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ABSTRACT

Through proper management of the sensory factors inherent in the classroom environment, teachers can improve the comfort, development, and academic performance of students. Some principles and practical procedures that may be applied directly by the classroom teacher are suggested in this pamphlet. A number of guidelines, references, and suggested readings are included. (Author/MLF)

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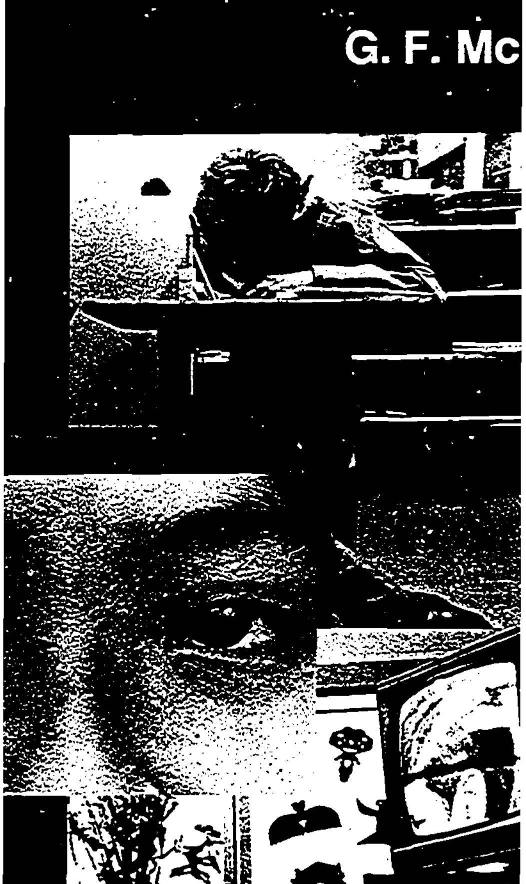

SROOM TEACHERS
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The "What Research Says to the Teacher" Series

is published to provide classroom teachers and prospective teachers with concise, valid, and up-to-date summaries of educational research findings and their implications for teaching.

Each pamphlet in the series is designed to serve two prime functions: to suggest principles and practical procedures that may be applied directly by the classroom teacher and to provide a springboard for further study and use of research findings.

To serve the first purpose, authors of booklets in the series select from each field those research findings that promise to be of most help to the classroom teacher. However, research has not yet provided scientifically valid findings on many aspects of teaching. In such cases, the best that can be offered is expert opinion.

It is impossible, of course, to provide a complete summary of research in any field in 32 pages. To help teachers further explore research findings, selected references are listed at the end of each booklet in the series.

The series was initiated in 1953 by the Department of Classroom Teachers (now Association of Classroom Teachers) and the American Educational Research Association under the leadership of Frank W. Hubbard. Beginning in 1966, the Department of Classroom Teachers assumed full responsibility for publication of the series, with the assistance of the NEA Publications Division. One measure of the success of the series is the use of approximately two million copies of the booklets by educators in the United States and throughout the world.

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SENSORY FACTORS IN THE SCHOOL LEARNING ENVIRONMENT

In order to create an environment that will have a positive effect on the health and physical development as well as the academic performance of their students, classroom teachers need to understand the effects of the many sensory stimuli arising in the classroom. Traditionally, teachers have depended upon their own commonsense observations of how sensory stimuli work in the learning environment. Some of the research findings reported in this booklet confirm such observations; other findings provide new information and insights.

UNITY OF THE SENSES

Stimuli can either facilitate or inhibit perception. The senses are functionally linked, and stimulation of one affects the sensibility of all the others. Thus, a moderate input of sound or light improves sensory reception, while an excessive input inhibits or retards it. Research has shown how disagreeable odors retard motor performance and vision, and how moderate lighting in a room makes hearing and tactile discrimination easier (1).

The exact nature of this interplay between the senses is still uncertain, and the processes by which it occurs are still vague. One possible explanation is that the nerve fibers that handle sensory information in the brain are in close proximity and are not insulated from each other; stimulation of one fiber can be conducted to a neighboring fiber. If this accessory stimulation is moderate, it may lower the threshold on the second fiber, facilitating the transmission of other stimuli. If the accessory stimulation is excessive, it may raise the threshold, inhibiting the reception of incoming signals.

The classroom teacher can safely act on the principle that moderate stimulation of one sense will facilitate the reception of information through the others, and that excessive stimulation will inhibit this process. Classroom lighting, background noise, temperature, air velocity, and humidity should all be moderate; odors should be neutral. General classrooms and study areas should not be located close to noisy and odoriferous areas such as workshops, chemistry laboratories, and kitchens. It is the responsibility of the school planner to isolate the classroom from external sources of sensory extremes, and it is the duty of the classroom teacher to manage the existing factors in a moderate manner.

While the most common stimuli found in the classroom are energy forms—light, sound, heat, vibration, etc.—other factors such as time of day, seating arrangements, novelty, colors, other classmates, and, of course, the teacher are also important environmental stimuli. In fact, any physical element or situation in the classroom which causes a change in the human organism, no matter how small, can be considered a stimulus.

The human organism's reflexes enable it to function in a state of dynamic equilibrium by organizing and reorganizing its internal and external mechanisms to act upon environmental stimuli. These reflex mechanisms function in a manner that assures accuracy in reception, speed in response, and maximum conservation of energy.

Reactions to Stimuli

Generally speaking, there are three gross reactions to stimuli: orientation, adaption, and defense. It is the orientation reaction, according to the Russian physiologist Pavlov, which brings about the immediate response in human beings and animals to changes in the world around them. When there is a moderate but significant change in some environmental stimulus, the organism immediately orients its appropriate receptor toward the change, with the intention of making a full investigation of it (2).

The orientation response is one of attention or inquisitiveness. In the classroom, a light suddenly turned on or a book falling from a desk and striking the floor evokes this type of response. The orientation response includes such basic physical reactions as increased sensitivity of the senses and orientation toward the stimulus source, and such specific reactions as an increase in general muscle tonus and brain electrostimulation, greater depth of respiration, and slower heart rate. All of these responses tend to raise the level of a student's readiness to perform physical and mental tasks.

A teacher can take advantage of the orientation reflex to underscore important points in his lesson presentations. By striking the chalkboard with a pointer he can draw attention to those words and sentences he feels are most important. In his visual displays he can focus the students' attention to key areas by using brighter chalk, color, or even light to capture their attention.

If the stimulus is weak or moderate, the initial orientation response is followed by an adaptive reaction. For example, when illumination is decreased, adaptive reactions include pupil dilation, which increases light influx, and dark adaptation, which increases retinal sensitivity. Adaptive reactions to an increase in illumination include pupil contraction, which decreases light influx, and light adaptation, which decreases retinal sensitivity (3).

