A good luminous environment helps us to do what we want to do and makes us feel good while we do it. Although it may seem simplistic, this statement summarizes the real objectives of lighting design—to provide a comfortable, pleasant, reassuring, interesting, and functional space for the people who will inhabit it.

We are comfortable when we are free to focus our attention on what we want or need to see, when the information we seek is clearly visible and confirms our desires and our expectations, and when the background does not compete for our attention in a distracting way. When these conditions are satisfied, we consider that a space is attractive and has an appropriate focus. We are distracted and made uncomfortable when the visual information is irrelevant or confuses our understanding of the environment. Our discomfort is increased when visual noise—irrelevant or confusing signals—dominates the field of vision and interferes with the ability to perceive relevant, useful facts about the nature of the environment or the progress of activities.

**Activity needs for visual information**

Almost every built environment is created to house some form of human activity. To perform almost any task, to engage successfully in almost any activity, one needs certain definable types of visual information. When reading, one needs to be able to see the words on the page clearly; when carving wood, one needs to be able to see and judge the progress of the work. A luminous environment which yields the required information easily will obviously be more satisfactory than one which does not.

When approaching the design of any luminous environment, therefore, it is important to analyze first the activities which will take place, to list them according to their various characteristics, to determine the needs for visual information associated with each activity, and to assign them priorities. Each activity can be ranked according to its frequency, its relative importance, its location, the people who will participate in it, and whether or not it takes place simultaneously with other activities in the same space. It is important to define visual tasks and activities as carefully and completely as possible before attempting to design a lighting system. The designer must ask such questions as: “What are the tasks? How frequently are they performed? Where? Are they vertical or horizontal? Two or three dimensional? Pencil, ink, or printed? Colored or black and white?

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MORE USEFUL

Asrûdin entered the teahouse and declaimed: ‘The Moon is more useful than the Sun.’

‘Why, Mulla?’

‘We need the light more during the night than during the day.’

—The Pleasuries of the Incredible Mulla Asrûdin
Would the presence of daylight help or hinder the perception process? The answers to questions such as these provide the only meaningful basis for the formulation of design objectives and performance criteria for the luminous environment.

Unlike biological needs, activity or “task” needs have always been recognized as objectives for lighting—too often, unfortunately, as the only objectives. Even so, optimum lighting conditions for tasks are seldom achieved, because quantity rather than quality of light is the common method of specification. Increasing the illumination on a task or an object can increase its visibility or it can decrease it, depending on the qualities of the illumination far more than on the quantity of light provided. The direction of the light, its source concentration, its color, and its other qualities must be appropriate to the specific nature of the information required and the characteristics of the object being viewed.

For each activity or task there are optimal luminous conditions under which we would ideally like to operate, and which would most facilitate the performance of the task or activity. The typical approach to lighting, however, starts with the isolation of one “most difficult task,” such as reading smudged fifth carbon copies, which is then taken as the basis for lighting levels everywhere in a space, with no regard for how often and where within the space that task is likely to take place. Although they may demand different and even conflicting qualities or quantities of light, all other tasks and activities which take place in the same space are not considered. Biological needs are never mentioned.

This “shotgun” approach is directly responsible for most of the bad aspects of our luminous environments. It is ridiculous that a committee in New York or Washington should have the power to specify inflexible lighting criteria based on abstract “most difficult tasks,” for all offices across the continent or all classrooms from kindergarten to university, when they have no knowledge of the actual tasks, their mix, and their frequency of occurrence. One would never argue that since lumberjacks require 5000 calories per day, everyone should eat 5000 calories per day. Light, like diet, must be balanced and related to the unique needs of each person’s physiology and the activities in which each engages. This is the reason why we advocate a “rifle” approach to task lighting, rather than the conventional, wasteful, and often counterproductive “shotgun” approach which calls for every corner of a space to be drowned in enough light to accommodate the most demanding sort of task, regardless of its probable location or frequency of occurrence—different spots for different activities. As I type these words, the illumination on my desk is less than one-fifth of the current United States recommended level for an office environment, yet in my office that is all the light I need for most of my activities. When I need more light, or a special kind of light for a special activity such as viewing slides, I push a switch and adapt the luminous environment selectively to meet my particular needs of the moment. Flexibility and quality, not sheer quantity, are the essentials of a good multiuse luminous environment.

It is unfortunate that very little useful research has been done to generate statistical data on typical activity patterns and durations in common types of spaces. Such applied research would be very helpful for the designer who must frequently work from an incomplete program, often for a building type with which he or she is relatively
unfamiliar. Most lighting codes which establish minimum illumination levels for different types of space incorporate implicit assumptions about the nature of activities which are expected to take place, and yet research often proves these assumptions to be highly erroneous. For instance, reading and writing are the visual tasks which are most commonly used as the basis for illumination codes. The implicit assumption is that reading and writing are sufficiently important and frequent activities that the overall luminous environment should be adjusted to suit the exigencies of these particular tasks. But are reading and writing important and frequent activities in most spaces? At the suggestion of the author, the M. I. T. planning office conducted a survey in 1967 of visual activities in typical classrooms at M. I. T.; the results are presented in Table II-1. This study revealed that reading and writing constituted less than 20 percent of the activities in the surveyed spaces, and that none of the activities recorded involved pencil handwriting—the task on which the illumination recommendations of the lighting industry are based. Note that these surveys were conducted in academic spaces, in which one would expect to find a higher proportion of time spent on reading and

