized,
giving evidence of a coordinating intent: for example, an extremely
compact Gothic portal is neither confusing nor difficult to understand,
because of the clarity of its overall organization.

The effect of perceptible order in the visual environment

Discomfort and distraction are largely but not entirely interdependent.
It is quite possible to have a situation that is distracting but not
positively uncomfortable. An increase in the perceptible order of the
visual environment may reduce its distracting quality. For instance, a
disorderly layout of light fixtures can be made less distracting by
rerearranging them into more orderly and understandable pattern, or by
clearly relating the fixtures in a consistent fashion to other elements of
the architecture—structure, the partition module, window mullions,
furniture, etc. The perception process always attempts to extract
meaning out of apparent chaos (documented by the Gestalt
psychologists’ principle of closure). This has obvious implications for
the design of the luminous environment.

Pattern, perceived order, and expectation

When bright light sources are directly visible, or when their images
can be seen reflected from some specular surface such as a piece of
glass or a wet roadway, pattern becomes even more important than
usual as a signal. Pattern is an easily perceptible form of order, and
triggers expectations of completeness and consistency. As pointed out
in the previous chapter, expectations and a patterned context draw the
eye to an omitted element of the pattern, which becomes a de facto
focus, whether intended or not (Fig. 42). Here we have yet another
example of the role of expectations as they influence our evaluation of
the luminous environment.

Figure/background effects

In the attributive phase of perception, a signal is always selected from
its background according to the needs which currently control the
focus selector and influence the experience filter, unless there is a
perceptual ambiguity—i.e., a signal which cannot be classified as
either figure or background (signal or noise). Upon encountering an
ambiguous stimulus of this sort, the focus selector shifts back and
forth at some expense in effort and discomfort. The attributive
category to which the stimulus is finally assigned is initially
influenced by current needs, subsequently by which of the two
options has a higher information content (and is therefore more
understandable and interesting). If one looks at black and white
stripes of uniform width such as the ones in Fig. 43, it is difficult
to select one set of stripes as figure over the other as background,
since neither relates to any immediate need and both contain
effectively equal qualities and quantities of information. The same
difficulty is encountered with a different configuration such as Fig. 44. Compare either the top or the bottom portion of the figure with the middle section; clearly it is most difficult to separate figure and ground in the center section, where the two possibilities most closely resemble each other.

Good camouflage patterns and much of the graphic work of Maurits Escher are successful because they cunningly manipulate figure/background ambiguities.5

Venetian blinds (Fig. 46) frequently create a figure/background conflict similar to that of Fig. 43, although the intensity of the ambiguity is reduced because one set of stripes—the view—is more interesting than the other. Nevertheless, it should be recognized that other types of sun-control devices are less distracting because they introduce less of a figure/background ambiguity into the visual field. For this reason, very fine sun screens of an even texture and large-scale sun-control devices are generally preferable to solar-control systems such as Venetian blinds.

The conflict between figure and background is increased further when the shapes are all similar. Note the dazzle effect in Fig. 48: when the shapes are similar and the black and white areas are equal in size, the experience filter examines the arrangement to try and discern some form of intelligible order and relation to context in an attempt to distinguish between intended figure and intended background. Alternating dark and illuminated panels or ceiling coffers (Fig. 49) often create similar dazzle effects and should be avoided.

Constancies in the process of visual perception

Everything we see is interpreted during the process of perception in relation to reference files in the experience filter, which means that all conscious visual perceptions—brightness, color, distance, size, movement, perspective, solidity, etc.—are determined in part by prior experience. These files are not all present at birth; most must be learned. Fortunately, an incoming stimulus need not be identical to a prior stimulus in order for attributive classification to be possible. Through the experience filter, the brain is capable of association involving generalization and abstraction; in other words, it can recognize new and different views of a familiar object. This ability is dependent on sufficient prior experience with the object in question. The experience filter must contain adequate information concerning the expected appearance of the object when viewed under different conditions of light, from different angles and from different distances, etc. A person who has been blind from birth and is suddenly given the ability to see by surgery cannot make this sort of associative visual generalization.6

This translational associative ability, which involves what are called constancies in the terminology of perceptual psychology, enables us to separate functionally important changes in the visual environment from changes in incoming stimuli which are only caused by movements of the head or the body or by changes in the nature of the incident illumination. Constancies involve the ability of the brain to recognize objects and their characteristics under different conditions, so that although the actual measured stimuli which fall on the receptors of the eye may be quite different under different

47 Background shapes different from figure.

48 Background shapes similar to figure.

49

5For an excellent discussion of the graphic work of Escher which is highly relevant to the present analysis of the process of visual perception, see Marianne L. Lamber, "Sources of Ambiguity in the Prints of Maurits C. Escher," Scientific American, vol. 231, no. 1, pp. 90–104, July 1974.

circumstances, the experience filter learns to disregard differences caused solely by changes in lighting conditions or by shifts in the viewpoint of the perceiver. Nevertheless, lighting should reinforce rather than contradict established constancies.

We are all totally dependent on constancies to find our way around in the built environment. This fact underscores the importance of consistency and clarity in the design of the luminous environment to provide orientation and visual guidance for its users. Such orientation can be relatively unsophisticated—systems of directional signage, for instance—or it can be quite subtle, operating below the level of the conscious mind, and involving the careful differentiation and consistent application throughout a project of different types of lighting to each element of a circulation system, such as elevator cores, fire stairs, reception and information nodes, public corridors, private corridors, lounge areas, etc.

Constancies enable us to make cognitive leaps in the experience filter, associating the same meaning with quite different patterns of visual stimuli. Although they are far from identical, the six sketches in Fig. 41 are all recognizable as representing a cube because constancies of form and shape tell us that each probably represents a topological form which is conventionally called cube. Constancies exist for all aspects of visual perception—brightness, color, shape, size, pattern, etc.—and they play important roles in our interpretation of the luminous environment, which will be examined in some detail in the remainder of this section.

**Shape constancy**

Shape constancy simply means that we can recognize the shape of an object or pattern even though it may be modified by a change in viewpoint, illumination, or distance from the eye. When viewed from across a room, a rectangular table is understood to be rectangular even though its optical image (as it would be traced from a photograph) is a trapezoid. Objects and two-dimensional images are seen in context, which establishes a frame of reference in the form of a common perspective; this in turn influences the types of possible associative patterns in the experience filter to which incoming stimuli will be compared for classification. If we could not make this kind of automatic adjustment for perspective distortion, we might interpret a plate seen from an angle as an ellipse (Fig. 50) rather than a circle.

Shape perception and interpretation are also influenced by expectations; indeed, constancies are a form of subconscious expectations. Expectation enables us to project the curve of the street beyond the corner in Fig. 52, despite the fact that we cannot actually see what happens beyond a certain point.

Shape constancy also enables us to recognize the drawings in Figs. 41e and 41f as cubes, even though the two-dimensional images are quite different from each other.

When faced with situations involving the perception of threedimensional objects in which there is no evidence of the direction of the light source, we usually base our interpretation of shape on the unconscious assumption that the light comes from above—the normal direction of daylight. In a laboratory setting, the brain can be confused, leading to misinterpretation. (In Fig. 53 the mind assumes a single light source, and reads the right figure as a hole and
the left one as a bump in the surface, whereas both are in fact bumps, the right one illuminated from below and the left one from above). In the real world, however, the location of the source is usually obvious, as in Fig. 54, and the mind compensates automatically for any unusual directional qualities of the light.

**Size constancy**

Perception of size is influenced more by context than by optical size (which is measured as a solid angle from the eye to the object). By itself, the parallax factor of our stereoscopic vision is not particularly helpful for judging size, once an object is more than about 15 feet away. Without a context, we cannot tell whether we are looking at a small object a few feet away or a larger object of similar proportions and coloration at a considerable distance. We usually judge the size of an object by how it relates to the optical size of other known objects in the visual field and to the memory of the relative size of the various objects. A given plate appears smaller on a large table than on a small table of the same color and shape (Figs. 55 and 56), particularly when seen from a distance or in a photograph. But if other, familiar reference objects of known size are present, as in Fig. 50, then the perceived size of the plate will be less affected by the size of the table. An open-ended line appears to be longer than a closed one of the same length (Fig. 57), due to the distorting effect of its context—the terminal arrowheads.

Is the object in the center of Fig. 58 a Ping-Pong ball or a beach ball? The way it is perceived and the size which we judge it to be will be determined by which of its contextual neighbors the mind’s eye chooses to relate it to. On the other hand, if we know how big the ball actually is, we can use that information to judge how far away the hand and the figure must be.

When deprived of all other contextual information which would reveal the absolute size and distance of several objects, the brain may still be able to determine at least their relative distance by comparing their relative size (Fig. 59), or how they overlap (Fig. 60) and particularly how they overlap when the observer is moving with relation to them. Note that the larger tree seems nearer in Fig. 59, while the smaller is clearly nearer in Fig. 60.

