

Vision and the Computerized Office



In the past, concern for worker safety primarily involved avoiding accidental injuries or deaths from hazards in the factory. Today, with the office as the most common work setting, attention has turned toward subtle but still serious health problems associated with office work, especially musculoskeletal disorders (MSD) that result from activities as varied as awkwardly reaching over and over again to carrying a laptop and other materials from meeting to meeting.

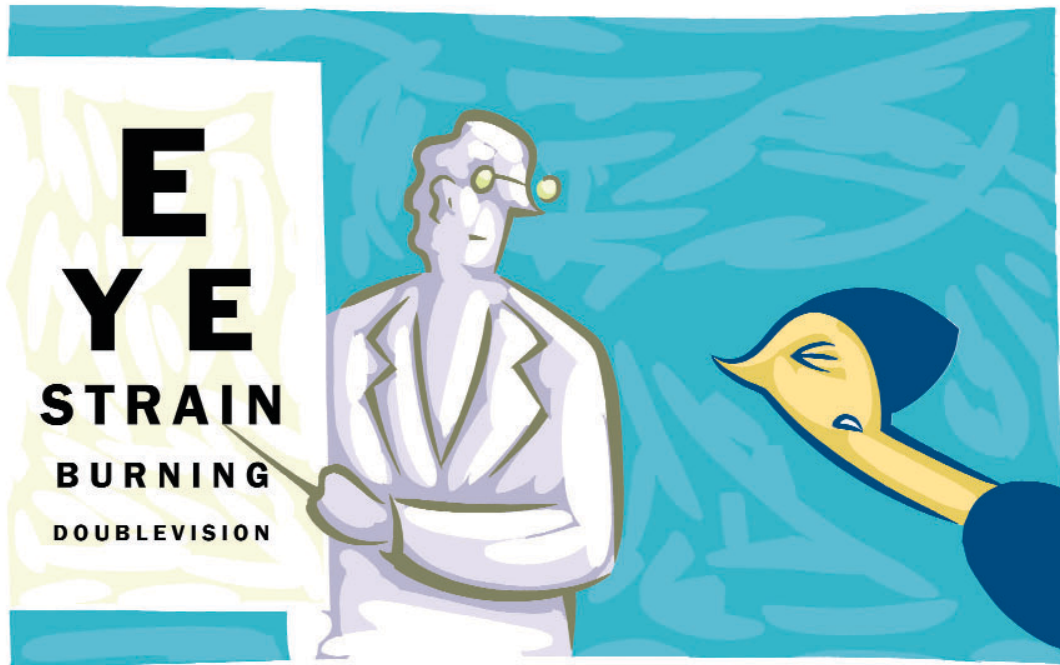
The large-scale introduction of computers to the workplace that began in the 1980s has added another issue: vision disorders collectively known as Computer Vision Syndrome, or CVS. Since that time, the most commonly reported symptoms of discomfort and fatigue among office workers have been related to vision.^{1,2,3} When people rely on a Video Display Terminal (VDT) screen (or combine a laptop computer and docking station with a VDT screen) to do the majority of their work for extended periods of their workday, vision symptoms often result. There is no question that a symptomatic work force is not working up to its potential. Vision complaints come with the same kinds of indirect costs as any health problem, such as lower productivity, absenteeism, higher turnover, and lower morale.

Vision experts agree that less-than-ideal workplace conditions and screen technology can exacerbate the problem, and that ergonomic interventions must be part of the solution. The vast majority of vision specialists acknowledge that improving conditions in the workplace that affect vision, plus providing vision treatment when symptoms are present, is a win-win proposition both for workers and employers.^{4,5}

What vision problems are we talking about?

“Eyestrain” and “visual fatigue” are the familiar, rather unspecific words most people use to discuss work-related eye complaints. The medical term for these kinds of symptoms is “asthenopia.” This is a catchall term that refers to any patient-reported visual symptom or distress resulting from using the eyes.

Optometrists and ergonomists specializing in vision use the term Computer Vision Syndrome (CVS) to describe the symptoms workers experience during and after performing computer work. CVS symptoms may include eyestrain, headaches, blurred vision, dry and irritated eyes, neck and/or back aches, light sensitivity, and double vision—or any combination of them.