When a stimulus is of an excessive magnitude, defensive reactions occur. These include a number of physiological changes: increased heart rate; excessive contraction of the skeletal, facial, and neck muscles; eye blinking; and increased blood pressure. The subject reacts in the extreme by turning away from the stimulus, by aggressively approaching it with the intention of terminating it, or sometimes by "freezing" in place. Defensive reactions can be observed when an excessively bright light is turned on or a sudden loud noise occurs. If the stimulus continues, after a while the subject will adapt to it, but at the cost of decreased sensitivity (e.g., a temporary hearing loss) or an expenditure of additional energy.

Quite often a teacher unknowingly sets up perceptual conflict when he directs his students to view a classroom television set or some other informational display set up adjacent to a glaring luminaire or exposed window. Here the students' autonomic defensive mechanism directs them to turn away from the excessively bright light at the same time that their classroom task is to attend to the visual presentation.

It is important for the teacher to be able to predict the basic responses of students to stimuli of different magnitudes so that he will be able to coordinate these in a way that will aid learning and physical comfort. He should strive to evoke the orientation reaction and to eliminate defensive reactions in his students. The teacher as manager of the classroom environment should not allow conflicts between task and surround to occur.

THE VISUAL LEARNING ENVIRONMENT

Although the composite perception of all the senses is most important, and vision is but one avenue of information, it is generally agreed that most learning comes through the sense of vision.

The eye is a combination receiver, projector, and transmitter. It is a point-by-point receptor that scans visual space and projects these points onto the retina, which in turn transmits them in the form of an electrochemical stimulus to the brain. The brain then decodes the information in the light of past experiences, personal preferences, and so on. The result is what we know as vision.

Viewing Distances

We have the ability to perceive objects over an extremely wide visual field of approximately 200 degrees. However, of this area only a narrow field of 30 degrees offers a high degree of visual acuity. It is estimated that approximately 70 percent of all vision takes place within this narrow field. Consequently, if we want an object or display, such as a projection screen, to be viewed with relative accuracy, it should be of such a size or at such a distance as to fall within this 30-degree cone of the viewer's vision.

When computed in image widths, the cone of critical vision turns out to have a length of 2W—that is, two times the width of the display. This distance has become the universally accepted *minimum* distance for viewing most displays when detection of information is important, as in classroom movies, slides, and filmstrips. For example, with a projection screen 4 feet wide, the minimum viewing distance would be 2 x 4 feet, or 8 feet. However, in special cases where viewing accuracy is not important, as when a teacher is trying to create a simulated environment via projected media, a shorter viewing distance might be desirable.

The only medium that deviates from the 2W rule is television. Here most specialists recommend a 4W minimum viewing distance, because at distances less than 4W the scan lines of the image are too prominent and thus distracting. The result is like viewing a pointillistic painting too closely; the picture appears as a field of unrelated color dots. Given a standard 23" classroom television with a horizontal measurement of 19 inches, the minimum viewing distance would be 4 x 19 inches, or 76 inches (roughly six feet).*

The *optimum* viewing distance for the detection of information in the visual field is 6¼W (4). Therefore, for a TV monitor 19 inches wide, the optimum viewing distance would be 6¼ x 19 inches, or 119 inches (approximately ten feet). At this distance, the eye takes in the whole image, rather than concentrating on a particular section. A shorter viewing distance results in the concentration of eye fixations at the center of the display. A greater viewing distance causes concentration of eye fixations on the outside borders.

The *maximum* viewing distance for displays and projected media cannot be identified so easily as the minimum or the optimum. The maximum distance a viewer should sit from a television or projection screen depends upon the visibility of the elements displayed. Practically speaking, if a viewer in the last seat can identify the display on the screen accurately, he is within the maximum distance parameter of the viewing area.

Viewing Angles

As a viewer moves away from the axis perpendicular to a displayed image, he experiences an increasing amount of distortion because he is viewing a flat surface from a more and more oblique angle. He begins to see a circle on the screen as an ellipse, for example. Viewing locations up to a point 45 degrees

* Because of the X-rays that may be generated by color television sets manufactured prior to 1970, the closest viewer of such a set should be at least 6 feet back, regardless of the image width.

from the outside of the screen will produce images with an acceptable amount of distortion. Beyond this angle, viewing is excessively distorted, and the legibility of words and the identifiability of charts are adversely affected.

However, any viewing location more than 15 degrees from the perpendicular axis (see figure 1) requires the viewer to turn his head in order to see. These locations, although well within the acceptable area with regard to legibility, produce more visual fatigue and are less desirable than those within the 15-degree cone. A simple solution is to turn each seat in the classroom so that it faces the display (see figure 2). This kind of arrangement eliminates head turning. (It also eliminates some of the seats in a standard classroom seating plan.)

For vertical viewing angles, the problem is compounded because small compensatory vertical head movements are more fatiguing than small lateral head movements. Research indicates that for maximum visual comfort a viewer's line of sight

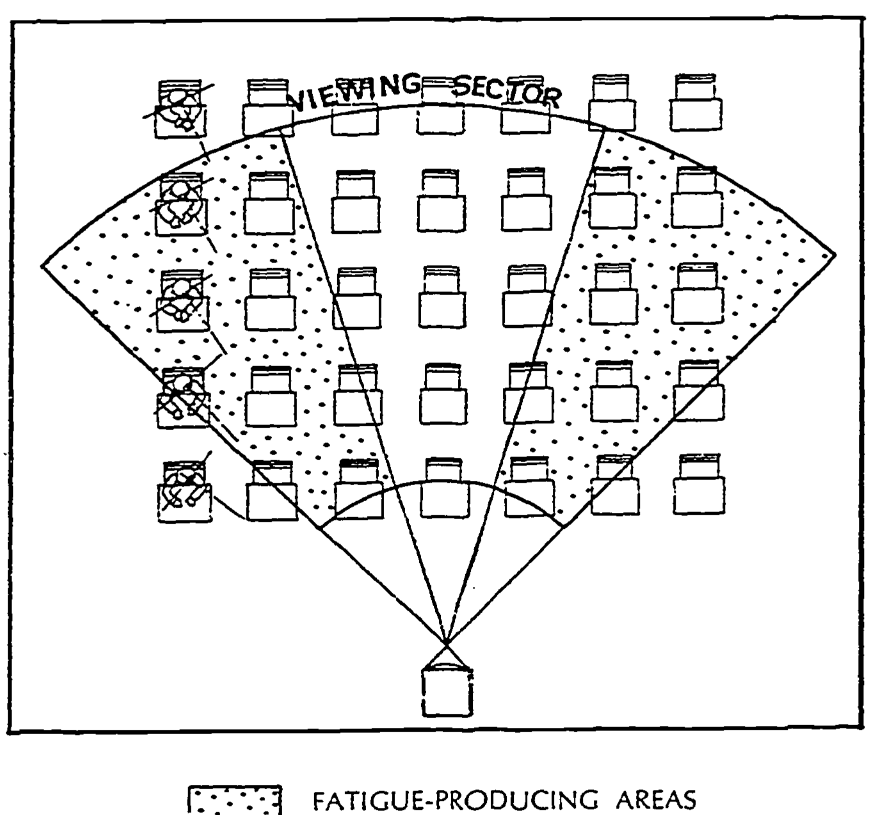


Figure 1. Standard Classroom Seating Arrangement

should not be inclined drastically. Displays should not be positioned so that they force a viewer to look up (angle of elevation) much more than 10 degrees or to look down (angle of depression) much more than 24 degrees (5). The optimum line of sight for a seated viewer looking at a distant display lies about 5 degrees below the perpendicular visual axis parallel to a level floor (see figure 3).