**The perception and accurate judgment of color**

From the point of view of the physicist, the color of an object can be accurately described by quantitative analysis of the amount of energy which it radiates at each wavelength in the visual spectrum. The stimuli which fall on the retina of the eye are produced by the interaction of light and surface. The perception of color, on the other hand, is influenced by many other factors. Light itself consists of various quantities of energy at various wavelengths. The surface of an illuminated object selectively absorbs and reflects different parts of the spectrum of the light falling upon it, which explains why beams of light from sources with different spectral qualities may produce different colors when reradiated from the surface of a given object.

The accurate judgment of color requires full-spectrum light; light which is produced by heated “black body” sources such as an incandescent lamp filament or the sun. In order for two objects to be
perceived as having the same color under a wide range of different spectral qualities of illumination, the two objects must contain proportionate amounts of the same colors, i.e., their surfaces must absorb and reflect different wavelengths of light in a similar manner. To ensure this sort of perfect match, the illuminant under which they are compared must contain the entire spectrum of light, without any frequency bands omitted or accentuated. Such accurate color judgment is required for matching paints, for instance.

For most purposes, however, we do not need such exacting qualities of illumination to perceive colors accurately, due to the existence of color constancies in the process of color perception.

If the eye worked like a camera, objects would appear very different under different qualities of light. Luckily, we do not need to “change films” in the eye every time we encounter a different quality of light; the unconscious processing mechanisms of perception perform the adjustment automatically. The brain usually compensates for the color of light in making color judgments. This color constancy also affects our perception of apparent brightness: a light-colored object, dimly illuminated, is perceived as such, not as a dark-colored object. Given sufficient contextual information—familiar objects seen under the same light—we can judge the light to be dim because we know from prior experience that this must be the case. Without prior experience, we may be unable to make this distinction. To interpret color correctly, the experience filter requires information concerning the selective reflectance properties of the surface of the material in question and the spectral characteristics of the light. Both types of information can usually be found in the visible context.

Perception of color is definitely influenced by certain conditions of background and illumination. This phenomenon—the modification of perceived color by context—is called simultaneous contrast. Simultaneous contrast affects all aspects of color perception: hue or chroma (judgment of color as red, green, blue, yellow, etc.); value (the relative lightness of darkness of a color, measured by reference to a scale from white to black); and intensity or saturation (the purity of a color of any given hue, which increases from a neutral gray to reach a maximum at the pure hue).

Color constancy prevails over simultaneous contrast in the formation of color perceptions as soon as the eye is given a connecting clue. Figs. 61 and 62 demonstrate this effect with regard to value.

The mind perceives what it expects to perceive due to color constancy, and is swayed little by the speciﬁcs of the incoming stimuli as long as it has prior experience on which to form its expectations and sufﬁcient contextual information for correct orientation. Color constancy makes us perceive our friends as we expect them to appear. We do not perceive people as being of signiﬁcantly different colors under direct sunlight, in the shade, under an overcast sky, or indoors under ﬂuorescent or incandescent lighting, despite the fact that if they were photographed in these situations with the same film and no color-correction filters, they would appear to be quite different colors. If, however, the incident illumination on a scene changes color rapidly or drastically, people are seen as being “tinted” by a colored light. This effect will be familiar to anyone who has stood under a ﬂashing neon sign with alternating colors. Such tinting may or may not be disturbing, depending on our expectations; in a discotheque, a
funhouse, or a theater, it may seem perfectly natural. In an interior corridor lit with a sequence of fluorescent tubes of different types, on the other hand, the effect may be very annoying if there is no perceptible reason for the inconsistency. Color constancy is an adaptive process which requires time to come into play; when color changes are too rapid, or when sources of radically different qualities are visible simultaneously, color constancy cannot compensate effectively.

The importance of consistent use of colored sources in the visual field

Each type of light source—the sun, an incandescent light bulb, a fluorescent tube, a metal halide lamp, an arc lamp, etc.—has its own unique and typical spectral characteristics, and each therefore has the potential to produce different colors from a given surface. When the color quality of illumination in a visual field is consistent (i.e., all objects are illuminated by the same kind of light), there is relatively little color distortion. Surfaces of similar materials are perceived as similar, and the average person is unaware of any distortion. If part of a continuous surface is illuminated by daylight, however, and part by incandescent light, the area under incandescent illumination appears yellowish by comparison. When the daylight is gone, the surface which previously appeared yellow now appears to be white. The mind can and does compensate, due to color constancy. Expecting white light, the mind perceives things as if they were illuminated by white light unless some evidence in the visual field indicates that this is not the case. If different types of sources are used the effect will not be disturbing as long as the different source types are carefully and consistently coordinated with different classes of objects in the visual field. Suppose that the brick walls of a space are illuminated by incandescent sources, while the floor is lighted by fluorescent lamps. The different color characteristics of the two kinds of light may not be noticed at all. On a continuous surface such as a plaster wall, however, intermittent or inconsistent illumination from different types of sources would be immediately apparent and disturbing unless the mind’s eye could discern some reason for the difference. For instance, if there are paintings displayed on the wall, which are illuminated brightly by incandescent spotlights while the wall itself is evenly illuminated by daylight or by a continuous fluorescent fixture concealed at the top of the wall, the mechanism of perception disregards the gradations of color on the wall because of the obvious intended focus. The wall is perceived as a continuous white surface.

The mind responds quite negatively to the inconsistent use of different source types with no apparent justification. The mind’s eye has no inherent objection to the use of different *types* of source, however, only to their *inconsistent* and *arbitrary* use. Positive, consistent differentiation of elements in the visual field by the use of different types of sources can provide extremely useful information which helps to satisfy biological needs for orientation.

A note on the use of tinted glass

Since mirrored, tinted, and low-transmission glass all modify the spectral characteristics and the intensity of the light which passes through them, they alter the qualitative characteristics of the light
which influence color vision. This effect will be offset by color constancies as long as there is no comparable, correctly colored scene visible against which the mind’s eye can compare the altered stimuli. In other words, the color of the tinted glass will be noticeable and disturbing if the viewer can simultaneously see another view of accurate color and brightness as in Fig. 63. When there is such a basis for comparison, the view through the tinted glass is perceived as distorted and gloomy, because a more pleasing alternative is visible. This situation leads to feelings of deprivation and annoyance. If there is no reference view available, on the other hand, color constancy assumes dominance of the perception process, reducing somewhat the unpleasant effect of the tinted glass.

The perception of brightness

The visual system is capable of detecting objects over an extraordinarily large range of surface luminance. An object in direct sunlight may be as much as 1 million times brighter than the same object illuminated by moonlight, but the human eye can perceive both (Fig. 64).

<table>
<thead>
<tr>
<th>COMMONLY EXPERIENCED BRIGHTNESS LEVELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>incandescent lamps—over 10,000FL</td>
</tr>
<tr>
<td>lawn or dark road, sunny day—1600FL</td>
</tr>
<tr>
<td>clear sky—700-1500FL</td>
</tr>
<tr>
<td>overcast or hazy sky—500-4500FL</td>
</tr>
<tr>
<td>snow, overcast day—850FL</td>
</tr>
<tr>
<td>snow, sunny day—6800FL</td>
</tr>
<tr>
<td>lawn or dark road, snow, moonlight—.015FL</td>
</tr>
<tr>
<td>sidewalk, moonlight—.01FL</td>
</tr>
<tr>
<td>bright vision below—.001FL</td>
</tr>
<tr>
<td>book, one candle—.3FL</td>
</tr>
<tr>
<td>streetlight—.03FL</td>
</tr>
<tr>
<td>surface 50FC</td>
</tr>
<tr>
<td>luminous ceiling—50FL</td>
</tr>
<tr>
<td>lawn or dark road, overcast day—220-400FL</td>
</tr>
<tr>
<td>concrete pavement, overcast day—550FL</td>
</tr>
<tr>
<td>surface fluorescent lamp—2500FL</td>
</tr>
<tr>
<td>concrete pavement, sunny day—4400FL</td>
</tr>
</tbody>
</table>

Such ratios can be measured in the laboratory, but they have little relation to the subjective perception of relative brightness. Subjects’ descriptions of the perceived luminance or brightness of objects in the field of view do not vary directly in arithmetic ratio with the measurements of the absolute luminance of the objects. This is an important fact for the lighting designer to understand: it means that doubling the amount of light in a space will not make it seem twice as bright (although it will consume twice as much energy). One must be wary, therefore, not to make simplistic cost-benefit analyses about lighting which fail to take account of the fact that each additional doubling of the light level produces a much smaller increment in the perceived brightness of the scene. In fact, doubling light levels produces what experimental subjects typically describe as a “just noticeable difference.” The perception of brightness, just like the perception of shape or color, is influenced by a host of other factors besides the absolute intensity of the stimulus in question. Context plays a role, as do expectations, so that we may meaningfully describe a “bright moonlit night” or a “dark overcast day” even though the latter scene may have an average luminance thousands of times greater than the former.