Symptoms resulting from computer use can involve either or both of the eye's systems, affecting eye focusing, eye movement, and ocular coordination. The eye, as a sensory organ, has two dimensions: the visual system and the ocular system. The visual system refers to sensory functions—the ability to perceive objects and to focus, coordinate and move the eyes, and to transmit visual signals to the brain. The ocular system refers to the physiological workings of the eye—for example tear and blood flow and tissue conditions.

What is the scope of the problem?

According to a recent survey sponsored by the American Optometric Association, 61 percent of computer users in the U.S. are concerned about vision problems resulting from prolonged use of computers.⁶ The most common health problem reported by computer users is eyestrain—including symptoms of blurred vision or difficulty focusing, double vision, tiredness, and burning, sore, or itchy eyes.⁷ Many studies have found that visual symptoms occur in 75 to 90 percent of computer workers.⁸ A survey of optometrists indicated that 10 million eye-care exams are given annually in the U.S. because of visual problems at computers.⁹ Eye-related healthcare and glasses for problems related to VDT use costs Americans nearly \$2 billion each year.¹⁰

The 55-and-older age group, which made up 13 percent of the labor force in 2000, will grow to 20 percent by 2020.¹¹ This is significant, especially when you consider workers who require reading glasses (nearly everyone beyond the age of 40) often have special problems at computers and optical prescriptions typically do not address computer work. However, recent advancements in progressive lens and the use of eyeglasses with a special prescription designed for computer use have been shown to reduce vision-related symptoms in computer users suffering from presbyopia, which occurs when the lens of the eye gradually loses its flexibility with age.

Several conditions affecting vision symptoms have improved in recent years, particularly the development of flat-panel computer displays. These use Thin Film Transistor (TFT) technology to display text and images with clarity that is virtually indistinguishable from the printed page. However, even if flat-panel displays become more widely used, they will not completely address issues related to vision and the computerized office because display quality is only one factor in the equation. The growing number of tasks performed on computers, longer hours working at them, and a workforce made up of people working

beyond retirement and those who began using computers as children are just a few other conditions that might be making things worse.

Some vision experts argue that the pervasiveness of vision symptoms is an early warning sign that the way we currently configure our VDT tasks—against the background of existing technology and office furniture—is simply more than we can ask of our human visual abilities. Many VDT workers who do end up needing vision correction may indeed have had a pre-existing vision disorder, but it simply had not crossed the "problem threshold" until their work placed greater demands on their vision system.¹²

What are current standards and regulations for VDTs and vision?

There are several standards now available that call for voluntary compliance. The 1984 National Institute for Occupational Safety and Health (NIOSH) standards are the oldest and most basic. NIOSH developed these standards for its own employees and hoped that other organizations would accept their invitation to comply. The standards, developed to accommodate computer equipment available at the time, still have relevancy. They call for lower light levels in the VDT workplace, glare controls, and vision testing for all VDT workers.

The BSR/HFES100 Human Factors Engineering of Computer Workstations (Draft Standard for Trial Use issued March 31, 2002) is the proposed successor to ANSI/HFS 100-1988, the current U.S. standard. BSR/HFES100 is now available for public review and comment. The new document recognizes the increasing importance of computer workstations and the consequent benefits to users and employers from workstations that are ergonomically designed and integrated to enhance productivity and comfort. BSR/HFES100 guides designers on ways to accommodate variation both in the size of individual users and manner of usage. It also provides guidance to the individuals who must integrate individual workstation components designed for a wide variety of users into a system that fits the intended individual user.

Two municipalities have adopted regulations regarding VDT work. The City of New York VDT Ordinance mandates eye exams for VDT workers employed by the city and guarantees payment for necessary eye wear. The San Francisco Worker Safety Ordinance requires employers who employ video display terminal (VDT) operators to comply with worker safety requirements.