**Table II-1. Results of Pilot Photographic Study by M.I.T. Planning Office in 1967**

_This study was carried out by photographing spaces and their occupants from the front corner of the room. The photographs were then analyzed to determine the exact visual task of each person in the scenes. Each person photographed constitutes “one observation.”_

<table>
<thead>
<tr>
<th>Visual Activity</th>
<th>Classroom Observations</th>
<th>Lecture Hall Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
<td>Total, %</td>
</tr>
<tr>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gazing</td>
<td>30</td>
<td>11.7</td>
</tr>
<tr>
<td>Lecturer or conversation</td>
<td>64</td>
<td>25.0</td>
</tr>
<tr>
<td>Horizontal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading (continuous):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pencil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ink</td>
<td></td>
<td></td>
</tr>
<tr>
<td>typewritten duplicate printing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>other (name)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Writing (includes reviewing):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>continuous notes drafting</td>
<td>62</td>
<td>24.2</td>
</tr>
<tr>
<td>Vertical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chalkboard</td>
<td>100</td>
<td>38.1</td>
</tr>
<tr>
<td>Displays</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projection: transparency opaque</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three dimensional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL NONTASK ORIENTED</td>
<td>94</td>
<td>36.7</td>
</tr>
<tr>
<td>TOTAL TASK ORIENTED</td>
<td>162</td>
<td>63.3</td>
</tr>
<tr>
<td>TOTAL</td>
<td>256</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

*Chalkboard or lecturer: It is not possible to distinguish from photographs in large lecture halls exact visual activities without the type of apparatus used by Mackworth. The chalkboard test is a conservative estimate; classroom observations indicate that a more accurate study would show a substantial number of observations of the lecturer.
writing than in other types of spaces. The conclusion should be obvious: it is not reasonable to tailor the luminous environment to suit the special needs of an activity which is neither frequent nor of long duration.

Further surveys should be conducted in other types of spaces to check the validity of this and other implicit assumptions which have been built into most contemporary lighting codes.

Biological needs for visual information: new criteria for design

Human perception is an active, information-seeking process which involves many mechanisms in the eye and the brain, some conscious and others unconscious. William James underlined the selective nature of perception when he wrote:

> Millions of items of the outward order are present to my senses which never properly enter into my experience. Why? Because they have no interest for me. My experience is what I agree to attend to. Only those items which I notice shape my mind — without selective interest, experience is an utter chaos. Interest alone gives accent and emphasis, light and shade, background and foreground — intelligible perspective, in a word. It varies in every creature, but without it the consciousness of every creature would be a grey chaotic indiscriminateness, impossible for us even to conceive.¹

We direct our voluntary attention to elements of the visual environment which provide information we need to perform our conscious activities. As James put it, "our voluntary attention is always derived; we never make an effort to attend to an object except for the sake of some interest which the effort will serve."² One criterion for a good luminous environment is therefore obvious: it should make readily perceptible the information which we require for our conscious and voluntary activities. In the following discussion, we will refer to needs for such activity-related visual environmental information as activity needs.

In much oversimplified form, activity needs are often misused to justify the illumination minima specified in lighting codes. But activity needs are not the only needs which must be satisfied by the luminous environment, nor are they necessarily the most important. In the same passage, William James went on to write:

> But both sensorial and intellectual attention may be either passive or voluntary.

> In involuntary attention of the immediate sensorial sort, the stimulus is either a sense-impression, very intense, voluminous, or sudden, . . . or else it is an instinctive stimulus, a perception which by reason of its nature rather than mere force, appeals to some one of our normal congenital impulses and has a directly exciting quality . . . we shall see how these stimuli differ from one animal to another, and what most of them are in man: strange things, moving things, wild animals, bright things, pretty things, metallic things, words, blows, blood, etc., etc., etc.³

Classifying the objects of involuntary attention cited by James into broader categories, and extending the et cetera, I suggest that these "normal congenital impulses" relate directly and logically to the essence of human beings as biological organisms — to their safety and security, sustenance and stimulation. I propose that we call James's "normal congenital impulses" biological information needs, because they

²Ibid., p. 416.
³Ibid., pp. 416–417.
derive directly from the biological nature of the human being.

Such information is required by everyone, everywhere, everywhen, regardless of their immediate state of activity or inactivity. The intensity of the various biological information needs is conditioned to a certain degree by the experience and cultural background of each individual, and by the nature of the particular circumstances in question. Yet underneath the diverse aspects of human individuality, there lie more fundamental, universally shared characteristics—the basics of human nature. Rene Dubos, in So Human an Animal, wrote:

While civilization obviously conditions what man becomes, it does not significantly affect his biological nature; what changes is his social milieu. . . . as the English historian Arnold Toynbee wrote: “Scratch the surface and efface what we receive from an education which never ceases and we shall discover something very like primitive humanity in the depths of our nature.” This is true not only for social behavior but also for biological and emotional needs.4

When fully concentrated on a demanding task, we become relatively unconscious and unconcerned about anything else, and any irrelevant visual information may be an undesirable distraction. As formal tasks demand less focus, or as our attention strays, the focus of perception turns to the search for information related to the satisfaction of biological needs. We seek facts of orientation: where we are, the shape and structure of the space, the nature and quality of furnishings and finishes, the identity of our neighbors, who they are and what they are doing, the time of day, and the weather. Our senses are constantly monitoring the environment for signs of change; all the senses take part in this biological Distant Early Warning system. In his book Perception through Experience, M. C. Vernon states that “The type of motivation to which perception is mostly directly related is the necessity of maintaining contact with the environment and adapting behavior to environmental change. . . . the perceptual capacities seem to function in such a manner as to produce rapid reaction to change, whereas in an unchanging environment they may cease to operate effectively.”5 When we have no specific activity to occupy our attention, the monitoring of biological information may become our conscious activity.