A research group at the Pratt Institute found no correlation between their observations of apparent (perceived) brightness in a number of buildings and the actual measured footcandle levels. This is as we should expect, because the colors and reflectances of the room...
surfaces, the use of the space, time orientation, and other factors, all
have an important bearing on the perception of brightness—a bearing
which is not taken into account at all by direct footcandle
measurements. Measured physical brightness, therefore, does not
determine perceived brightness in a simple, one-to-one manner. This
fact underlines the need to consider relative, not absolute, luminance
levels during the process of lighting design, and points up one of the
conceptual fallacies behind many quantitative lighting codes.

As noted in the Preface, limits to brightness ratios have been
proposed as meaningful qualitative criteria for interior luminous
environments. Contrary to most current thinking in the field of
lighting, high brightness ratios are not inherently undesirable, as long
as the eye can perceive and justify the cause of the high brightness
ratio. A brilliantly illuminated crystal chandelier is a pleasure to
behold, regardless of the high brightness ratios which it may engender
in a space.

Adaptation and the perception of brightness

In the preceding sections we have discussed at several points the
effects of bright sources in the visual field. Bright sources cause the
iris of the eye to contract, reducing the amount of light which falls on
the retina. This phenomenon of adaptation profoundly influences the
perception of brightness. As Hopkinson describes the process:

In any given scene, the eye sensitivity settles down to a general
average state of adaptation. This acts as a “reference standard” such
that individual items of the scene which have a higher physical
luminance than this reference level “look bright,” and those with a
lower luminance “look dark.” The brilliance of the highlights and
the murkiness of the shadows consequently depend not only on
their intrinsic physical luminance, but also on the state of
adaptation to the eye. Raise the adaptation and the shadows look
darker. Lower the adaptation (screen the window with your hand)
and the shadows look brighter. So do the highlights. Thus a surface
with a luminance of 100 footlamberts has an apparent brightness of
100 when one’s eye is adapted to 100 footlamberts, but the same
surface would have an apparent brightness of 230 when one’s eye
was adapted to 10 footlamberts.8

This extremely important process of adaptation explains why a room
may appear gloomy and dimly lit during the day but bright and
cheerful at night. At night, there are no bright windows or direct
sunlight in the space which would cause the eye to adapt, reducing
the apparent brightness of other surfaces in the space. Because of
adaptation and expectation, we need more artificial light in many
interior spaces during the day than at night, to balance the higher
daytime levels so that the interior does not appear dim and gloomy.

It is also clearly wasteful, therefore, to run interior lighting at full
intensity at night, when artificial sources no longer have to compete with
daylight illumination. Switching, dimming, or multilevel ballasts should
be provided so that light levels can be reduced at night when the eye
needs less light to see well and to interpret a space as appearing
bright. If there must be lighting codes, they should incorporate
requirements for the provision of such control devices, both to
conserve energy and to increase the comfort and quality of the
luminous environment, rather than concentrating on specifying

8R. G. Hopkinson and J. D. Kay, The
Lighting of Buildings, Praeger, New York,
1960, p. 46.
arbitrary minima to be met at all hours of the day or night, with no regard for what is really appropriate and necessary.

The influence of simultaneous contrast on brightness perception

The perception of brightness, as well as color, is influenced by simultaneous contrast. Objects of the same surface luminance will be perceived as brighter or darker depending on the relative luminance of their context. Only displayed objects are highlighted in Fig. 65; they seem considerably brighter than they would appear if placed in a brightly illuminated room, even if the surface brightness of the objects themselves was kept constant. The illumination level on the painting in Fig. 66 is kept intentionally low for reasons of preservation, yet the painting seems much brighter than the paintings in Fig. 67, which receive 10 times as much light from a glaring luminous ceiling. The painting in Fig. 66 would appear still brighter if the surrounding walls were dark colored or unit.

Comparative brightness judgments

Assessment of the relative brightness of objects which are not simultaneously visible involves the entire perception mechanism. If, in a laboratory, a white disk is illuminated to various luminance levels, a doubling of the luminance produces a "just noticeable difference" to the eye. If the disk is completely darkened for a minute before it is reilluminated to a higher level, the eye may be unable to detect any difference at all. In our daily experience, however, context, experience, and expectations all come into play as the eye adapts to each scene. These factors influence the perception of brightness, and color our judgment as to whether an object is dark or light, too bright or too dim. They may make a totally enclosed interior space seem brighter than a sunlit exterior, even though the measured luminance levels may be a thousand times greater outside.

It is most instructive to buy or borrow an inexpensive footcandle meter and measure the illumination levels in various spaces, subsequently comparing them with one's judgment of the "brightness" of the space. A "bright" cocktail lounge will generally have substantially lower measured light levels, for instance, than a cafeteria which is perceived as equally bright. Compare your response to sunlight on a windowsill and to a light fixture which seems to be equally bright; then measure the actual surface brightmesses. You will probably find that the light fixture seems much brighter than it actually is, because it is not so pleasant to look at. Compare your evaluation of the light levels in an exterior corridor with a window at the end by day and by night. When does the space seem brightest? Usually, the corridor will seem brighter at night, because the eye is adapted to nighttime brightness levels; during the day, the bright sky dominates the field of vision, forcing the perception mechanism to evaluate the corridor as relatively dark, even though it may be far brighter in terms of measured luminance than at night.

Easy experiments such as these will soon convince anyone with normal perception that measured and perceived brightness levels do not interrelate in a simple, mechanical way. This, in turn, should lead one to question the validity of brightness ratios, footcandle levels, and other conventional criteria as useful tools for the design of the luminous environment.
Luminance gradients, three-dimensional form, and the perception of brightness

One effect of the adaptive ability of the perceptive mechanism is that we do not necessarily perceive unevenly lighted surfaces as being unevenly lighted. Expectations and constancies of shape also influence the interpretation of brightness gradients in the visual field, so that surfaces are perceived as continuous and evenly lighted as long as the luminance gradients (the rate of change of luminance, not the absolute luminance) seem natural and appropriate for the shape of the surface. The various planes of the monitor skylight in Fig. 68, for instance, appear evenly illuminated because the brightness gradients fall off consistently and evenly, in a natural and comprehensible way. Hurvich and Jameson state that brightness will appear to be more or less uniform throughout an area where the luminance gradient is constant. Adaptation, expectation, and the perceived relevance of brightness gradients to the forms which they define are all important determinants of the final perception. The key factors are relative luminance levels and their rate of change, not the absolute intensity of the illumination at any given point.

A ceiling, for example, appears to be flat, evenly lighted, and of one consistent color when the luminance gradient is constant across the entire surface. When there is an exterior window in the room, as in Fig. 68, the surface brightness of the ceiling by the window may be 20 times the brightness near the interior wall, yet the ceiling still appears to be quite evenly illuminated.

A variation in the rate of change of luminance implies a change of shape to the mind’s eye. A change in luminance gradient is particularly noticeable if the shape on which it occurs is obviously flat (see, for instance, Fig. 37), and does not in fact change shape as the luminance gradients suggest. This effect will be disturbing unless the justification for the confusing gradient is apparent to the eye: for instance, scallops of light caused by point-source fixtures are less noticeable if they are obviously coordinated with some modular architectural element such as columns, reveals, or panels (Fig. 69). If, however, similar scallops are seen on an otherwise flat wall they are much more disturbing and distracting (Fig. 15) because the gradients which they generate contradict the actual planarity of the wall for no apparent reason.

Note that scallops of light on a flat wall may be perceived as appropriate if the strong highlights they cause serve to create an obviously intended focus on some element of the design (Fig. 70). Conversely, the unpleasantness of a poorly coordinated, unnatural effect will be heightened if the fixtures which produce the uneven gradients were obviously not intended to serve as focal decorative elements (Fig. 15).

If the continuity of a planar surface is clearly interrupted by a beam or a stripe, the two areas thus defined may be perceived as having different colors or luminances, even though the luminance gradient is constant over the entire surface and the overall illumination has identical color characteristics. The eye “averages out” the gradient in a defined, bounded area which is perceptibly continuous and planar; subdivision of one area into several smaller areas can lead to the perception of a different “average” brightness in each area due to the localized averaging process.

This phenomenon can be utilized to reduce the perceptual
distortion of structure resulting from sharp brightness gradients: the distorting effect will be diminished if the designer can locate a color change (Fig. 10) or a prominent joint line where a drastic rate change in brightness gradients is unavoidable due to the geometry of the situation.

Flat, uniform surfaces are expected to appear that way; uneven gradients are much more noticeable on a flat ceiling (Fig. 71) than on an articulated (three-dimensional) one (Fig. 72) where the shape of the ceiling itself helps to justify the gradients to the mind’s eye as long as the relation between shape and gradient is consistent throughout the visual field. One of the disturbing aspects of the lighting scheme in Fig. 37 is the inconsistency and incompatibility of the relationship between structural form and luminance gradients.