The federal Occupational Safety and Health Administration (OSHA) proposed 1999 Ergonomics Program Standard mentions CVS, describing it as “a repetitive strain disorder that appears to be growing rapidly, with some studies estimating that 90 percent of the 70 million U.S. workers using computers for more than three hours per day experience it in some form.” The proposed standard goes on to request public response to the questions, “What work practices or controls can employers use to prevent or reduce the occurrence of CVS?” and “Are studies of the effectiveness of these approaches available?”¹³ OSHA’s state occupational safety and health programs in California have adopted ergonomics standards. Employers are required to comply with the specific provisions of those standards. Other states with approved occupational safety and health programs may choose to follow OSHA’s four-pronged approach to ergonomics, adopt ergonomic standards, specifically include ergonomics in standards establishing safety and health program requirements, or use their general duty authority in appropriate enforcement situations.

While the Americans with Disabilities Act (ADA) does not directly address VDT-related vision problems, it may still be relevant. Many vision and occupational health specialists point out that the act should be understood to cover people with limited vision abilities. In this case, it is reasonable to conclude that a VDT worker with a vision disorder could request special tools, technology, or environmental conditions that would enable him or her to perform the job more effectively. Additionally, the act requires that state and local governments comply with basic requirements and effectively communicate policies, practices and procedures to those with hearing, vision, or speech disabilities.

What can be done to minimize risks?

Vision experts and ergonomists agree that workplace conditions, particularly the physical environment, are critical factors in bringing about or aggravating the symptoms associated with CVS. Those responsible for the facility are encouraged to seek the help of a vision expert in order to make the most of their investment in workers’ visual health. This is especially important when planning a lighting-system overhaul, which involves a great many complicated considerations.

While each workplace will have its own unique requirements, the ergonomic interventions listed below provide a starting point for reducing vision risks in the VDT work environment.

1. Avoid excessive near-point VDT viewing

Since long durations of sustained VDT work have been shown to induce ocular, visual, and systemic symptoms, the most straightforward way to reduce risks is to avoid long, uninterrupted work sessions. The first step is to make the VDT task as comfortable as possible. Then, workers should reduce session length by alternating VDT work with short rests, other tasks, or both.

- **Think about viewing distance between monitor and eyes** Some experts believe that the optimal viewing distance corresponds to the natural resting point of the eye, known as the Resting Point of Accommodation, or RPA. The RPA varies for each person but averages about 31-1/2 inches. Since VDT workers generally sit 15 to 24 inches from their screens, this theory would conclude that viewing a VDT monitor any closer than this RPA distance contributes to eyestrain. However, as one expert points out, “there are many other factors to consider. For one, the relationship between the accommodative effort and the convergence between the eyes can be strained, therefore creating one of the major causes of tiring of the eyes while viewing a display screen.”¹⁴ Assuming that the screen’s legibility, the text size, and the nature of the task can support it, a longer viewing distance may be better. Studies have shown that viewers consider a distance of just under 20 inches (50 centimeters) too close for typical computer tasks.¹⁵ Other research indicated that people report greater visual fatigue at a 50 centimeter viewing distance compared to 100 centimeters (39-1/3 inches).¹⁶ As a result, a viewing distance of 20 to 28 inches is most common.¹⁷ Some of those who study vision have observed that people who use very high resolution, large monitors—like CAD operators—often sit 30 to 36 inches from the screen. NIOSH findings also support this theory by pointing to increased viewing distance as a means for reducing the potential for eyestrain.¹⁸