Excessive angles of elevation tend to arise in the classroom where the teacher, attempting to place the display or TV or projector screen high enough for students in the back to see, overcompensates and places it too high, causing students in the front rows to view up at fatiguing angles. Excessive angles of depression, on the other hand, are likely to be present in auditoriums where seating is stepped or inclined drastically from the front to the back rows.

Whenever there is a deviation from direct line-of-sight viewing—whenever the screen or TV monitor is too high, too

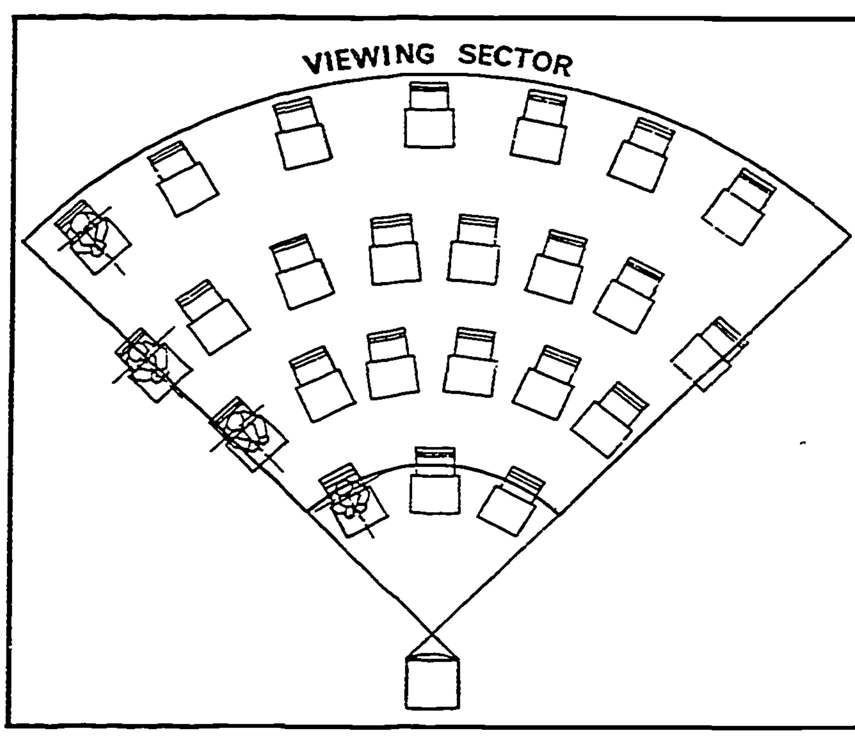
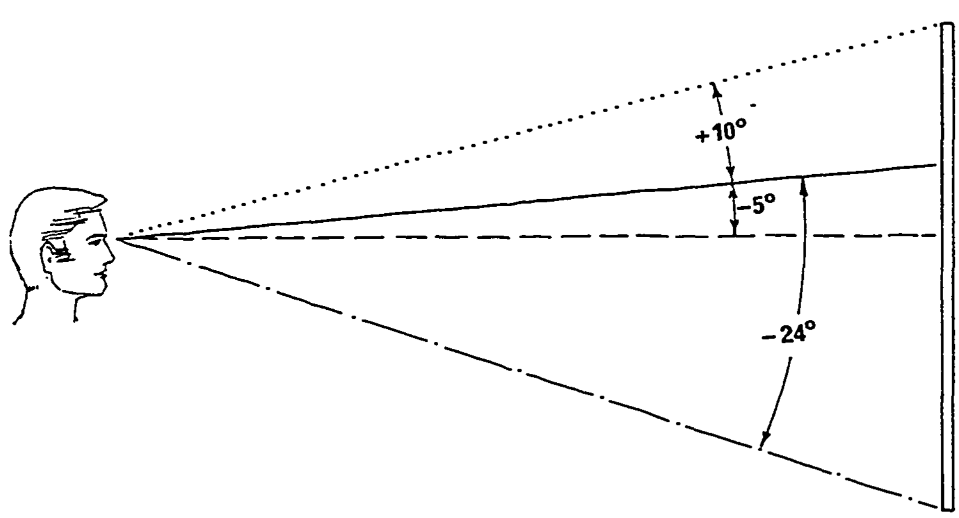


Figure 2. Modifying Classroom Seating To Minimize Visual Fatigue



PERPENDICULAR VISUAL AXIS
OPTIMUM LINE OF SIGHT
MAXIMUM VIEWING ANGLE OF ELEVATION
MAXIMUM VIEWING ANGLE OF DEPRESSION

Figure 3. Visual Comfort Cone for Distant Tasks

low, or too far to the side of the viewer—he must crane his neck or twist his body to see, and stress will result. Repeated, prolonged stress of this kind in young children over a period of years can cause skeletal deformations. Stress usually demonstrates its presence in one of two ways:

- Gradual deterioration in performance. For example, a student may make few errors during the early part of a test involving a visual display, but more and more as the test proceeds.
- Undue fatigue. A viewer may be able to maintain his high performance despite the stress factors, but at the expense of wasted energy. When the viewing session is over, he will find himself more tired than he should be.

Lighting

Lighting is perhaps the most important sensory factor to be considered in the learning environment. Although current engineering journals recommend much higher levels of illumination, research indicates that a lighting level somewhere between 30 and 50 footcandles is adequate for the comfortable and effective completion of most visual tasks (6). In other words, the amount of illumination that is emitted by a 150-watt frosted lamp on a piece of white paper 30 inches away will be adequate for general reading and writing tasks. Most fluorescent fixtures found in the classroom provide more than enough light for most learning tasks. In fact, a teacher may even find that turning off one or two overhead fixtures improves physical comfort for simple nonvisual tasks. On the other hand, if additional illumination is necessary for critical seeing tasks, supplementary table and desk lamps should be used.

Brightness-Contrast Ratio

It is the quality and placement of light that are most important; quantity is a secondary factor, as long as minimum acceptable levels are maintained. One of the most important factors in classroom lighting is the brightness-contrast ratio (BCR)—the ratio of the brightness of the central task area to the brightness of the "surround" or background. In order to guarantee depth perception in three dimensions, contour detection, and visual comfort, the BCR should be somewhere between a minimum of 2.5 to 1 and a maximum of 10 to 1. The optimum BCR is 3 to 1, the standard adopted by the Illuminating Engineering Society.