As James points out, “figure” objects, which are often relatively bright or strongly patterned with regard to their visual background or context, automatically attract our involuntary attention. If these automatic foci give us desired or needed information we are likely to find them satisfying and reassuring; an example would be a well-placed illuminated EXIT sign, bright enough so that we are aware of it but not so bright as to interfere with our other perceptions. However, if bright or strongly patterned stimuli which trigger our involuntary attention are informationless, ambiguous, or distracting, we find them annoying. Luminous environments in which biologically necessary information is unavailable, distorted, confused, or overpowered provoke feelings of dissatisfaction and discomfort, unless there is clear evidence that this deprivation was consciously intended to call forth some agreeable or exciting response. Planned distortions of biologically necessary information can be exciting in the context of a funhouse, but they have no place in most environments.

In considering James’s comments on the nature of involuntary visual attention, one must always bear in mind that visual perception

is a process which involves much more than the eye alone. It cannot be analyzed as a simple stimulus-response system, because seeing involves the brain as well as the eye, and through prior experience the brain plays a major role in determining which characteristics of objects make them worthy of attention—figures seen against a background of visual context. Since the brain is constantly monitoring the visual environment for new information which might be of significance with regard to biological or activity needs, things which are unexpected or which contrast with their visual backgrounds because of some unusual quality are likely to be treated as figures by the visual-processing system, attracting the attention of the beholder. Note that it is not necessarily the strength of a particular quality such as brightness or movement which attracts the attention; depending on the nature of the context, it might be that an absence of a particular quality such as color or movement might establish a figure/background relationship demanding the visual attention. A face drained of color, a motionless figure lying on the ground, a sudden darkness overhead can all trigger the attention of the viewer. The key here is contrast with context or expectation, not necessarily the simple strength of the stimulus.

Consider 10 fans of an identical model, all gray except one which is painted red. The attention is drawn to the red one because of its color contrast with the others. If nine had been red, and one gray, the gray one would have attracted the visual attention because the very neutrality of its color made it a figure against a red background. Suddenly one fan starts to turn. Immediately the eye is drawn to it, since its new quality of movement distinguishes it from all the others. Then all the rest start. The eye wanders; all are now the same, in motion. There is no figure, no background. But if one slows down and stops, the eye will be drawn to it by its lack of motion, a new figure quality which distinguishes that fan from all the others. Clearly contrast and context, prior experience and expectations all influence the operation of the involuntary attention, and a quality which distinguishes a focus for the attention one minute may quickly be supplanted by its opposite.

If they want the environments which they design to respond effectively to all the needs of the user, designers must understand the workings of these innate, automatic perceptual mechanisms related to the satisfaction of biological needs.

It should be obvious that biological needs for environmental information are extremely important, yet in lighting codes and in the normal processes of programming and design, these needs are given no explicit recognition whatsoever. There can be no question that our luminous environments should be structured to facilitate the perception of biologically necessary information, but until these needs can be articulately and concisely expressed, they will be given lip service in principle and ignored in practice, as they have been in the past. We must be able to state more precise environmental objectives than “create a mood” or “create an attractive space.”