-
- **Consider gaze angle** Research on optimum gaze angles seems to agree that downward is best. How far downward is, of course, the question, but there seems to be a fairly wide range of good angles. Ergonomists and vision experts have observed that the “natural line of sight” for VDT viewing is 10 to 15 degrees below the horizon.¹⁹ This may be simply a matter of convention, however, based on what current office furniture and computer design supports. More recent ergonomic studies found that gaze angles of 10 to 35 degrees are common. They attributed these different results to the fact that previous studies failed to take into account the relationship of spine posture and gaze angle. Studies specifically addressing vision found that a downward depression of the eye of 10 to 20 degrees improves focusing abilities.²⁰ Meanwhile, studies focused on orthopedics found that a forward head-and-neck posture of up to 15 degrees produces no perceptible discomfort or excess muscle activity.^{21,22} Putting these two together, it is reasonable to conclude that a neutral gaze angle—that is, one that does not produce strain—can be anywhere from 10 to 35 degrees downward from the horizon to the center of the screen.^{23,24,25}
 - **Alter focal distance within optimum range** Maintaining the same near-point focal distance for long periods is particularly hard on the eye’s accommodative mechanism, the part of the eye that continually refocuses the eye as it fixes on objects at different distances. It is one of the key risk factors for accommodative dysfunctions, such as spasms.^{26,27} Offsetting the visual exertion of looking constantly at the same near-point visual target simply requires a change in viewing distance enacted every 5 to 10 minutes.²⁸ Some suggest a 20-20-20 rule: Every 20 minutes look at least 20 feet away for 20 seconds. To achieve visual relief workers can alter their focal distance by changing posture, moving the monitor, or both.
 - **Move the monitor** In an ideal situation, a VDT worker could move the monitor in and out to change focal distance without changing postures, or move it up and down to establish good gaze angles for several postures. Of course, moving monitors around is only practical when they’re sitting on something movable, like a computer arm or an adjustable platform. Many VDTs already have a tilt feature that allows the user to change the angle of the monitor but not to move it in and out. Computer arms are fine for moving in and out, but they often don’t travel low enough to get a good gaze angle for smaller people or forward postures. Some bi-level work surfaces feature an adjustable platform that moves in and out a few inches as well as up and down. This can be an ideal solution if the particular table design can be adapted to the task and workstation design.
 - **Change posture** This may be the best way to alter focal distances since it is important to change posture because one of the key risk factors for musculoskeletal disorders is holding a single position without movement for long periods.^{29,30,31} Workers can sit upright, recline slightly, or sit forward slightly in order to alter viewing distance. Naturally, this changes the gaze angle as well. It may be necessary to shift the height and angle of the monitor a bit in order to maintain an acceptable gaze angle. Perhaps the best way to keep track of the relationship among all the ergonomic factors involved in VDT viewing is to think of an ideal “vision cone.” This is an imaginary area encompassing the optimum range of gaze angles and viewing distances for a given posture. As the spine leans forward (taking the head and eyes with it, of course), the vision cone shifts downward. As the spine leans backward, the vision cone shifts upward. Workers who are aware of their vision cone can make adjustments in their posture, monitor height, and screen distance while keeping all elements in an ergonomically correct relationship. To achieve this, facility managers should give careful consideration to the furniture supplied, making sure that workers can adjust furniture simply and easily in order to achieve some postural variety and change of focal distance. For forward postures, the bottom of the monitor may very well need to be lower than the surface on which the keyboard rests, so that the bottom edge of the screen appears just above the keyboard. Some bi-level work surfaces support this, as do some adjustable VDT corner work surfaces. It may be possible to achieve a range of postures and good gaze angles when using a standard adjustable work surface with a mobile keyboard tray, although the degree of postural change would be more limited. Not every worker needs a wide range of adjustability, however. Those who work for long durations and have little visual variety in their task need more adjustability than those who naturally get visual stimulation while performing a variety of tasks.
 - **Take vision breaks** Even when VDT workers are practicing good posture habits, it’s still important to control the length of VDT work sessions. The simplest and most straightforward way to do this is for workers to take breaks. Full-time computer users should take three-to-five-minute breaks each half hour or 10 minute breaks each hour. It can also be helpful to occasionally close the eyes for few seconds or to lift the head and focus on a point about 20 feet away.