This contrast factor applies even to such simple activities as writing on a chalkboard. Legibility will suffer if there is too much or not enough contrast between the chalk and the board. White chalk on a black board represents an excessive BCR and often is a source of reflected glare. Yellow chalk on a deep green board provides a desirable BCR, as long as the board's darkness is not lessened by incomplete erasures. Boards should therefore be kept clean of old chalk dust.

One does not need elaborate measuring devices to set up BCR's that are approximately correct. Subjective judgment works fairly well. It is important that a proper BCR be maintained when using visual aids, for it will promote both visual comfort and seeing accuracy. Since different visual aids vary in their light output, classroom lighting should be varied also. A general principle to remember is that all visual aids should be displayed in rooms dark enough so that image details and colors are accurately rendered, but no darker.

Location of Light Sources

In general, lights or highly directional reflecting surfaces should not be located within a student's central visual field. Such objects as low-hanging light bulbs and unshaded desk and table lamps should be shielded from direct view; the placement of glass or polished metal surfaces should be carefully considered. All forms of glare reduce visual acuity and induce physiological stress.

Similarly, studying by windows should be avoided when there is direct sunlight streaming in or when a student's seating arrangement is such that one eye receives more illumination than the other. Such an arrangement forces only one eye to do the work. Prolonged reading under such conditions can lead to permanent visual impairment. When presented with such an adverse lighting condition, a student will usually adapt by adjusting his seating posture, using the elements of his body to shield his eyes from the glare. Unfortunately, adapting in this manner also alters his angle of view and his postural balance, resulting in distorted vision, wasted energy, and inappropriate physiological functioning. Such an undesirable viewing arrangement can be very damaging to a young developing child, setting up harmful stresses in either his eyes or his body (7).

Flicker

Light "pulsed" or "flickered" at certain frequencies can also have detrimental effects on normal human functioning. Most incandescent and fluorescent luminaires flicker at such high frequencies that the light appears fused and provides comfortable seeing conditions. However, the ability to fuse intermittent light depends principally upon the level of illumination and the age of the observer. Since young students have higher fusion levels than their teachers, it is quite possible for classroom lighting a teacher finds comfortable to have flicker frequencies which are distracting and physiologically debilitating to some of his students. Especially likely offenders are bright incandescent lamps (or the ends of fluorescent lamps) which flicker at about 55 to 60 Hz (cycles per second) and motion picture projectors which have an interruption rate of 48 Hz when running at sound speed or 32 Hz when running at silent speed.

Certain flicker frequencies can actually produce headaches, nausea, hallucinations, or even epileptic-like seizures in about 3 or 4 percent of normal children (8). These frequencies apparently parallel the brain's vital alpha rhythm (8 to 13 Hz). The currently popular fad of using strobe lights at mixed media shows, while only discomforting to most people, can be quite dangerous to those having epileptic tendencies. For the latter even the flickering light of a TV set can prove a hazard. The classroom teacher should familiarize himself with his students' health records and report any signs of epileptic behavior to the school nurse. Lamps that show signs of flicker should be replaced, and auditorium-type projectors should not be used in small settings.

Color

Color is a vital part of most people's lives. It can change moods and judgments of size, weight, and distance, induce body tonus, and in general enhance the quality of life.

Many of our psychophysical responses to color have been attributed to the phenomenon known as chromatic aberration. The human eye is not color-corrected, meaning that it does not focus light of different colors at the same point. In order to bring colors into focus, the lens of the eye must vary its shape. For example, the eye projects violet and blue in front of the retina, the lens flattens, and the result is that these colors appear to recede. Red and orange, on the other hand, are projected somewhere behind the retina; the lens grows convex, with the result that these colors appear to be approaching.

An object either colored or illuminated by the color blue will thus appear to be farther away and smaller than a red, orange, or even yellow object.

Chromatic aberration is probably the physiological basis for the psychological effects of colors, i.e., for our perception of colors as "warm" and "stimulating" or "cool" and "relaxing." Many color specialists recommend that rooms scheduled to be action-oriented be decorated in the warmer colors (yellow, orange, red), and those planned for quiet activities in the cooler colors (green, blue) (9). Perhaps in the future we will see learning spaces decorated in multicolors—each corner painted a different hue—and students assigned or self-directed to work in the area that will be most conducive to their optimum performance or behavioral stability.

Many elementary school teachers intuitively make use of the effects of chromatic aberration by wearing bright and colorful clothes on days when they plan to introduce new and difficult lessons. Visual displays such as slides, bulletin boards, and dioramas can also make good use of the psychospatial effects of colors by highlighting the most important elements with red and orange and adding depth to the backgrounds with blue.*

THE ACOUSTICAL LEARNING ENVIRONMENT

Sound is measured both by its wave frequency in cycles per second (Hz) and by its sound pressure level in decibels (dB). Most people are capable of hearing a standard sound pressure

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* The classroom teacher should remember that there is a wide range of incandescent and fluorescent lamps available, each with its own color-rendering properties which, together with the color treatment of the walls and other reflecting surfaces, modify the apparent brightness of the classroom and give rise to specific color sensations. For example, unfiltered incandescent light gives red, orange, and yellow objects a relatively accurate appearance, but causes green and blue objects to appear dull. A color-coded display prepared under home lighting may not be effective under classroom lighting. If colored objects or skin tones look unpleasant in the classroom, or if the overall environment just seems disagreeable, the teacher might consider talking to his building supervisor about changing the lamps. Such a change would not be too expensive and could result in a much more acceptable learning environment.

level of 60 dB over a range of frequencies between 30 and 15,000 Hz. They are, however, capable of "feeling" sounds outside this frequency range.

The decibel rating of a sound is an approximation falling somewhere between its subjective loudness and its actual physical intensity. It is a logarithmic ratio between the sound and other known sounds. As in all logarithmic measurements, even small increases in decibels are significant. While most people can just barely perceive a 3-decibel change in a sound level, they will clearly notice a 5-decibel shift. A 10-decibel increase or decrease will essentially double or halve the apparent loudness of a sound (10).

Noise in the Classroom

Noise has been universally defined as unwanted sound. Whether a sound is noise or not is a subjective judgment determined by the meaning the sound has for an individual and by the situation in which it occurs. A school bell signaling the start of recess may be perceived by many students as a sign of relief from a tedious morning. But the same bell terminating an all-too-brief exam period will be perceived as an intrusive, frustrating noise.