Table II–2 summarizes briefly a number of important biological needs, and lists perception-based criteria for the design of relevant, appropriate luminous environments. Characteristics of good hardware systems and lighting appropriate to the satisfaction of various biological needs are also suggested, although the selection of hardware should always be held in abeyance until all reeds have been analyzed.
<table>
<thead>
<tr>
<th>Biological Need for Visual Information</th>
<th>Critical Time or Situation</th>
<th>Visual Information Required</th>
<th>Implications for the Luminous Environment and Hardware Systems: Desirable Qualities</th>
<th>Qualities to be Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation</td>
<td>All times; maximum when moving</td>
<td>Level horizontal reference clues Use material tips, e.g., in masonry, moldings, expansion joints, fixtures, etc., to establish clear horizontal orientation</td>
<td>Avoid inclined surfaces without clear visual information defining the nature of the incline; avoid spaces defined by irregular or curvilinear enclosing surfaces without clear horizontal clues</td>
<td></td>
</tr>
<tr>
<td>Definition of ground surface contours, enclosing boundaries, obstructions, level changes</td>
<td></td>
<td>Define level changes and edges with highlighting, consistent shadows, changes in material (color, surface, or reflectance)</td>
<td>Avoid distracting elements in the visual field at level changes; avoid confusing elements such as inconsistent shadows or carpet patterns which tend to obscure rather than to emphasize level changes</td>
<td></td>
</tr>
<tr>
<td>Location relative to destinations and exits</td>
<td></td>
<td>Articulate the building layout and circulation system by a clear differentiation of circulation nodes and destinations with distinctive patterns of decorative light sources or by selective highlighting of elements such as elevator cores, etc.; corridors should be differentiated from work spaces, and different types of corridors should be treated differently; good graphics should be used, particularly at decision points such as corridors and intersections</td>
<td>Avoid unified lighting schemes which apply the same design to functionally disparate spaces, providing no visual guidance information to the users of the space location</td>
<td></td>
</tr>
<tr>
<td>Physical security</td>
<td>When danger is expected from people or animals</td>
<td>Location of potential threats, the nature of the surrounding enclosure Eliminate unlighted areas and sources of glare which might conceal danger, clarify the nature of the surrounding enclosure—structure, possible exits, etc.</td>
<td>Avoid backlit signs as opposed to letters, in which the shape of the background typically dominates the intended message</td>
<td></td>
</tr>
<tr>
<td>When danger is expected because of weather</td>
<td>Comprehensible structure with clear contours and visual logic Use forms consistent with the expectations of the viewer: use light gradients consistent with the forms of the structure which they illustrate</td>
<td>Avoid binocular structural forms such as the typical luminous ceiling; avoid obscuring structural elements with unshielded light sources; avoid using sources inconsistently (different sources to light identical surfaces)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When danger is expected from fire</td>
<td>Location of control and prevention equipment; escape routes clearly visible Use lighting to articulate circulation paths and exits; use color-coded fire extinguishers and clear EXIT signs</td>
<td>Avoid unevenly illuminated EXIT signs and EXIT signs which do not dominate their surroundings sufficiently to be clearly visible; eliminate other signs in the vicinity of EXIT signs which would compete for the visual attention; avoid overly bright EXIT signs, on the other hand, in dark environments, such as theaters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>When danger may be caused by intense light or glare</td>
<td></td>
<td>Use proper glare shields or other control devices on luminaires so that sources do not</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table II-2: SPECIFIC BIOLOGICAL NEEDS FOR VISUAL INFORMATION AND THEIR IMPLICATIONS FOR THE LUMINOUS ENVIRONMENT AND FOR THE SELECTION OF HARDWARE SYSTEMS.
and evaluated for their visual implications. The table is not intended to be complete or definitive; introspection will reveal other biological needs which deserve consideration in the design of luminous environments.

Among the most important biological needs for environmental information, we may list an awareness of the following:

- **Location**, with regard to water, heat, food, sunlight, escape routes, destination, etc.
- **Time**, and environmental conditions which relate to our innate biological clocks
- **Weather**, as it relates to the need for clothing and heating or cooling, the need for shelter, opportunities to bask in the beneficial rays of the sun, etc.
- **Enclosure**, the safety of the structure, the location and nature of environmental controls, protection from cold, heat, rain, etc.
- **The presence of other living things**, plants, animals, and people
- **Territory**, its boundaries and the means available within a given environment for the personalization of space
- **Opportunities for relaxation and stimulation of the mind, body, and senses**
- **Places of refuge**, shelter in time of perceived danger

Changes in the perceived status of these important aspects of the environment trigger warning signals in the brain, demanding attention. We pay more attention—conscious and unconscious—to biologically important factors than we do to other sensory data which are less relevant to our physical, intellectual, and emotional well-being.

If the incoming sensory data are ambiguous, so that we are unsure about the definite status of biologically important elements of the environment, we become uneasy and uncomfortable. If the incoming data are unambiguous and if the perceived facts indicate that everything is as expected and under control, we relax. On the other hand, if the facts indicate danger, we feel tense and wary. We react negatively to informationless environments such as a dark alley or a window at night through which we can be seen but cannot see, because that which we can neither comprehend nor classify might contain danger.

**The need for orientation**

For protection of the body, an awareness of its location, movement, and state is necessary at all times. Our sensory monitors which provide the necessary environmental information for such orientation operate continuously, even during sleep. High-quality continuous visual information is required for all physical activities, such as walking, running, jumping or working.

When we are walking and even when we are seated, awareness of the horizon is important. The human mind can cope with a horizon which is unclear because of low contrast. But our biological need for horizon orientation makes us uncomfortable when the horizon is
completely obscured, as in Fig. 6. If the fog obscures the crisp edge between sky and sea, for instance, while eliminating orientation clues normally provided by the directional quality of sunlight, we may become disoriented and uneasy.

The example in Fig. 6 may seem somewhat irrelevant to most architectural situations—fog is after all relatively infrequent inside most buildings—but the principle involved remains valid. Inside buildings, we normally use other visual clues besides the physical horizon to give us orientation to the horizontal; when these clues are distorted or absent, the effect can be very disturbing. One such disorienting space can be found in the TWA terminal at Kennedy Airport in New York (Fig. 7). The corridors which lead from the main lobby to the departure lounges have sloping floors and smooth, featureless, nonvertical walls—an environment which gives the beholder no clues whatsoever as to the true vertical and horizontal. This disorienting effect is heightened when there are no other people in the corridor who can be used as references. Vertical pictures, graphics, or visible expansion joints which would create reference planes would alleviate the unpleasant sensation of disorientation.

Another well-known example of a disorienting space is the spiral exhibition gallery in the Guggenheim Museum in New York (Fig. 8). Many people are somewhat uncomfortable in this space because they cannot tell whether to stand perpendicular to the gently sloping floor or parallel to the pictures which are hung on a true horizontal. Although the pictures do give reference lines indicating the true horizontal, the incoming sensory data are sufficiently ambiguous so that one becomes uneasy—though the untrained observer may be unable to articulate the source of his or her distress.