**Expectation as a component of the process of perception**

The expectations which are triggered during the process of perception influence both the activity and emotional state of the perceiver. They also govern the operation of the focus selector. Expectations condition the attributive classification of stimuli by preselecting categories in the experience filter against which the incoming stimuli are most likely to be matched in the process of associative assignment of meaning. Expectations establish frameworks for comparative judgment and evaluation: they make a white rabbit seem perfectly normal, while a white tiger or a white lobster (both of which exist) seem extraordinary. The intensity of the whiteness is obviously not the most important factor in these evaluations; it merely raises the curtain, as it were, for a drama whose script has already been written in the unconscious mind by the expectations.

Because they establish standards of comparison, expectations affect every evaluative reaction to the luminous environment: too bright and too dim both imply comparison with some standard or reference. Expectations have been covered in considerable detail elsewhere in this chapter; therefore, only one additional aspect—the relation between expectations and the color temperature of light—will be discussed briefly here.

**Expectation and the color temperature of light**

Expectation based on the time of day influences the evaluation of the color temperature of artificial light as appropriate or inappropriate. We expect illumination to be of a high color temperature (relatively blue) when luminaire levels are high because we refer them unconsciously to daylight, which has a relatively high color temperature. We expect low color temperatures (i.e., a warmer quality of light) when luminaire levels are low—perhaps by association with firelight, candlelight, and so forth. Kruithof had measured the range of color temperature under which objects appear “natural” and pleasant at different levels of luminance. His results (Fig. 73) substantiate the conclusions just presented, which were derived from the principles of perception. These conclusions support the general use of light sources with relatively low color temperature in interior environments, particularly at night.
The affective component of perception

Perceptions of the luminous environment always include an affective component: an evaluative or emotional response to the perceived state of affairs. Typical pairs of opposed terms which we use in verbalizing affective judgments are:

- Distraction / Positive Focus
- Glare / Sparkle or Glitter
- Gloomy / Cheerful
- Dull / Dramatic or Interesting
- Chaotic / Ordered
- Public / Intimate
- Unpleasant / Pleasant
- Unfriendly / Friendly
- Inappropriate / Appropriate

Obviously, such judgments tend to be qualitative rather than quantitative. For instance, we say that a space is glaring and uncomfortable, not that it has a brightness ratio of 30 to 1 and an average luminance of 200 footlamberts.

Our evaluation of a space depends on how well it meets our expectations. We base our judgment of whether a space is "light" or "dark" not on the actual luminance levels in the space but on whether or not the luminous environment meets our expectations and satisfies our needs for visual information by emphasizing what we want or need to see. Relevance and appropriateness are the key concepts here. An unhighlighted mural which is located as an obvious focal point for a room would be judged "inappropriately dark" regardless of its actual measured luminance because one expects that it was intended to be featured. Highlighting a dirty wastebasket, on the other hand, would create a scene described by most people as "too bright." The janitor, however, might find such highlighting useful.

Elements in the visual field are typically judged to be "too bright" when there is no perceptible reason for them to be brightly illuminated or when they interfere with our ability to perceive information required for the satisfaction of activity or biological needs. An evenly overcast sky, for instance, is evaluated as "unpleasantly bright" because it competes with our perception of the landscape, which is of greater interest and importance. During a performance in a theater, a lighted chandelier will always be perceived as too bright (even if only barely illuminated) because it is distracting. During intermission, on the other hand, the same chandelier brilliantly illuminated will be evaluated as beautiful and sparkling rather than glaring, annoying, distracting, or too bright.

When the largest, brightest, and most colorful elements within a space are the intended objects of attention, a positive focus exists which is likely to satisfy and please the users of the space. If, on the other hand, such objects are not the intended focus of attention, they will be perceived as annoying distractions, which may lead to a judgment of the entire space as unpleasant. This often happens when direct high-brightness fixtures are used; the standard lensed fluorescent troffer is particularly offensive in this respect.

Sparkle versus glare

Sparkle is defined in Webster's Dictionary as "an attractive brilliance."
Something which is perceived as sparkling is in and of itself attractive, a desirable and natural focus for a space. Its brightness may interfere with the perception of other elements of the visual environment, but because the source itself is attractive this does not cause an annoying distraction. Sparkle ought to be perceived as the result of a design intent. A bright element in the visual field is evaluated as sparkling if it is the desired object of perception—a chandelier, a view, or a patch of sunlight—but the same element would be evaluated as glaring if it merely caused a distraction without satisfying any activity or biological need for visual information. Glare is dazzling light which interferes with the perception of what we want or need to see—i.e., visual noise. Thus the relevance or irrelevance of a stimulus can play a more important role in causing the sensation of “glare” than abstract considerations such as luminance levels or brightness ratios.

In his study of artificial light sources of large areas, Hopkinson\textsuperscript{14} concluded that glare is just acceptable at 150 footlamberts, and that the sensation of glare is relatively independent of the size of the glare source. He also points out in a note that these conclusions are inconsistent with our everyday experience with daylight: it is not visually uncomfortable to walk about outdoors on a sunny day, even though everything in sight may be many times brighter than 150 footlamberts. Nor does it cause discomfort to look out of a window at a daylight scene, even when the eye has adapted to moderate interior brightness levels. The explanation of these discrepancies between psychophysical experiments in the laboratory and real-world observations may be the key to understanding the true determinants of visual comfort in the luminous environment: relevance and appropriateness.

For a meaningless, informationless, and uninteresting surface such as a translucent diffuser on a fluorescent fixture or a typical luminous ceiling, a surface brightness of considerably less than 150 footlamberts will generally be perceived as unpleasant—“too bright”—whereas a more interesting or relevant feature of the visual environment might be 10 times as bright without causing any discomfort or displeasure. Relevance and interest, not the measured surface brightness, are the critical factors; yet these factors, being very difficult to quantify, are almost always omitted from experimental research on glare and from conventional lighting criteria. Such omission effectively invalidates the results of such research as useful criteria for the design of the luminous environment.

The sensation of visual gloom

The sensation of visual gloom is usually caused by the lack of some expected and desirable quality in the luminous environment—a lack of information or a lack of appropriate focal points aggravated by the awareness of a more satisfactory alternative.

A space may be perceived as “gloomy” if inadequate or inappropriate lighting makes it difficult to perform activities. This can happen, for example, when there is not enough light to perceive a visual task accurately, or when a focal object is obscured by shadows, bathed in light of an unnatural color or silhouetted rather than highlighted, or when distracting glare sources or veiling reflections interfere with one’s ability to perceive desired signals.

However, frustration of biological needs for environmental

information is far more likely to be the cause of feelings of gloom. If, for instance, the design of an interior space cuts one off from contact with sunlight or deprives one of a view of the outdoors, the space will feel gloomy (except, of course, when there is a clear justification for the deprivation, as in a photographic darkroom or a movie theater).

When the perceived brightness of a space does not meet our expectations we may feel that the space is gloomy regardless of the actual ambient light levels. Unless dim lighting seems called for (as it might in an intimate dinner club), a dimly lit space will be perceived as gloomy during the day because our biological clocks are oriented to daytime and our eyes are adapted to high daytime luminance levels. Generally speaking, we expect interior spaces to be bright during the day, while dimly lit spaces seem perfectly natural at night because of adaptation and orientation to the nighttime environment with its typically low light levels. Thus a dark cocktail lounge will never seem gloomy at night because of a lack of light (although it may feel depressing because of drab decorations or a morose clientele).

The sensation of visual gloom can also be caused by inappropriate focal points in the luminous environment which draw attention away from what we want or need to see. For example, consider the scene in Fig. 74. The ground objects are dark in comparison with the overcast sky. A uniformly overcast sky is always the brightest element in the visual field. Because we usually want to focus on the ground objects which are more visually interesting and more relevant to our needs than the brighter but informationless sky, the overcast sky makes the entire scene seem gloomy despite its high ambient light levels (which may be as high as 5,000 footcandles). We judge the scene to be gloomy partly because the luminous environment emphasizes the uninteresting sky and partly because the diffuse light from the overcast sky robs the scene of the visual richness which comes from the play of highlight and shadow. Note that a sky full of billowing clouds, while casting no shadows, seems exciting rather than gloomy because there is still drama and visual interest in the scene.

On a sunny day (Fig. 75) ground objects are typically brighter than the blue sky vault while shadows define and emphasize the three-dimensional aspects of form. The scene feels “right”—bright and cheerful.

At night we judge a street scene such as the one in Fig. 76 to be “brightly illuminated” because the focus in the luminous environment is on the building facades where it belongs. Although the sky overhead is pitch black and luminance levels are perhaps a thousand times lower than in the daylit scene of Fig. 74, the positive focus in the night scene eliminates any sense of dimness or visual gloom.