Even when students are studying quietly there is ambient sound present in the classroom. This background sound is created by many things: the flow of air from the air exchange system, the mechanical sound of the fans that move this air, the buzzing of light filaments and fluorescent light ballasts, the vibration of the electric clock, and the sounds intruding from the class next door. Such background noise is accepted as a desirable component of the classroom as long as it is not excessively loud. In fact, architects purposely design classrooms so that they have a certain amount of continuous background noise. This constant noise level is usually low—about 35 decibels—but it is sufficient to cover up most of the noninformational sounds created by such general classroom activities as writing, page turning, foot shuffling, and so on. If a classroom were free of all background noise a student could literally hear himself think. He would be constantly distracted by the sound of his own breathing and heartbeat, let alone the movements of the students around him.

Clearly, a certain amount of background noise in the classroom is a necessary thing. However, it should not be so loud as to make verbal communication between the students and their teacher difficult. For effective communication to take place there must be at least a 10-decibel difference (signal-to-noise ratio) between the sound level of the person speaking and the background. Since the sound level of normal conversation is about 60 decibels, it stands to reason that the background noise level in the classroom should remain below 50 decibels.

The classroom teacher can promote a desirable signal-to-noise ratio by preventing *extraneous* sounds from entering his classroom through open doors or windows. The signal-to-noise ratio for a student sitting by a door leading into a noisy corridor often approaches zero. Wherever climatically feasible, classroom doors and windows should remain closed during those hours that require mental and verbal activity. Students as well as teachers have a right to quiet, and they should express that right whenever noise intrusion hinders their learning activities. The sense of freedom in the classroom should be such that a student who is being disturbed by outside sounds will not hesitate to leave his seat and close a door or window.

Effects of Excessive Noise

Today the problem of noise pollution within the classroom caused by external sources such as traffic, construction, and aircraft has reached grave proportions. In fact, recently two public schools in one city had to be closed down because of excessive noise from a nearby airport. The city's mayor sued the airport for interfering with the educational program (11).

Excessive noise is inimical to the "listening" process, that is, to the psychological process by which one comprehends verbal information, as well as to the "hearing" process, which is the physiological process of receiving meaningless sound. When we consider that the average person spends 45 percent of his waking hours in some listening-related task, the problem of noise and communication becomes apparent. Excessive noise has also been shown to have an adverse effect on reading comprehension and on retention, recall, and recognition of materials (12).

While total quiet is never recommended, it is important that the school learning environment provide spaces of "relative" quiet to serve as retreats from the din of school and nonschool activities. Classroom noise levels exceeding 70 decibels will not only interfere with communication but will also produce a disorienting, chaotic learning environment. Noise levels of 85 decibels and above are generally considered psychologically and physiologically excessive.

It is well known that prolonged exposure to excessive noise levels causes both temporary and permanent hearing loss. Such loss is usually thought of as an adult problem, but this is a misconception. Even our youngest citizens are not immune. A recent study of 3,000 students at three grade levels revealed that 5 percent of the sixth graders, 14 percent of the ninth graders, and 20 percent of the twelfth graders showed some measurable hearing loss induced by the general noise level of their environment (13). Temporary hearing loss may become permanent unless the victim is given a sufficient hearing recovery period away from the noise.

Other disabilities that can be caused by excessive noise include cardiovascular disorders, nausea, weight loss, fatigue, irritability, insomnia, and impaired tactile functioning (14). Again, relief can be found only by eliminating the noise or by moving away from it to a quieter environment.

Noise Reduction

Efforts to reduce noise are based upon isolation, absorption, and containment. Isolation means eliminating the medium a sound needs in order to travel. For example, placing a rubber or neoprene pad under a noisy projector or typewriter can do much to keep its noise from being transmitted via the table and floors. Likewise, placing audio speakers away from the front wall of a classroom will keep their sound from being transmitted as vibration through the structure and disturbing the adjacent room.

A well designed classroom is one in which reverberation (the persistence of a sound after its source has been cut off) is long enough to strengthen speech, but not so long that words run into each other. Sound-absorbing material such as fiberglass, acoustical tile, rugs, or drapes will help keep reverberation to a desirable level.* However, unless these materials are backed by thick, hard walls, they will be ineffective in containing noises within the classroom.

Another acoustical engineering technique is "wallscaping," that is, fixing rugs directly to the walls. Rugs on classroom walls not only cut down noise levels but also give a desirable visual texture to the rooms and serve well as tackboards.

Sound Masking and Background Music

When students need to concentrate on a demanding task, a small amount of "white noise" (meaningless sound made up of tones of all audible frequencies) may be used as a sound-masking device to keep them from being disturbed by extraneous classroom sounds like talking or traffic. "White noise" generators are currently available for less than fifty dollars, but the classroom teacher can produce a satisfactory substitute by simply making a tape recording of the sound generated by his TV set when it is turned to an unoccupied channel. He can then play this recording, which will sound very much like "white noise," in the classroom whenever he wishes to mask extraneous noises. The currently available environmental recordings of the sea, wind, etc., can also be used as noise-masking devices.

In recent years there have been many attempts to use music as background sound for various school tasks. The success or

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*The different reverberation times in different rooms should always be considered by teachers making tape recordings, for these will affect the intelligibility of the tapes when they are played back. When an audio tape made in a recording studio or classroom having a short reverberation time is played back in an auditorium or classroom having a long reverberation time, words seem to run into each other, pauses are lost, and speech becomes unintelligible. A teacher can compensate for this problem somewhat by making a concerted effort to slow down his speech when recording in a studio or any other room with a short reverberation time.

failure of such attempts has depended upon the nature of the music and the nature of the task. While nonfamiliar music, especially if it has few major frequency and volume shifts, can help many students concentrate on their work, familiar music can be an informational distraction. The rhythm of the music is most important. If it does not match the rhythm of the work task (typing, handwriting, or whatever), it can cause a decrement in the students' performance.

Music, in general, tends to speed up the fundamental physiological processes and to raise the level of body tonus. Because it also tends to increase muscle endurance, music can reduce or delay the fatigue associated with a physical work task.

Direction of Sound

Sound enhances visual perception by giving it contrast and adding information. Sounds can be used to direct attention to related visual elements (15). Because of the orientation reaction people tend to position their bodies in a direct line with the apparent source of a sound. Therefore, in setting up audiovisual aids, teachers should coordinate the placement of a projector's loudspeaker with the projected image. A movie theater provides the ideal arrangement: the loudspeaker is located directly behind the projection screen at a height approximately two-thirds the length of the screen. Theaters use a fixed, perforated projection screen which allows sound to pass undisturbed right through it, thus creating the illusion that the sound is coming from the elements appearing on the screen. For most classroom audiovisual presentations, placing the loudspeaker on a bench or chair directly in front of and below the extended projection screen will be acceptable.

THE THERMAL LEARNING ENVIRONMENT

Illumination and sound are the chief sensory factors affecting information display and transmission in the classroom, but other sensory factors affect the physical comfort and energy consumption that accompany study and work. Four of these factors come under the general heading of the thermal environment: air temperature, radiant temperature, humidity, and air movement. These are interrelated in such a way that each affects the contribution of the others to the resultant comfort level.