**Orientation as affected by expectations and prior experience**

The phenomenon of disorientation in ambiguous interior spaces brings up an important aspect of the process of perception. As James pointed out, our senses are constantly bombarded by a flood of impressions—incoming raw sensory data—which is sorted and processed by the mind and the sense organs themselves so that only relevant information is brought to the conscious attention. However, the incoming stimuli are not evaluated solely according to their quantitative characteristics—strength, duration, information content, etc. The meaning which they are given, the importance which is attached to them during the actual process of perception formation, is conditioned almost exclusively by prior experience with other, similar or related stimuli. The interpretive mechanism of the mind’s eye operates according to the basic principle that similar causes will produce similar effects; we can survive and function only because the world usually behaves and appears as we expect it to.

Obviously, expectations play an indispensable role in the process of physical orientation. We expect floors to be flat, because the vast majority of floors which we experience are flat. When we encounter a sloping floor, without clear visual signals that it is in fact sloping, our expectations tell us that the floor is probably flat, while the inner ear tells us something quite different. The inner conflicts which such perceptually ambiguous situations set up can be profoundly disturbing.

Expectations affect our emotional response to different
environments in a number of ways. In particular, they condition our response to the presence or absence of biologically necessary information. Our evaluation of any environment is colored by the memory of prior experience in analogous situations. In the seashore example, we know that under other circumstances we would be able to see the horizon; if we cannot see it, there is less biologically relevant orientation information available than there once was. The brain, consciously or unconsciously, is aware of the lack, and makes us uneasy. If we were flying or sailing, we would be acutely conscious of a lack of visible horizon; in fact, airplane instrument panels have artificial horizons for such occasions. On the other hand, in a basement or a coal mine shaft far under the surface of the earth, we would not expect to see the horizon; we have never seen it under such circumstances, and therefore its absence seems perfectly natural.

One must avoid making careless generalizations regarding biologically required information for orientation: under different circumstances, different types of information become necessary and appropriate. In certain sports, for instance, awareness of the horizon is relatively unimportant, and other orientation clues assume top priority according to the particular nature of the game. The luminous environment should provide appropriate information to meet these special needs. For instance, the handball player plays against the ceiling as well as the walls. The poor definition of the junction between wall and ceiling in Fig. 9 caused by the strong pattern of scallops on the walls is distracting and confusing. In the squash court in Fig. 10, the ceiling is not a playing surface; therefore good definition of that junction is less important to the players and the disturbing scallops were simply painted out. The same lighting fixtures which were inappropriate to the handball court are more satisfactory in the squash court in Fig. 10.

The need for time orientation

Time orientation is another important biological need for which we require types of visual information about the environment. Human beings, like most other organisms, possess inherent biological mechanisms which act as clocks of different sorts, to keep track of the rhythm of day and night as well as other biologically important cycles. As the seasons lengthen and shorten the hours of daylight, our internal clocks respond accordingly. This continually recalibrated time orientation gives us definite expectations of how light or dark it should be outside, and these expectations play a major role in our evaluation of any luminous environment, by establishing reference levels in the brain against which we evaluate incoming sensory data about the apparent brightness of the immediate environment. It is upsetting to go outdoors at noon and find it overcast and gloomy, because we expect it to be bright and sunny. We would be even more upset to walk outside at midnight and find it "bright as day"!

It should come as no surprise that expectation and time orientation play a major role in the evaluation of exterior environments; yet it is less well known that expectation and time orientation play an equally critical role in the evaluation of interior luminous environments. Because of time orientation, during the day we subconsciously expect it to be brighter outside buildings than inside, as in Fig. 11. At night, we expect it to be darker outside than

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*For a fascinating discussion of these biorythms, see Michel Gauquelin, The Cosmic Clocks, Peter Owen, London, 1965.*
inside (Fig. 12). During the day, we generally expect bright interior conditions, with walls and ceilings cheerfully illuminated, since they take the place of the sky and sunlit surroundings. At night, we expect the environment to be less bright, and luminance levels in the same space can be far below those appropriate during the daytime without making the space feel dark or generating feelings of gloom or sensory deprivation. Our eyes adapt to gradually changing luminous conditions during the cycle of the day and night, so that at night a candlelit room may be perceived as being brilliantly illuminated. The apparent brightness is high, even though the measured brightness or luminance is very low.

Sensations of gloom are likely to be caused not by low luminance levels, but by the contradiction from incoming sensory data of expectations based on time orientation. This happens frequently at dusk and on overcast days, as in Fig. 13, when the outside world seems to be darker than the inside. The length of this unpleasant period is extended by the use of low-transmission glass, which affects our perception of the relative brightness of interior and exterior conditions. If, due to the use of low-transmission glass, our eyes tell us that the outside world is darker than our time orientation tells us to expect, the effect is unpleasant because our time orientation is being fed distorted and unexpected data.