A glaring direct light fixture, translucent window or luminous ceiling which is allowed to dominate the visual field will always be perceived as an inappropriate focus for the luminous environment. The typical luminous ceiling (Figs. 67 and A4–6) is directly analogous to the overcast sky in the preceding examples: it makes the interior “landscape” which it illuminates seem gloomy for the same reasons. This unpleasant attribute of luminous ceilings is hardly helped by the fact that the typical luminous ceiling appears cheap and flimsy, highlighting only construction flaws, manufacturing defects, and maintenance problems. These characteristics disappoint our
biological need for structural security and comprehensibility.

Although most designers pay a good deal of attention to lighting those surfaces and objects which they have decided to emphasize as focal points, relatively few designers pay equal attention to what not to light. Just as a bright but uninteresting light fixture is always offensive when it becomes the dominant visual focus of a space, so a highlighted dish return area in an adjacent kitchen would be an inappropriate focus for the luminous environment of a dining hall and would probably cause the viewer to condemn the entire space as unpleasant and gloomy.

It is important to realize that where a positive focus is obviously called for, the absence of such a focus can generate equally strong negative feelings about a design as can an inappropriate focus.

In summary, far more spaces are unpleasant because they are visually gloomy than because they are inadequately lighted. In most spaces improvement of the luminous environment may simply call for the use of less light, distributed in a more relevant manner to upgrade the overall appearance of the space and to bring it into line with subconscious expectations and needs.

Dull versus interesting

A subject or space of great interest is seldom described as visually dull. However, something which is inherently dull cannot be made more interesting by merely increasing its surface luminance. An inherently dull environment can only be made more interesting by the addition of color, more relevant or appropriate foci for the visual attention, shadows from directional light which emphasize the nature of its three-dimensional forms, or by the use of dramatic luminance gradients (such as the effect created at night by pools of light along a path in a pleasant garden). A brightly lit scene, however, may appear dull and uninteresting if intended or desirable objects of attention are dominated by inherently dull or informationless elements such as an overcast sky or a luminous ceiling.

Order in the visual environment

Evidence of order in the visual environment is usually pleasing to the beholder. Observable order and organization set up strong expectations, and when these expectations of consistency are not fulfilled, the environment may be perceived as disorderly and chaotic. The office landscape in Fig. 77, for example, appears busy and disorganized because it fails to respond to the highly directional geometries of the background context. The angled buildings in Fig. 74, on the other hand, do not seem disorderly because the contextual background of sky and river and woods is inherently directionless, but in a more ordered context they too might appear annoyingly disorganized.

One aspect of order in the visual field which is commonly overlooked concerns the design of lighting for symmetrical buildings. When the plan is square and both structure and glazing are treated identically on both axes, one expects interior elements such as the ceiling module and the patterns and shapes of light fixtures to show an equally clear and consistent symmetry. Rectangular light fixtures look out of place in an otherwise symmetrical interior. (The standard 2x4 fluorescent troffer is often misused in this way.) If, on the other
hand, the lighting has been clearly and consistently related to the
disposition of furnishings or walls, rather than to some overall
pattern derived from the entire building, there will be no expectation
that lighting fixtures should align with window or structural
module, or that the lighting module should be regular if the furnishing
layout is irregular.

Security and insecurity

Two emotional states which are directly conditioned by expectations
are security and insecurity. It is common knowledge that the unfamiliar
breeds fear; we are afraid of the dark at least partly because it is
inherently informationless. Turning off the lights in your living room
does not create tension because you know the environment too well;
you have sufficient experience on file to enable you to find your way
around without the aid of your eyes—and you know where potential
sources of danger are located. If the lights go out suddenly and
unexpectedly in an urban park, however, the unfamiliar,
unpredictable, and now invisible environment generates immediate
apprehension and fear of danger. The dominant message is that there
may be danger in this “dark” park—an expectation—and one focuses
possible sources of danger and tries to find a safe escape route. When
no danger is expected, such as during an evening walk on a pleasant
country lane, identical luminance levels might be perceived as
intimate or romantic, rather than dark and threatening.

In designing lighting which is intended to engender a feeling of
security, the expectations of the users must always be one of the most
important inputs to the design process. User studies have clearly
indicated that where there is fear of crime on a street, every shadow is
perceived as potentially threatening. On this type of street, relatively
low intensity light sources on short, closely spaced poles (a geometry
which produces minimum shadows) were judged to provide a greater
sense of security than much more powerful luminaries mounted
farther apart on higher poles (which inherently tend to produce
extensive shadows).* The fact that the more powerful luminaires also
produce 20 times as much light on the road did not offset the sense of
increased danger due to the more extensive shadows. In this example,
shadows, not light levels, were the problems in the street environment,
and the traditional strategy of simply increasing light levels fails to
address that problem.

*Gary Hack, Improving City Streets for
Use at Night: The Norfolk Experiment,
Norfolk Housing and Redevelopment
Authority, June 1974.

The feeling of intimacy

Expectation, visual order, and the appropriateness of the inherent
hierarchy of foci in the luminous environment all influence our
affective evaluation of a space as intimate or public. Intimate spaces
are generally perceived as private, closely personal, or cozy, but they
need not necessarily be dark. An intimate environment can be created
in a dining room, for instance, by creating separate pools of light, as
well as by physically separating booths or by using plant materials as
screens. Sparkling screens of brightly illuminated reflective materials
which effectively block off weaker visual signals from other tables can
also be used to create the sense of intimate, private space.
How well do we see?

The higher the strength, quality, and information content of a visual stimulus, and the higher the signal-to-noise ratio in the visual environment, the better we can see, in the sense of being able to form useful, meaningful perceptions related to our needs for visual information. All of these factors are influenced in turn by the surface characteristics of the object of interest and the state of the observer, as well as by the source characteristics, quality, and quantity of illumination. Among the factors which must be considered in an analysis of the quality of human visual perception, therefore, we must list:

- The experience and attention of the observer
- The characteristics of the object: form, optical size, inherent contrast, color, texture, specularity, reflectance, etc.
- Simultaneous contrast
- Context: information content, patterns, figure/background separation, etc.
- Adaptation
- Illumination qualities: geometry, dispersion characteristics, directionality, spectral type, quantity, polarization, number and type of sources, consistency of directional characteristics and color-rendering effect, etc.
- Presence or absence of focus or distraction in the luminous environment.

The quantity of light is obviously only one of the factors which determine how well we see, and although it may seem surprising, it is usually a relatively unimportant factor. Each viewer has specific information needs and each object has specific characteristics. The quality of the luminous environment depends entirely on how well it responds to both.

Attention and experience

The first factor which influences how well we see something is the degree to which it stands out as a natural focus of the luminous environment. Strong simultaneous signals which compete for the observer’s attention can either detract from or emphasize focal qualities of the object of interest. If they obscure or confuse the desired signal, we call them distractions or visual noise (as in the ceiling of the Houston Astrodome). If they help to create a positive attraction to the intended focus (such as an EXIT sign) we say that they emphasize the signal, intensifying the existing focus.

The more the distraction, the harder it is for the observer to maintain a focus of visual attention on the signal; the stronger the focus, the less effort it requires. The motivation and mood of the perceiver determine the length of the attention span, as well as the willingness to concentrate and to follow through with activities.

As a general rule, unfamiliar tasks demand a higher quality and/or quantity of light, if performance is to be as high as it would be in a familiar task. Experienced observers need less visual information
to form meaningful perceptions. Given the same amount of information, they tend to perceive familiar objects more accurately than inexperienced observers, because they know what to look for. For example, a person who has never hunted can only find animals in the woods with great difficulty, no matter how brightly illuminated the woods may be, while a trained hunter takes full advantage of all relevant signals, because his experience filter has been conditioned by prior experience to recognize them at once.

**The form and surface characteristics of objects**

The clarity of object characteristics—form, surface texture, color, inherent contrast, etc.—has a great influence on how well we can see at various levels of illumination. Different types of objects call for different types of lighting, and a summary listing of typical information needs, related object characteristics, and the corresponding illumination qualities which will maximize the visibility of the desired information is given in Table III–1.

The information content and strength of a signal are a function of the optical size and inherent contrast of the object of interest. A zebra has high inherent contrast; a smudged fifth carbon copy has relatively low inherent contrast. If optical size cannot be changed (the object cannot be brought closer to the eye or magnified in some way) the information provided by contrast becomes the prime determinant of the quality of a signal. The amount of contrast produced by an object is dependent on its form and surface characteristics as well as on the quality and quantity of available light to make the contrast visible to the eye. Color perception is dependent on the spectral qualities of the light; perception of texture and form depends on the direction and relative concentration of the illumination. Different types of sources disperse the light they produce in different ways. Point sources such as incandescent lamps, metal halide lamps, and arc sources disperse light more or less evenly in all directions. This light then decreases in intensity according to the inverse square law. Line sources such as fluorescent sources disperse light in a cylindrical distribution the intensity of which decreases in direct proportion to the distance from the source. Area sources such as luminous ceilings, an overcast sky, indirectly illuminated walls or ceilings, and large translucent panels disperse light in different directions as a function of the solid angle and surface brightness of the source in each direction. Fixture characteristics can modify the original source distribution through the use of lenses, reflectors, and/or baffles. Obviously, the extent to which the inherent characteristics of the objects viewed will be enhanced or obscured by a given lighting system is dependent not only on the quality and spectral characteristics of the light but also on the directional characteristics of the light sources themselves, as well as their location with relation to both object and viewer.