The job of the thermal environment is to allow the human body to maintain its deep body temperature—98.6*—while performing its tasks. A human being can be thought of as a furnace; the food he or she eats is the fuel. Every activity the "furnace" engages in, whether primarily mental, such as problem solving, or muscular, such as athletics, consumes energy supplied initially by food intake. It is estimated that a child seated at a desk working at a mental problem uses more than twice as much energy as he does when asleep. When a task requires much energy, the environment must absorb the heat by-product that is generated. When a task requires little energy, the environment must provide heat at a level that helps the body to perform in comfort.

Temperature

The amount of environmental heat necessary for comfort will vary with a student's age, level of physical activity, clothing, and adaptation to local climate. Girls, in general, seem to prefer a warmer environment than boys, and young children prefer a cooler one than adults. One study indicates that a student's achievement level may affect his or her sensitivity to heat (16). Another study has found that certain temperatures evoke high levels of arousal while others dull attention (17). An improper thermal environment can alter growth, development, and learning (18). Children tend to become restless in a cold room and listless in a hot one. According to one researcher there is reason to believe that students may experience about a 2 percent reduction in learning ability for every degree that the room temperature rises above the optimum (19). Room temperatures between 68 and 76 degrees generally promote normal functioning.

Some researchers feel that providing enough heat for the students is not the real problem, but rather providing proper ventilation, air circulation, and cooling. in one study it was

* This is the mean, with approximate lower and upper limits of 97 degrees and 99 degrees Fahrenheit.

found that any time the outdoor temperature reached 50 degrees, the classroom temperature rose above the desirable level unless cooling was introduced (16). No wonder, since physiologists tell us that each child of elementary school age radiates heat equivalent to that radiated by a 100-watt incandescent lamp. It is not unusual for a classroom to show a 4- to 5-degree rise in temperature shortly after the students return from an active recess. Air-conditioning should not be considered a luxury, but rather in most cases an integral part of the school.

Radiation from the sun may also aid or play havoc with student comfort. Solar energy radiated in the form of visible light passes through classroom windows and is absorbed by objects lying directly in its path, which then convert the light to heat. This heat, in turn, is radiated to the rest of the room. The average classroom is like a greenhouse—a one-way trap for infrared radiation. While the glass windows allow sunlight in, they do not allow much of the resultant radiant heat to escape. This heat can affect the overall room temperature and cause wide temperature swings during a day. Most affected are students seated next to the windows, who may actually be receiving excessive heat exposure even though the average room temperature is not above normal. This "greenhouse effect" can be minimized by (a) better site planning with regard to the sun's transit, (b) large roof overhang, (c) tinted windows, (d) fewer or no windows, and (e) reflectant shades or blinds.

Solar heat gain need not be a problem if the school is designed to accommodate it. In fact, there are a number of schools heated year-round chiefly by sunlight. One, St. George's Secondary School in Cheshire, England, was constructed in 1961 for the express purpose of experimenting with solar heating. In most cases these schools also take advantage of the heat radiated by students and by the luminaires to produce the desired room temperature.

Humidity

Sensations of warmth and cold do not depend on temperature alone. Humidity and air movement also play a significant role in determining a person's comfort. It is common knowledge that dry air at a relatively high temperature may actually feel more comfortable than moist air at a lower temperature. Relative humidities between 30 and 70 percent have been found to be most comfortable for most people. Humidity exceeding 70 percent produces a clammy, sticky sensation, while humidity below 30 percent causes excessive dryness of the mucous membranes and increases the likelihood of respiratory diseases during winter months. Humidity control is an important consideration in schools where floors are carpeted, for low humidity in warm carpeted rooms will produce annoying and discomforting static electrical shocks.

Air Movement

Air movement's role in the thermal environment is to promote convection and evaporation, two natural methods of heat dispersion that help the body rid itself of excessive heat buildup during the performance of work and study tasks. If this work-related body heat is not lost, performance and physical comfort will be affected. In fact, some specialists have gone so far as to claim that most of the headaches, fatigue, dizziness, and nausea experienced in crowded, poorly ventilated rooms are caused not by high temperature, high humidity, or even the high concentration of carbon dioxide, but rather by inadequate body heat loss due to lack of air movement (16).

Although air movement is vital for the elimination of superfluous body heat, excessive air movement results in too much body heat loss and makes it necessary to increase the overall room temperature in order to maintain comfort. Needless to say, drafty rooms should be avoided as places of study.

Optimum Thermal Environment

One of the best predictors of thermal comfort is an Effective Temperature (ET) scale. It shows in a single reading the combined effects of air temperature, humidity, and air movement on subjective impressions of comfort. For example, when an air velocity of 15 to 25 feet per minute is combined with a room temperature of 75 degrees (dry bulb reading) and a relative humidity of 50 percent, an ET of 70 degrees is produced. However, the same ET is produced when the room temperature is lowered to 71 degrees and the relative humidity is increased to 90 percent, or when the room temperature is increased to 81 degrees and the relative humidity is lowered to 10 percent. Any combinations of air temperature, relative humidity, and air velocity that produce the same ET reading produce subjectively equivalent thermal environments.

ET scales have been used with mixed success over the past forty years. The chief objections have been that the earlier ET scales failed to take into account the effect of radiant temperatures and that the more recent ones, such as the ETR (effective temperature including radiation) and the WBGT (wet bulb/globe temperature), have difficulty integrating the effect of air movement. Yet, despite their shortcomings, these indices remain our best predictors of the optimum thermal einvironment.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers' charts* show that the optimum ET for men and women at rest and normally clothed in winter is 67.5 degrees, with a range from 65 to 70 degrees; in summer it is 71 degrees, with a range from 68 to 73 degrees. It is a bit more difficult to determine the optimum thermal environment for children. Effective Temperatures are likely to be one or two degrees lower for children because their bodies are still growing and developing. These physiological processes in themselves provide heat (18). Furthermore, the child's heat requirement varies significantly with the type of activity he is engaged in. Classroom thermal controls, in order to provide the optimum conditions, would have to take into account the type of activity going on at a given time.

A teacher armed with individual controls for ambient and radiant heat, humidity, and air velocity could conceivably "mix" the proper amounts of each and create the best combination for his students. Of course, even if such thermal controls were generally available, the dynamic nature of the thermal environment would require that the teacher spend a considerable portion of each day at another nonteaching task.

* ET indices are revised periodically and published in ASHRAE's *Handbook of Fundamentals*.

He has enough of them already. What may eventually be developed is an automatic integrated thermal control linked to a zoned heating and air conditioning system and equipped with remote sensing mechanisms that could be programed to provide the best thermal conditions for the scheduled activities of the day.