The need for consistency between lighting gradients and structural forms

For hundreds of thousands of years, people perceived the world around them illuminated by a single, directional light source—the sun. Whether because of species conditioning or because of each individual's childhood experiences while learning to see, we have definite expectations of how three-dimensional objects should appear. We perceive the third dimension not only through our stereoscopic vision, but also by observation of the light gradients and shadows which define volume and form. We have definite expectations of how most things—including structural elements such as flat walls, floors, and beams—should look when rendered in light. Uneven gradients of light which define the shape of three-dimensional solids seem pleasant and natural when consistent with our expectations (Fig. 1), but they can be disturbing, unnatural, and distracting when, for instance, a uniform flat surface is illuminated unevenly for no apparent reason (Fig. 15). Contradiction by the senses of biologically important expectations concerning the nature and form of structure is usually disquieting and should be avoided whenever possible.8

The ambiguous and irrelevant nature of most luminous ceilings

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8A more detailed discussion of how we perceive and interpret light gradients is given in Chapter Three, in the section "Luminance Gradients, the Perception of Brightness and Three-Dimensional Form."
(Figs. 14, 67) is unpleasant because most luminous ceilings conceal the real structure while substituting a flimsy, uneven, shoddy, ambiguous surface with badly finished joints. Rows of glaring fixtures which relate neither to any perceptible structure nor to the activities which they illuminate are likely to be found unpleasant for similar reasons: such fixtures confuse the comprehension of structure and give little evidence of the work of the concerned hand of the designer to tailor space to the use of its occupants.

The need for contact with sunlight

Visible evidence of the presence of sunlight satisfies a basic biological need, providing important clues about three-dimensional form and orientation in addition to indicating the state of the weather. For some activities, such as relaxing on a beach, sunlight may be entirely positive. But while we all enjoy seeing signs of the sun's presence, being in the sunlight itself may be unpleasant if the light or heat interferes with what we want to see or do (Fig. 16).

As long as it does not interfere with our activities we welcome sunlight inside buildings. Direct sunlight on a desk or work area, however, can be extremely bothersome, particularly if the condition persists for a long time, and if one is unable to control it or move away.

Even a small patch of sunlight is adequate to satisfy this particular biological need—a minimal area of clear glazing overhead can add more dramatic life and vitality to a space than acres of translucent glazing, which tend to contribute only unbearable glare and unpleasant solar heat (consider the Pantheon and compare it to a greenhouse with walls and roof of corrugated translucent plastic). The small areas of direct sunlight in Fig. 17 interfere with activities in only a small portion of each space; since the occupants are free to move about, no one is inconvenienced by these biologically satisfying shafts of sunlight. Analogous conditions may be seen in Figs. B4-4 and H2-8. It is important to note that light fixtures of equivalent size and brightness, if substituted for the patches of sunlight, would make most people feel uncomfortable. Unlike the sunlight, the light fixtures would seem arbitrary and out of place, distracting, glaring, and informationless rather than pleasing—one more piece of evidence that it is the meaning of bright sources in the visual field, and not merely their surface luminance or size, which determines our emotional response to them.

We react negatively to being deprived of desirable sensory information without some compensation. Obscured or pebbled glass windows are disturbing for this reason. We react favorably to stained-
glass windows, on the other hand, because they substitute another desirable form of positive visual experience for the view which they replace. If translucent panels are given a definite color or are overlaid with some pattern of interesting information, such as the maps in Fig. 19, they are at least more interesting to view.

Translucent panels give us no pleasure when backlit as they are in Fig. 18. As large, bright area sources they demand attention, yet because they are informationless they are more frustrating than pleasurable, whereas a window of comparable dimensions and luminance which framed a view would make a positive contribution to the space. We react negatively to informationless translucent panels backlit by the sun, not only because they are ambiguous, but also because the presence of sunlight tells us that we might have been able to have a view as well. Evaluation of the luminous environment is always comparative, never absolute: that which might be is always a factor in the evaluation of that which is.

The need for view

Manning has demonstrated that daylight is desirable, not only because of its illumination and spectral qualities, but because of the view which is usually associated with the daylight. Since people enjoy looking at sunlight falling outdoors as well as inside interior spaces, clear windows are desirable. North-facing clear windows are particularly valuable in this respect because they require no solar-control devices, which often destroy the view that the window was intended to provide in the first place. The view through many types of sunscreens, heavily mullioned windows, or Venetian blinds is uncomfortable because of the undesirable competition between the elements of the glazing plane and the view beyond. Such solar-control structures can generate substantial annoying visual noise which detracts from the pleasure of the view. The high brightness and prominent joint pattern of glass block walls attract the attention of the viewer, but the distorted irregular light pattern from the glass prisms is often difficult to understand and ambiguous, hence biologically unsatisfying.

When applied to fenestration, the characteristic American attitude that “more is better” (or, perhaps, “more is cheaper”) has brought us more curses than blessings. Anyone who has had to work in a glass curtain-walled building with no provision for solar control will be familiar with the problems of excessive solar heat loads in summer, unpleasant radiant cooling in winter, excessive sky glare and shadows, etc. Technical solutions such as mirrored glass can mitigate these problems but not solve them completely.