**Context**

The clarity with which an object is perceived is influenced by its context. One aspect of context is its information content: the shape of a wire sculpture, for instance, can be clarified by a single set of shadows thrown against a flat, featureless background surface. Multiple shadows, shadows thrown onto a complex background, or a visually noisy background, on the other hand, will confuse the
perception of the same sculpture. The confusion will be redoubled if the sculpture is complex and the location of the sources is not evident. Clearly, care must be exercised during the design of lighting systems incorporating directional sources to avoid this sort of counterproductive confusion.

Other aspects of context which influence the quality of perception are phototropic effect, simultaneous contrast, and color. Phototropic effect—a term which comes from the Greek words "to seek light"—refers to the automatic attraction exerted on the focus selector by bright sources in the visual field. Bright sources which are not the intended focus of attention cause the eye to adapt to a high average brightness level, reducing the perceived strength and quality of the desired signal. We react defensively when such sources cannot be excluded from the field of vision (Fig. 78). When the competing background is of a higher luminance than the signal, the clarity of the signal is reduced. The effect is greatest when the offending background elements are located close to (or surround) the signal. A glossy table top can be an annoying source of reflected glare if overhead fixtures fall into the mirror angle. Competing glare from work surfaces can be reduced by locating light sources outside the mirror angle. Simultaneous contrast—the contrast between figure and background—can enhance the distinctive qualities of the signal. The relation between the color characteristics of the desired focus and the background can either reinforce the signal or effectively camouflage it. The characteristics of one particular ruby, for instance, can best be seen against a featureless black or dark green background, as any jeweler knows. If the same stone were to be seen lying on a heap of other rubies, simultaneous contrast and color contrast would be minimized.

Signal quality as a function of the quantity of illumination

It has already been emphasized that using relevant and appropriate qualities of light, rather than indefinitely increasing the quantity of incident light, is usually the most effective way to maximize the visibility of desired or needed information. Above levels of luminance on the order of 10 footlamberts, the geometry of light source and objects viewed becomes far more important as a determinant of signal quality than the absolute quantity of light.

To increase visibility by brute strength (additional footcandles) rather than skill (fewer footcandles used to better effect) is not only grossly wasteful; it is likely to have undesirable and counterproductive side effects in the form of glare. When a space is sufficiently well illuminated to satisfy biological information needs, and a shortage of light is still the operative constraint on the visibility of a task, the task is usually so demanding that it should be given a special focus in the overall luminous environment. The most effective way to satisfy such special needs is via local lighting (see below) rather than by increasing the lighting throughout a space to the levels required for one highly demanding and probably localized task.

Visual capacity is often thought of as limited primarily by the strength of the task luminance, which suggests that better vision is simply a matter of increasing the incident illumination. However, the visibility of a task may be limited by either visual acuity or contrast sensitivity, both of which vary with task luminance. The relationships between task luminance, visual acuity, and contrast sensitivity are
<table>
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<th>Object Surface Characteristics</th>
<th>Positive Lighting Qualities</th>
<th>Lighting Qualities to Avoid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum surface brightness</td>
<td>Totally matte surface (carpet)</td>
<td>Illumination normal to the surface; the surface should be of maximum reflectance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Totally glossy surface (glossy paint; mirror)</td>
<td>Illumination at the mirror angle (particularly for mirrorlike surfaces with no inherent color which can only gain surface luminance by reflecting a source of illuminated surface at the mirror angle)</td>
<td></td>
</tr>
<tr>
<td>Brightness contrast from surfaces of varying reflectance</td>
<td>Totally matte surface (carpet)</td>
<td>Illumination normal to the surface</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Totally glossy surface (glossy photo)</td>
<td>Illumination from other than the mirror angle</td>
<td>Illumination from a source within the mirror angle; if such sources cannot be avoided, the negative effects of mirror reflections can be minimized by using sources of maximum size and minimum luminance</td>
</tr>
<tr>
<td></td>
<td>Dark glossy surface on a light matte background (dark printing on white matte paper)</td>
<td>Illumination from other than the mirror angle</td>
<td>Illumination from a source within the mirror angle</td>
</tr>
<tr>
<td></td>
<td>Light glossy surface on a dark matte background (white printing on black matte paper)</td>
<td>Illumination from a uniform source of maximum size at the mirror angle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dark matte surface or a raised projection on a glossy background (matte paint or raised lettering on glass)</td>
<td>Illumination from a uniform source of maximum size at the mirror angle</td>
<td>Illumination from a concentrated source at the mirror angle</td>
</tr>
<tr>
<td></td>
<td>Dark matte surface or an indentation on a glossy background (grout joints in tile work)</td>
<td>Illumination from a uniform source of maximum size at the mirror angle, or from a concentrated source from the viewing angle</td>
<td>Illumination from a concentrated source at the mirror angle</td>
</tr>
<tr>
<td></td>
<td>Metallic glossy surface on a dark matte background (gold or silver printing on a dark matte book binding)</td>
<td>Illumination from a uniform source at the mirror angle</td>
<td>Any illumination from outside the mirror angle</td>
</tr>
<tr>
<td>Color contrast</td>
<td>Same as above except that a full spectrum source should be used for discrimination between a full range of colors; a limited spectrum source may be acceptable for discrimination between a limited range of colors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brightness contrast from variation in light transmission characteristics</td>
<td>Transparent surface (stained glass and glassware)</td>
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<td>Backlighting from a concentrated source directly behind the transparent surface or object</td>
</tr>
<tr>
<td></td>
<td>Projected image</td>
<td>Projection onto an opaque nonspecular surface</td>
<td>Stray light from other sources falling on the screen from any angle</td>
</tr>
<tr>
<td></td>
<td>Translucent surface (white glass)</td>
<td>Backlighting; a concentrated source is acceptable if located some distance behind the translucent surface, unless the surface is closer to transparent than translucent</td>
<td></td>
</tr>
<tr>
<td>Information Need</td>
<td>Object Surface Characteristics</td>
<td>Positive Lighting Qualities</td>
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<tr>
<td>Shape</td>
<td>Simple closed solid (ball)</td>
<td>Illumination from a single concentrated source, or diffused illumination with a dominant direction somewhat displaced from the viewing angle</td>
<td></td>
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<tr>
<td></td>
<td>Closed solid with surface detail (sculpture, face)</td>
<td>Illumination from a single concentrated source, or diffused illumination with a dominant direction somewhat displaced from the viewing angle</td>
<td>Overlapping shadows from several concentrated sources</td>
</tr>
<tr>
<td></td>
<td>Solid object related to other surfaces by cast shadows (ball in the air, steps in sunlight)</td>
<td>Illumination which creates a single sharp shadow</td>
<td>Illumination which creates multiple shadows, particularly if the shadows are cast from several different directions</td>
</tr>
<tr>
<td></td>
<td>Simple open object understandable in silhouette (picket fence)</td>
<td>Illumination with a dominant direction; multiple shadows are usually acceptable</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex open object (wire sculpture)</td>
<td>Single sharp shadow cast by a source located away from the viewing angle</td>
<td>Multiple shadows</td>
</tr>
<tr>
<td></td>
<td>Dark raised solid (dark raised letters)</td>
<td>Concentrated or diffuse illumination from the viewing angle</td>
<td>Illumination from a concentrated source at an angle other than the viewing angle, particularly at grazing angles</td>
</tr>
<tr>
<td></td>
<td>Light raised solid (light raised letters)</td>
<td>Illumination from any angle which produces consistent sharp shadows</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Totally glossy solid with no inherent color (polished metal sculpture)</td>
<td>Illumination from a large uniform source at the mirror angles</td>
<td>Illumination from a diffuse source surrounding the object; supplementary concentrated illumination can be used to create highlights, reducing the negative effects of a large uniform enveloping source</td>
</tr>
<tr>
<td></td>
<td>Moving solid (runner)</td>
<td>Illumination with a dominant vector from the viewing angle such that it creates shadow gradients on the object; best seen against a uniform contrasting background</td>
<td>Visual noise in the background; minimize by locating potential sources of distraction such as light sources as far from the line-of-sight as possible</td>
</tr>
<tr>
<td></td>
<td>Surrounding enclosure (room, courtyard)</td>
<td>Illumination which defines planes of enclosure with even light gradients</td>
<td>Illumination which upsets or destroys the visible form of surrounding surfaces, with confusing or distracting illumination gradients which are inconsistent with the true form of the surfaces</td>
</tr>
<tr>
<td>Texture</td>
<td>Simple rough texture (brick wall)</td>
<td>Illumination from a single concentrated source or from diffused sources at grazing angles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Complex rough texture (electrical circuits)</td>
<td>Illumination from diffuse sources at grazing angles or from a concentrated source at neither grazing nor normal angles</td>
<td></td>
</tr>
</tbody>
</table>
summarized in Fig. 79. As the luminance of the task increases, visibility also increases up to a point, but both curves very rapidly reach a point of diminishing returns above which very large increases in background luminance are required to produce even small increases in visibility.