In the absence of such a device, the classroom teacher will have to make do with such simple holding measures as controlling solar heat by proper use of blinds or shades and providing additional ventilation when needed by opening windows at student work height. When he feels slightly cold he should put on a sweater or jacket rather than turning up the thermostat —the children, who need less heat, most likely will be comfortable.

CLASSROOM SPACE AND FURNITURE

Anthropologists tell us that every organism has an intuitive and learned concept of physical space and its interrelationship with it. This sense of space is closely related to the sense of territoriality—the invisible set of spatial limits that one sets up around oneself and allows to be entered only under specific circumstances. A leading anthropologist has divided this envelope of "personal space" into four major distance categories: intimate (6 to 18 inches), personal (1½ to 4 feet), social (4 to 12 feet), and public (12 feet or more). He has also identified the kinds of behavior we can expect to occur when these spaces are not respected (20).

Students and teachers alike are continually establishing and reestablishing their concepts of personal space and territoriality. The young child in particular tries to zone off areas he can call his own. It is no wonder that when these personal spaces are violated—as in the overcrowded classroom—students tend to become less productive and to lose their sense of identity.

In general, classroom spaces can be classified as those that tend to keep students apart and those that tend to bring them together. Students need to have both types of space available to them: spaces where they can be alone with their thoughts and imagination, as well as spaces that help them interact with others. Today's modern schools include both types of spaces.

Carrels and library reading rooms tend to separate students, while playgrounds and small conference classrooms tend to bring them together.

Seating Arrangements

Spatial arrangements are not the sole determinant of social interaction in the classroom. Seating arrangements, too, play an important role. Students have been shown to experience a greater feeling of equality and uniformity when seated around a rectangular table than when seated at a V- or Y-shaped one (21). In the rectangular arrangement students tend to speak primarily to those opposite and closest to them. However, as soon as a person is seated at the head of the rectangular table, this interaction pattern changes dramatically; now those seated diagonally across from each other tend to engage in conversation about six times as often as those directly opposite each other and about twice as often as those seated side by side (22).

Interaction in circular seating arrangements is affected by placement and distance as well as by postures and other physical impressions individuals make on each other (23). Students in small circular arrangements tend to speak to those opposite them, while those in larger circular arrangements tend to have more interaction with those seated next to them. When there is an authority figure in the center of a circular seating arrangement, students tend to show more progress and produce a greater number of ideas. Nevertheless, students generally prefer the circular arrangement without the central authority figure (24).

Figure 4 shows some of the seated interaction patterns. The classroom teacher, by selecting an appropriate configuration for a specific activity, can do much to promote greater productivity and student involvement.

Innovations in Classroom Design

It is encouraging to note that a number of today's newer schools have been designed around the modular program and thus have classrooms of different sizes and shapes where a

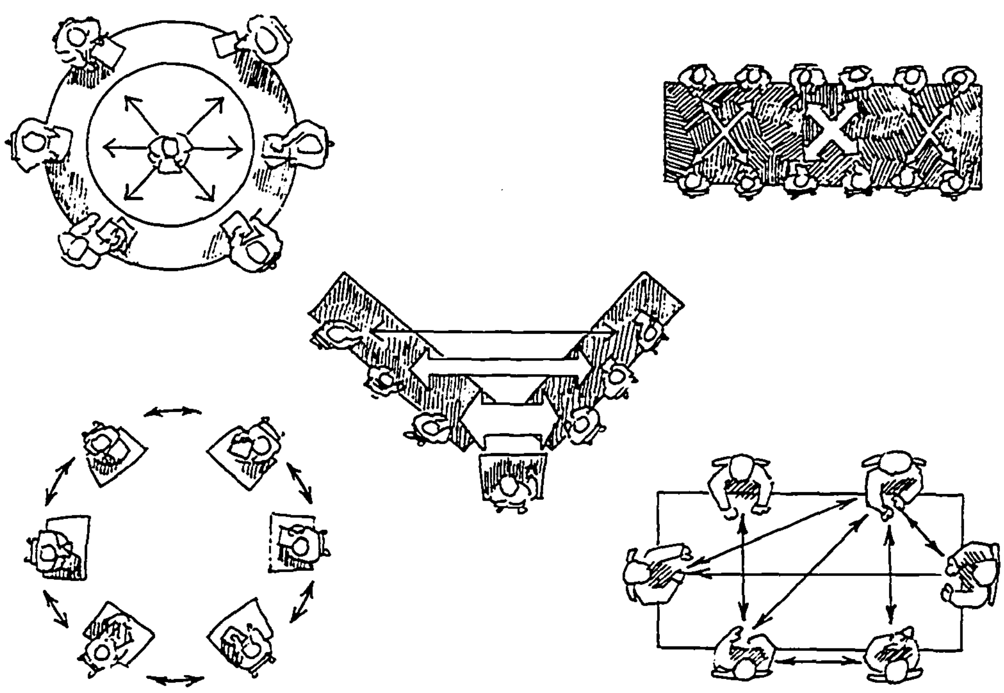

Figure 4. Social Interaction Patterns Resulting from Different Seating Arrangements

variety of interaction patterns can be effectively set up. The large multiclassroom represents another attempt to use space as an instructional element. Its proponents argue that the large open space adds a sense of freedom and informality to the learning situation and gives increased versatility to the instructional program. This could very well be true, but the success or failure of the multiclassroom, as of other innovations, depends heavily upon teacher attitude. The multiclassroom has been successful in schools where the teachers wanted it. Where it has failed, teacher attitude was negative; teachers complained of the noise, the reduction of visual privacy, and the challenge to their autonomy.

Here we see an example of the conflict between a teacher's concept of "personal space" and the spatial arrangement some educational planner thinks is necessary for a particular instructional program. Some teachers and students have gone so far as to partition off their class space with bookcases, desks, portable chalkboards, and the like, in an effort to achieve a sense of territoriality. Fortunately, much of the new educational thinking is sensitive to these and related problems. Attention is being given to the design of flexible spaces which will provide for the territorial needs of students and faculty, and efforts are being made to reeducate teachers to perceive these flexible spaces not as invasions of their dominions, but as opportunities for the dynamic expansion of their instructional programs.

It should be noted that some commercial enterprises already have in production portable apparatus for converting the "open" classroom into small group sensory modules. One such company sells a package that includes a set of free-standing vertical panels (space arrangers and projection screens) on which pictorial materials can be displayed or rear-projected. Cardboard blocks strong enough to support an adult provide a colorful seating and building component. Such flexible mini-environments, it is claimed, allow the children to create and surround themselves with their own artwork expressing their growing awareness of their world (25).

Another new idea is the "special experiences" room, which offers students a total sensorium. One such room in Warminster, Pa., is dome shaped and uses a sophisticated film projection and sound system to provide simulated environments—a total surround of projected images, traveling sound, odors, and a limited amount of climatic control. According to the school's director, the room will be used for general instructional enrichment and for providing new experiences for perceptually handicapped students (26).