The role of the window in modern architecture needs reexamination. With today’s means for artificial illumination, the size, shape, and placement of windows should be chosen primarily to optimize the view. A horizontal view such as a skyline or shoreline should call forth horizontal windows—the fenêtre-en-longeur so beloved of the Modern Movement. When the view is all below eye level, window sills should be low, and there is no need for large areas of glazing well above eye height. High windows extending to the ceiling line are good in low buildings with interesting surroundings such as trees, other buildings, etc., especially if these surroundings protect the windows from the ravages of the summer sun. In high-rise

buildings, on the other hand, where little of interest can be seen above eye height, limitation of window heights reduces sky glare, excessive energy consumption, and problem sunlight control while sacrificing none of the interesting elements of the view (Fig. 20; compare with Fig. 78). When the most interesting mix of visual information is vertical, then vertical windows should be used. These are particularly appropriate when internal wall space is needed for other purposes such as teaching surfaces.10

The view through skylights and high cerestories is pleasant when the glazing is clear and uncomplicated. Otherwise, skylights should be baffled by a skylight well, which reads as an interesting, understandable surface providing desirable structural information. Under normal circumstances, one should never place a translucent diffuser at the bottom of a skylight well as in Fig. 21, because this has the same effect as obscuring a window: it reduces the meaningful character of the skylight to that of a light-figure surface, increasing the amount of discomfort glare which is experienced by the viewer.

A note on signs and other directional clues

Our environments are extremely complex. To find our way around in them, we rely primarily on the memory, in which are stored meaningful, recognizable patterns of visual information which are used by the mind in its continuous search for physical orientation and direction. The interstate highway sign with its distinctive profile, the yellow-striped crosswalk, and the crescent moon on a door all provide equally meaningful guidance to those who have encountered them before. All such orientation clues must be learned; they do not come built into the visual memory at birth.

It is important to remember that every environment contains more visual information than we can either comprehend or use. Out of this, we must be able to pick the particular patterns which will enable us to find our way around. Some of these directional signals are standardized: the red EXIT sign is a familiar example. However, we normally find our way by means of much subtler patterns of visual information, which may never reach the level of conscious awareness.

In an unfamiliar environment it is helpful if the perceptible patternings of visual information are sufficiently consistent that they may easily be used for orientation and guidance. One simple form of this sort of consistency in the luminous environment is the differentiation of public and private corridors with various kinds of lighting systems, colors, and materials. Another is the distinctive illumination of the walls of service cores and vertical circulation elements. A third is the use of decorative light fixtures to call attention to circulation nodes and important destinations.

Good graphics are indispensable in any complex environment; shopping streets, government buildings, office buildings, and universities would be incomprehensible without them. Yet graphics and other information systems, though critical, are often poorly designed with regard to the principles of visual perception. We frequently encounter backlit signs in which the large, brightly illuminated, geometric shape of the background dominates the actual message which it sets off (Fig. 22). Failure to apply the principles of perception to the problem of information transfer defeats the purpose of such signs, or at least undermines their effectiveness.

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10See, for instance, Case Studies E9 (the Pierrefonds Comprehensive High School) and G5 (Governors State University).
This is a classic case of counterproductive visual noise, a mistake that can easily be avoided by using illuminated letters against opaque backgrounds, which maximizes the visibility of the desirable signal by effectively eliminating the background as a competitor for visual attention (Fig. 23).

In the design of visual guidance systems, consideration of the principles of perception and visual noise is especially important. In the high-speed environment of the highway, safety and driving pleasure can be enhanced considerably by the clear definition of roadway alignments and intersections with consistent and comprehensible patterns of lighting, so that drivers need not rely solely on conventional signage for directional information. The clear and consistent use of distinctly different fixture types and mounting heights can be of invaluable assistance to both pedestrian and driver in terms of providing orientation to the hierarchy of city streets.

The need for focus on activities

Although we readily acknowledge the need for orientation and visual guidance clues in complicated, specialized, multiuse spaces, the conventional wisdom of lighting design gives no recognition to the equal desirability of creating an appropriate hierarchy of foci on activities in a general work space. Lighting can and should be used to create order and relevance in our work environments, instead of simply adding glaring, informationless, and distracting patterns of visual noise as it so often does. Elements of the visual field which are of interest or which provide visual information related to the satisfaction of activity or biological needs should be highlighted. As a general rule, spaces which enclose a strongly directed activity should create a strong luminous focus on that activity. Spaces with varying, multiple activities, on the other hand, should not create a dominant focus on any one specific activity, but should provide understandable backgrounds which allow the user to choose a focus and concentrate on it without distraction. Illumination should be of adequate quality and quantity for each activity. For relaxation, which is an important and often ignored aspect of every human environment, there should be obvious points of interest—featured works of art, for instance, or views which bring satisfaction to all. Relaxation and comfort will be enhanced by clarity of biologically important information such as circulation patterns, the nature of structure, views, evidence of sunlight, etc.

The definition of appropriate, visually defined foci in the luminous environment simplifies tasks and facilitates concentration. It can also save an enormous amount of costly, scarce energy which would otherwise be wasted in providing unnecessary levels of illumination throughout entire spaces, regardless of needs. It makes no sense whatsoever to illuminate that which we neither want nor need to see. Obviously, however, this sort of qualitative objective is alien to the conventional approach to lighting design, which defines good lighting only in terms of providing specified minimum footcandle levels everywhere in a space, with no premium assigned to the selective emphasis of that which we want or need to see, or to the concealment of that which we would rather not (or do not need) to see.