The operation of the law of diminishing returns can easily be seen in the relation between visual acuity and surface luminance of a task. Visual acuity means the sharpness of vision, measured by the smallest size of detail which can be seen at a given distance. Our visual acuity is at 57 percent of maximum when the object of interest has a surface luminance of only 1 footlambert. At 10 footlamberts, acuity has reached 78 percent of maximum. When luminance is doubled from 10 to 20 footlamberts, visual acuity is increased by only another 3 percent;
from 50 to 60 footlamberts, the increase produced in visual acuity is only 1 percent; and when the increase is from 100 to 110 footlamberts, the increase is a minuscule 0.1 percent—effectively undetectable. If this is so, one may well ask why lighting codes recommend such high levels of illumination—levels which require expensive investment in fixtures, levels which mean high operating cost and wasteful energy consumption while contributing almost nothing to our ability to see. For viewing small objects (when visual acuity is the limitation on visibility) a minor increase in the optical size of the object is worth more than an infinite increase in the quantity of illumination. A lens or a watchmaker's eyepiece can increase task visibility far more effectively under these conditions than pouring on more footcandles (Fig. 80).

When a chalkboard is to be viewed, for instance, a 25 percent decrease in viewing distance produces an improvement in visual acuity equal to increasing the amount of light 100 times (from 10 to 1,000 footcandles). When visual acuity is the limitation, the solution is for the teacher to write larger and for the visually handicapped to sit in the front of the room. However, acuity is limited more often by lack of contrast than by an absence of light.

The ability to perceive luminance differences between adjacent areas of the visual field is called contrast sensitivity. For contrast sensitivity, a relationship exists between luminance levels and visibility similar to that for visual acuity. Contrast sensitivity plays an important role in determining how well we can see: the higher the contrast, the less contrast sensitivity will be required to perceive a given visual task accurately. If it is necessary to detect subtle differences in contrast, high illumination levels will be required. Visual tasks which have little inherent contrast, such as reading smudged fifth carbon copies or light pencil handwriting, are often used to justify the needing high levels of illumination in work spaces such as offices or schools. However, it is usually more effective and less expensive to improve visual performance by increasing the contrast of the task than by increasing the illumination on the task severalfold. Increased contrast can be achieved at low cost, for instance, by using softer pencils or better duplicating processes.

The qualities of illumination—source concentration, direction, and polarization, for example—can greatly enhance or reduce the visibility of an object or task; therefore, they also influence the required contrast sensitivity. For instance, only 1 footcandle of concentrated directional grazing illumination might be required to make a chip in wood grain or the texture of board-formed concrete visible to the same degree as would 1,000 footcandles of diffuse illumination from a direction normal to the surface being observed.

For a given quality of task illumination, the required contrast sensitivity for a given level of performance of a given visual task is a non-linear function of the task luminance (and therefore, of the quantity of incident illumination) as shown in Fig. 79.

At a recent, government-sponsored symposium held in Cincinnati, lighting expert Dr. H. Richard Blackwell underlined the greater sensitivity of the visual system to changes in contrast than to changes in illumination levels, when he commented back in the 1930's... people thought that they knew what was good light, namely, indirect light. We discovered that, when we switched over from indirect lighting with very low levels to direct
lighting with the new fluorescent tube and increased light levels by three times perhaps, we did not really change or improve vision at all. Although the light went up by three, the contrast, generally speaking, went down . . . In many cases, you are worse off than before; and every architect in the business always thought this was true. But now science has finally caught up with common sense and we know why. It is because the eye cares linearly about contrast and non-linearly about the amount of light.\textsuperscript{18}

Contrast must reveal characteristics, not confuse or obscure them. For instance, high contrast caused by specular reflection of the light source from the surface of an object often hinders the perception of the object more than it enhances it. This problem is frequently encountered in the lighting of textured oil paintings—high light levels combined with bad reflections can do more to obscure a work of art than to make it visible.

It should be apparent by now that the nature and quality of perceived contrast are an important design variable, to be manipulated rather than taken for granted in the design of appropriate, relevant luminous environments. Successful design to maximize the perception of contrast is far more dependent on the geometry of lighting than on the quantity of task illumination provided.

**Local lighting**

Local lighting produces maximum focus and minimum distraction as long as the light source itself is baffled from view. The Luxo lamp is a familiar example of a highly flexible local lighting fixture. Using this type of fixture, objects of interest and tasks can be brightly illuminated while the background produces only minimal distraction because of its much lower brightness levels and the absence of glare.

Local lighting can be arranged to deliver a given quantity of light with maximum effectiveness, without simultaneously inflicting glare or intense heat on other persons in the room. There are many ways of delivering local lighting: for example, it can be "piped" through acrylic rods. Local lighting combined with magnification of the task can be more effective in increasing signal quality than an infinite increase in general illumination without magnification (Fig. 81).

**Examples of object types and relevant lighting characteristics**

This section contains a series of photographs which illustrate different object characteristics in various contexts, illuminated to various luminance levels by appropriate (and inappropriate) qualities of light. These examples demonstrate the importance of relevant lighting qualities: geometry, dispersion and directional characteristics, degree of diffusion, spectral type, number and consistency of sources, etc.

A light source at the mirror angle is shown in Fig. 82. Figs. 83 and 84 show a totally glossy object—a photograph—and totally glossy background—the surrounding pane of glass. The illumination is modest, the position of the source is proper relative to the specular surfaces (i.e., away from the mirror angle for those surfaces). Frame shadows have been eliminated by using shallow frames and by avoiding illuminating the display from a grazing angle.

Fig. 85 illustrates a totally glossy object with inherent color—the wet swimmer—as well as a solid object seen against a glossy

85 Surface reflections interfere with perception of swimmer.
86 Diffuse daylight from behind the observer improves the visibility of swimmers.
87 Underwater lighting plus lighting concealed above the spectator gallery produces almost perfect visibility at the Johns Hopkins Athletic Center, Baltimore (Meyer, Ayers and Saint Architects; William Lam Associates/Lighting Consultants).

background – the swimmer seen against the surface of the water. The reflected image of the window creates complex veiling reflections on the surface of the water which make it impossible to see the swimmer under water unless the pool receives additional light from other than the mirror angle. This can be accomplished by the introduction of diffuse (north or reflected) daylight, indirect illumination of the ceiling, or the introduction of supplementary underwater lighting as in Fig. 87. Fig. 86 was taken in the same pool as Fig. 85, but facing the other way – away from the major window. Comparison of the two makes immediately obvious the importance of correct orientation of light sources with respect to the surfaces and objects which they are intended to illuminate.

Surfaces are classified as matte or specular depending on the directional qualities which they impart to the light which they reflect. A matte surface diffuses the light falling upon it, reradiating it in all directions: "flat" paint and Persian carpets are good examples of matte surfaces. At the other extreme is the perfect mirror, a flat specular surface which reflects incident light without changing in any way its degree of angular dispersion. Most surfaces fall between these two extremes, diffusing somewhat but maintaining the general directional qualities of the incident light: a polished table top and a piece of white Formica are both semimatte surfaces.
Specular surfaces require special kinds of illumination. Details of a specular surface can best be brought out by either grazing light or by a large uniform source at the mirror angle. Mirrors and polished metallic surfaces can only gain luminance from a mirror reflection, since their perceived brightness is determined almost entirely by the brightness of what they reflect. This explains why polished metal buildings are particularly difficult to light at night—they simply reflect light from sources on the ground up into the sky; if the sources are placed high up, they are seen as points of light on the side of the building. If the surface of the metal is not perfectly polished—for instance, if it has a brushed or sand-blasted finish—it will diffuse the light to a certain degree, alleviating this problem. Flat polished metal letters seen against a dark background are equally tricky to illuminate well. They may appear brighter than the background during the day because they reflect the sky or other bright elements of the surroundings; at night, however, they can only be illuminated from the mirror angle if they are to appear bright.

The series of photographs in Figs. 88, 89, 90 illustrate the unusual difficulties inherent in the proper illumination of certain types of book titles. Visibility of dark, glossy titles on light-colored bindings is maximized by exactly the opposite lighting qualities which would maximize the visibility of silver and gold (specular) titles on dark bindings. Probably the most difficult book titles to read are those printed in silver or gold which act as mirrors and appear bright only if there is a bright surface at the mirror angle which they can reflect—the same problem encountered with the illumination of flat polished metal letters.