Furniture and Posture

The design of classroom furniture is crucial to students' physical comfort. When we consider that approximately 75 percent of a seated person's weight is concentrated on four square inches of his buttocks, it is understandable that a poorly designed chair can cause compression fatigue, which results in weariness, ache, and numbness in that part of the body.

According to one orthopedic report, improper seating support can result in kyphosis (curved or bent back) and scoliosis (twisted spine) in children between the ages of 11 and 16 (27).

To promote proper weight distribution for a concerted study task, the chair back should be 5 degrees aft of vertical and the seat pan inclined 15 degrees from the horizontal. For more relaxed visual activities, such as general reading, the chair back angle should be 21 degrees, and the seat pan angle 5 degrees. (See figures 5 and 6.) In addition, the seating surface should be padded to promote blood circulation in the buttocks area. Most students should not sit in a fixed position for longer than an hour at a time, and some students may find half that time prohibitive. Squirming is often an indication that improper blood circulation is occurring and that it is time either to move to another seat or to make an adjustment in the original one.

Although often it was too rigidly enforced, the formal reading position we were all subjected to in the traditional schools of our youth (back as straight as possible, feet placed squarely on the floor, textbook tilted up at an angle and gripped with both hands) appears to have had a relatively sound physiological justification. Horizontal writing and reading surfaces force students to bend forward excessively, setting up stresses in their skeletal and visual systems which can cause digestive, respiratory, or postural defects (7). Proper reading and writing posture is promoted by tilting the work surface approximately 20 degrees from the horizontal for concerted study tasks, and 45 degrees from the horizontal for relaxed reading tasks. (See figures 5 and 6.) Most work tables and desks available to the student will probably be horizontal, but proper posture may be achieved by propping up the reading material with a thick book, or by writing on a propped-up clipboard. Horizontal work surfaces, of course, are best for three-dimensional manipulative tasks.

Early training in proper postural orientation to different tasks is important. Should faulty postural orientation become a habit during the early school years, it will be difficult to correct later. For example, if a young student "learns" the wrong typing position he will suffer excessive fatigue and the possibility of postural defects all through his later life whenever it becomes necessary to spend several hours at a time typing.

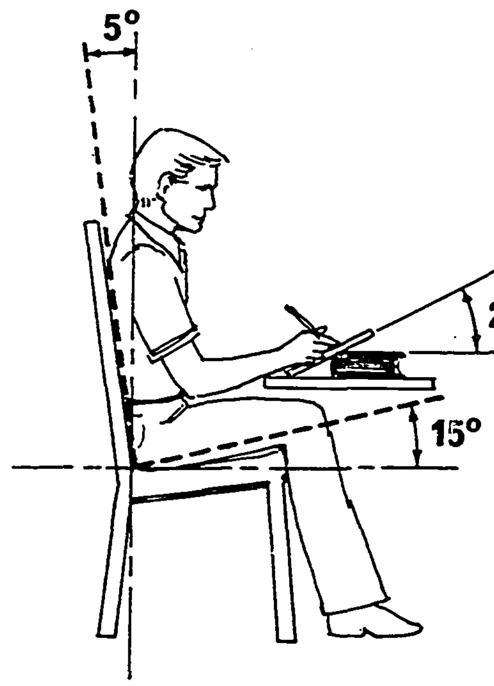

Figure 5. Proper Postural Arrangement for Study Task

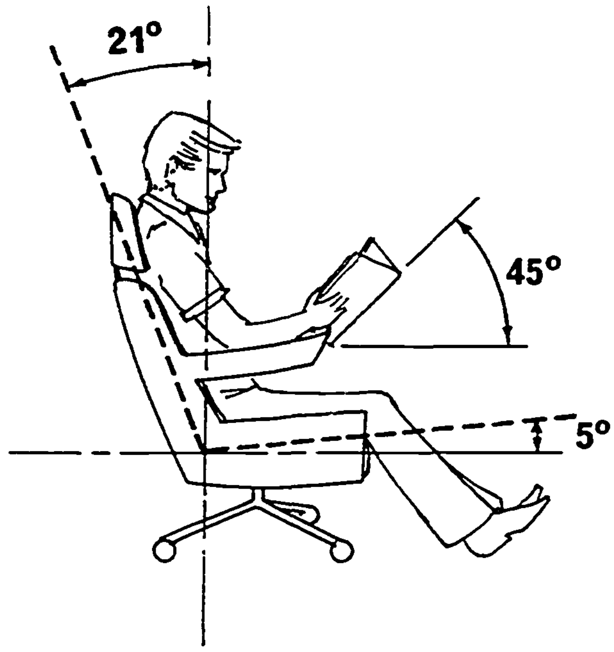

Figure 6. Proper Postural Arrangement for Relaxed Task

INTERNAL SENSORY FACTORS

Many other sensory factors inherent in the learning environment merit consideration but, because of space limitations, cannot be included here. However, we would be remiss if we did not at least mention proprioception—the perception of stimuli produced within ourselves. Proprioception includes those means of perception lying within the tiny nerve endings in the joints, tendons, and muscles of our body which tell us, among other things, about weight, resistance, and the position of our body and its movements. When a physical act is repeated in a definite pattern over a period of time, the body develops a sort of motor-skill memory. Riding a bicycle, playing a musical instrument, and typing are all examples of proprioceptive learning. While this motor-skill memory is important for a child's physical development and enjoyment of physical activities, it also has a transference to the development of important cognitive processes. Such activities as climbing, jumping, skipping rope, and walking the balance beam will hasten a young child's perceptual readiness for such important learning activities as reading and writing.

The teacher of young children should encourage his students to participate in physical activities and provide them with games and apparatus. Above all he should remember that a lack of basic perceptual motor-skill development can cause children to become less able to participate in classroom learning activities. The teacher's awareness of this problem will prevent him from labeling as "slow learners" youngsters who are actually intelligent but perceptually disabled (28).

Proprioceptive learning remains important as the child matures from preschool through the grades. The more mature student, for example, makes use of proprioceptive impulses to reinforce his cerebral performance. Proprioceptive feedback establishes body tonus—the state of being "up" to perform a specific activity—which provides the reinforcement necessary to counter disruption and distraction during a particularly difficult mental task (29).

CONCLUSION

The classroom is not just a shelter the teacher and his students have to live with, but rather an educational tool that can be manipulated in many ways. Through proper management of the sensory factors inherent in the classroom environment, the teacher can improve the comfort, development, and academic performance of his students. We have suggested a number of guidelines drawn from research findings. However, it is possible that by rigidly following optimum standards and specifications without providing the element of variation, teachers and school planners risk producing a static environment which can by its very nature have adverse effects. Rather, the learning environment should provide stimuli that continuously vary within permissible parameters. The classroom should be a place of diversity, a place where mental and physical growth and development can proceed unimpeded by environmental constraints.

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