Two spaces in which positive focus has been achieved through
appropriate coordination of lighting systems and architectural elements are shown in Figs. 24 and 25. The usual complex clutter of light fixtures has been eliminated in the kitchen (Fig. 24). The space has been organized by arranging nonglaring indirect lighting around the hood islands. The illuminated ceiling conveys a cheerful sense of spaciousness and helps to eliminate feelings of gloom during the day, when time orientation and expectations demand a bright “sky” overhead. The lighting in the courtroom (Fig. 25) was carefully conceived and coordinated with the architecture to create an appropriate setting and focus for trial proceedings. In both spaces, the positive focus achieved increases the relevance of the luminous environment.

The need for definition and personalization of territory

Wherever they go and whatever they do, people show a clear tendency to personalize the spaces in which they live and work. This biological need to define territory and to personalize private space has strong implications for the design of the luminous environment. In public spaces such as libraries, control over local lighting and furniture arrangement may be the only available means by which the user can carve a personal niche out of the general public turf. Provision of such simple and inexpensive devices as Luxo lamps or individual carrel lights can make a tremendous difference in the extent to which people feel at home and in control of the public spaces they use (Fig. 26).

In large, open office landscapes, people generally seek ways to define and identify their particular location— their place. If the structure of a building and the organization of its luminous environment provide large-scale elements such as major ceiling coffers or columns, to which the inhabitants can relate their sense of place, the environment is likely to be more satisfactory in this respect than if the only architectural elements available for place identification are an endless sea of featureless acoustic ceiling tiles punctuated at regular intervals by an equally endless array of closely spaced light fixtures (see, for instance, Fig. 30). The scale and arrangement of such fixtures add nothing to one’s ability to relocate elements in the visual field.

A brief comparison of the spaces in Case Studies E8 (Fig. 30), G5, and H5 (Figs. 28, 29) with those in Case Studies E2, E3, and F1 will reveal the generic difference between the two ways of organizing the luminous environment. Readers can judge for themselves in which type of space they would find it easier to orient themselves.

A note on exterior spaces

The typical activities in most outdoor spaces—circulation, congregation, etc.—have lighting needs which are primarily biological in nature; appropriate lighting for such spaces must therefore reveal and emphasize that environmental information which satisfies the biological needs for safe movement, orientation, security, pleasure, relaxation, stimulation, etc.

In daylight, all is revealed. Usually, the amount of light in no way limits the visual information available to the user of an exterior space. Good environmental design for daylight conditions creates a positive focus on information relevant to activities and biological needs.
it is desirable to obscure irrelevant or distracting visual information, this is usually difficult to achieve during daylight hours because of the high overall light levels and their general, unselective distribution. At night, however, the physical and financial constraints which preclude the simulation of daylight levels and distribution can be used to advantage to selectively reinforce the relevant and obscure the irrelevant.

It should be emphasized that attainment of high illumination levels along circulation paths is not the primary design problem involved in the lighting of exterior spaces. If clear and undistorted orientation information is provided for the user, while other biological information needs are satisfied, very low light levels on the order of one-tenth of a footcandle may be perfectly adequate for safe circulation.

In exterior spaces as in buildings there should usually be a well-defined sense of "background" and "foreground." Background spaces should be illuminated as unobtrusively as possible to meet the functional needs of safe circulation, protection of persons and property, etc. Whenever possible, those needs should be taken care of with "spill" light from the positive delineation of circulation spines and nodes, signage and displays, entrances, and other focal elements relevant to the definition of circulation. Foreground spaces, on the other hand, are the major spaces in a city—focal points for orientation or special places of congregation—and should be treated accordingly.

A number of the case study projects which are presented in the second half of this book play foreground space roles in their communities. In each case, the exterior lighting of the buildings themselves and of their extensions such as billboard kiosks, stairs, and terraces provides illumination and definition for the surrounding spaces. The National Arts Centre of Canada (Case Study H1) and the Quebec Government Center, Complex "C" (Case Study H5) are excellent examples of this approach to exterior lighting.

Summary

A good luminous environment is simultaneously comfortable, pleasant, relevant, and appropriate for its intended uses. The definition of the terms comfortable, pleasant, relevant, and appropriate need no longer be left to the vagaries of "artistry"; they can be defined much more specifically. A good luminous environment satisfies as many of the needs of its users as possible, and must provide the specific qualities and quantities of visual information which are required for the activities that take place within it. But in addition to activity needs for visual information there are always biological needs which must also be satisfied, and which may be even more important than the activity needs. Designers who give these biological needs for visual information the priority they deserve in the process of programming and design will find that in most spaces, lighting which provides well for biological needs simultaneously takes care of most activity needs.

11 The relevance of a given luminous environment and its correlation to user satisfaction can be empirically measured. In 1969, the author, together with David Canter (then environmental psychologist from the University of Strathclyde, Glasgow), conducted a pilot experiment in two spaces: a lecture hall and a corridor at M.I.T. Students who used the spaces were asked to rate (1) the desirability of seeing various elements of the visual environment related to activity and biological needs (such as the lecturer, the blackboard, other students, walls, ceilings, light fixtures, view); (2) the extent to which the luminous environment created an emphasis on these elements; and (3) their evaluation of the overall environment on a semantic scale: pleasant or unpleasant, comfortable or uncomfortable, etc. Evaluations in the third category were compared with the match revealed by the first two questions between the desired hierarchy of information in the visual environment and the actual hierarchy. A good match between the desired and actual hierarchy of visual information produces a statistically significant correlation with a positive evaluation; a bad match produces an equally significant correlation with a negative evaluation.