Visibility of specular titles is maximized by increasing the contrast between them and the background binding. This can be done by increasing the illumination at the mirror angle (which will be reflected most effectively by the specular type) relative to illumination from other angles (which will be reradiated more effectively to the eye by the bindings). However, this is difficult to accomplish in conventional library stack geometries, for obvious reasons.
Tilting a book up maximizes specular reflection from reflective type if the ceiling surface is brightly and evenly illuminated. Tilting the book down greatly decreases the brightness of the binding, but legibility will be increased if the brightness of the binding decreases faster than that of the reflective printing. The same effect can be achieved by shielding the binding with one's hand.

Either of these steps is more effective than simply increasing the overall illumination levels substantially without changing the geometry. Correct lighting geometry is far more important in the proper illumination of specular materials than the absolute illumination level. For most library conditions, a large area source overhead such as an indirectly illuminated ceiling (Fig. 88) combined with a light-colored floor material will maximize the visibility of the required information. Although the direct sources in Figs. 89 and 90 produce an identical quantity of vertical footcandles on the bindings as the indirect source in Fig. 88, the difference in legibility is immediately apparent.

The clarity of raised objects, such as letters, is particularly affected by the contrast between the letters themselves and their background. A shadow from a dark raised letter on a light-colored background reduces clarity because the shadow resembles the tone of the letter, confusing the outline of the letter itself. Spacing the letter from the background reduces the confusion somewhat, by increasing the separation between the two dark images—letter and shadow. Dark letters are better when flat or recessed, so that shadows either do not exist or fall within the letter itself. On the other hand, shadows are helpful in the perception of light-colored raised letters, because they increase rather than decrease the amount of useful information available to the eye. When light letters are recessed, shadows reduce both the clarity of the image and the contrast between signal (letters) and background. Fig. 91 illustrates these various conditions.

Transparent objects such as glassware are best illuminated by backlighting (Fig. 92). In the laboratory, for instance, titrations are often more visible when seen in silhouette against the background of a well-lighted featureless white wall than when the illumination falls directly on the equipment itself—a lighting geometry which is likely to cause distracting ceiling reflections and glare.

For the perception of three-dimensional objects, the geometry of light sources is extremely important. Most of our ability to perceive volumetric form comes not from the contrast inherent in the object itself but from the gradients of light and shadows produced by the illumination which falls on the object. Shadows are poorly rendered by uniform diffuse lighting such as that produced by an evenly overcast hemispheric sky. Under such circumstances, when we are deprived of the information provided by modeling and shadows, we must rely more on outline, color, and other information for the perception of shape and form. At the other extreme of the scale, light from a single concentrated source produces maximum shadows and modeling, but much useful information may be hidden in the shadows themselves.

A simple three-dimensional object such as a cube illuminated by several concentrated sources may still be comprehensible, because the perceptual process compensates for some inconsistency in gradients and shadows as long as the nature and location of the sources are also comprehensible. However, when several complex objects are viewed
simultaneously, multiple gradients and inconsistent shadows can be thoroughly confusing.

If there are no other reference clues to the size and position of an object in its context, the shape of a shadow and the sharpness of its edges can provide enough information to establish its relative position (Figs. 93, 94, and 95).

The best condition of illumination for most three-dimensional objects corresponds to the condition we encounter outdoors: a combination of directional sunlight and diffuse skylight, which produces consistent, sharp shadows, all from the same angle, as well as sufficient light from other directions to fill in detail in the shadows. Indoors, lighting from a window produces soft shadows with a coherent grading (the window can be regarded as a uniform area source). The equivalent in interior lighting to the sunlight condition would be a combination of overall diffused lighting supplemented by a directional component from a point source (or a set of consistently directional sources). Artificial diffused lighting with a dominance in one direction can produce the same desirable modeling effect as interior daylighting from windows on one side of a space.

The characteristics of illumination which are most relevant to the perception of closed solid objects with detail, such as a typewriter or a camera, can best be understood by considering the qualities of lighting which are most appropriate for the perception of faces. High-quality perception of three-dimensional objects such as faces requires visibility of detail and color as well as overall form. Illumination should have a dominant direction (vector) neither coinciding with the viewing direction (i.e., from behind the observer, which produces minimum modeling), nor perpendicular to the viewing direction (which produces maximum modeling). When the direction of the lighting is poor, the ratio between maximum and minimum illumination should be low, particularly for viewing faces: the optimum brightness ratio would be less than 10 to 1, ideally between 2 to 1 and 5 to 1. For illuminated faces with a low brightness ratio, the direction of the light is not so critical (Fig. 96), whereas with a high brightness ratio, sidelighting is much better than light from overhead. If the direction is good, of course, the brightness ratio can be much higher than 10 to 1. Such ratios, and good object visibility, can be achieved with a combination of directional and diffused
sources; alternatively, diffused sources of varying strengths can be used, which in combination produce light with a dominant vector, like that from a window. The diffuse sources need not necessarily be light fixtures: illuminated walls, floors, table tops, and other room and furniture surfaces can serve as general sources of diffuse light. This sort of moderately directional light is preferable to that produced by a large uniform area source overhead such as an overcast sky or a luminous ceiling. Multiple point sources are likely to cause multiple and confusing shadows.

Shading and shadows should be neither excessively dense nor confusing. Dense shadows from the side are better than those from above or below because faces are more symmetrical about the vertical axis. Shadows from the side emphasize individual characteristics (Fig. 98), while those from above or below tend merely to emphasize the symmetry (Fig. 97).

Summary

Visual perception involves far more than a passive and mechanistic response to patterns of light: it is a complex, active process of information selection, filtering, interpretation, and storage in which context, prior experience, and expectations are combined with incoming sensory data to create meaningful perceptions. Unless distracted, we look at what we want or need to see, as dictated by activity and biological needs for visual information. The visual attention is automatically directed by the focus selector to elements of the visual field which will provide the needed information. A distracting stimulus may cause the focus selector to redirect the visual attention. Such a stimulus need not be the brightest thing in view. The information content and context of stimulus also play important roles in determining its perceived relevance and importance. The eye adapts to general illumination levels over a very wide range, which explains in part why it is the relative apparent brightness of a stimulus and its context, and not the actual measured luminance levels, which determine its attractiveness to the mind’s eye.

We are comfortable when we are free to look at what we want or need to see; we are uncomfortable when the luminous environment
itself interferes with our freedom and ability to do so. The higher the strength, quality, and information content of desirable visual stimuli, and the higher the signal-to-noise ratio in the visual environment, the better we can see. These factors are influenced by the surface characteristics of the objects of interest, as well as by the source characteristics, quality, and quantity of the incident illumination. The experience and attention of the viewer, the nature of the visual context, adaptation, and the presence of positive focus or distracting signals in the visual field also affect the quality of human vision. Clearly, all these factors must be considered in the design of successful, relevant luminous environments.

There is no simple one-to-one relationship between measured luminance levels and the apparent brightness of objects as they are perceived by the viewer. Similarly, one cannot derive any simple quantitative formula to predict either the meaning which will be given to a particular stimulus or the emotional and evaluative responses which it will trigger. People perceive information and visual relationships, not absolute intensity levels of light. The final impression which will be lodged in the brain is principally determined by whether the stimulus is meaningful or meaningless, clear or ambiguous, relevant or irrelevant, expected or unexpected. These are the real questions which must be decided in the course of lighting design.

Considerations such as these explain why a pattern of light fixtures or a luminous ceiling may be perceived as glaring and annoying while a chandelier or a window view of even greater luminance may be judged to be sparkling and enjoyable, and why a well-lit concrete floor seems dull while a Bokhara carpet with much less light on it can be interesting and even exciting, and why a moonlit urban park may be seen as “dark” while a beach or a safe patio in suburbia with similar light levels would probably be judged as “unpleasantly bright.” In all of its complex aspects, visual perception is a thoroughly relativistic process.

Since the optimum lighting for different activities may vary greatly in qualitative terms, designers must know the surface characteristics of the objects to be seen, and must understand which illumination characteristics and geometries will enhance the relevant desired information and which will obscure it. At any level of illumination, the desired information which can be extracted from the task object can be enhanced or obscured according to the qualitative characteristics of the incident illumination. A small quantity of the right kind of light can produce far better task visibility than much larger quantities of an inappropriate kind. The designer must also recognize that the law of diminishing returns applies to the productivity associated with increasing light levels, and that for most tasks a level of illumination is soon reached at which the quantity of incident illumination ceases to be the effective constraint on the quality and speed of visual perception.

Knowing what information one wishes the luminous environment to convey is therefore far more important than specifying arbitrary general light levels. The eye adapts to light levels automatically; the mind responds to information. This simple premise lies at the heart of the design process proposed in the following chapter, and served as the conceptual point of departure for the design of the projects presented as case studies later in this book.