Those who alternate computer work with other tasks—like sorting materials or walking over to the printer—can stick with the standard 15 minutes every two hours. What workers do on their breaks is just as important as taking them. Breaks should not be spent reading or doing some other visual task. In fact, they are best spent repeating simple relaxation techniques that promote visual relief. NIOSH and many experts recommend leaning back, closing the eyes for a minute, and then looking into the distance.³² Blinking frequently is also a good idea, since tear flow cleanses and soothes the eye.³³ Deep breathing is a restful accompaniment to these routines. Management need not enforce breaks with rigid regularity. In fact, that may serve only to increase stress levels among workers. And workers may do best to establish individual routines. In general, workers who experience vision symptoms should determine how long they can work before symptoms appear, then take a short break at a minimum of half that time.^{34,35}

- **Organize jobs to assure variety** Many jobs that involve VDT work can be re-organized to provide greater visual variety. Workers who spend half their time entering data and the other half sorting and filing documents, for example, should not do all the VDT work in one big batch. Instead, they should alternate an hour of VDT work with an hour of filing, or some similar arrangement.

2. Consider the display's characteristics

When workers are experiencing visual symptoms, it could be an indication that their task is more demanding than the current screen technology can support. Task difficulty depends on several factors: the number of hours worked on the VDT, the intensity of viewing, and the importance of viewing performance (in terms of speed, accuracy, and detail) to the task. When assessing display quality, consider image quality (resolution), image stability (severity of flicker), and image polarity (positive or negative).

- **Image quality** Resolution, which is based on the number of pixels per inch and the fineness of the pixels, is one characteristic of VDTs that is important to visual performance.^{36,37} Higher screen resolution has been shown to reduce vision symptoms and significantly enhance visual performance.³⁸ Organizations who suspect their screen technology is less than adequate might consider improving resolution first. However, organizations may not need to improve resolution for every worker. Casual VDT workers may do just fine without the ultimate in high resolution. For more

intense VDT workers, though, the more difficult the task—in terms of its duration, lack of visual variety, and cost of error—the more important resolution becomes. Screen technology has improved greatly in recent years. For one thing, dpi—dots per inch, or the number of pixels per inch on a screen, also known as resolution—has increased. At 70 dpi or less, onscreen characters may appear slightly fuzzy or blurry. Larger, 96 dpi monitors are accounting for the majority of recent screen sales. Visually demanding VDT tasks should be supported by 90 to 120 dpi. Many people are going from black-and-white to color, as well. Color does offer some comparative efficiencies; it may make some jobs easier visually by using highlighting and color-coding to distinguish among items. Vision specialists suggest, however, that for visually demanding jobs performed for long durations, color is not nearly as helpful as good resolution.

- **Image stability** VDTs continually draw and redraw the image on the screen in order to keep it updated. An electron beam scans the screen from left to right, top to bottom, charging the tiny phosphor pixels (tiny light sources) and thereby painting the image. A complete redraw cycle takes only a fraction of a second. The screen's "refresh rate," measured in Hertz, is the number of times per second that the screen redraws. Recent neurological studies have found that the brain registers this movement, called flicker, even if the person is unaware of it.³⁹ (By comparison, computer displays with active matrix liquid crystal displays, or LCDs, also known as Thin Film Transistors (TFTs), are flicker free.) The higher a monitor's refresh rate, the lower the flicker and the easier it is on the eyes. Experts refer to the threshold refresh rate at which flicker is noticeable as the "critical flicker frequency" (CFF). Unfortunately, it varies among individuals and depends on other qualities of the screen—such as size and brightness level—so a simple numerical recommendation is not always enough. The ANSI/HFS standard recommends a minimum refresh rate that is "flicker free" for 90 percent of the VDT user population. Some specialists believe this rate to be about 92 Hz.⁴⁰ But many experts find that a rate of at least 75 Hz is comfortable for the majority of work conditions.⁴¹ Researchers have found a refresh rate under 60 hertz causes a flicker effect that can cause moderate eye discomforts, and may increase strain associated with small rapid jerky movement of the eye especially as it jumps from fixation on one point to another.⁴² When documents are used with VDTs, aligning the document and screen closely can sometimes reduce perception of flicker. Turning



down screen brightness can also reduce the perception of flicker. Of course, this reduces contrast as well. Workers should use their judgment to determine whether reducing flicker is worth losing contrast.

- Image polarity VDT screens can have two kinds of polarity: positive (dark characters on a lighter background) or negative (light characters on a darker background). Each polarity has its advantages. With positive polarity, specular reflections are less perceptible, edges appear sharper, and luminance balance is easier to obtain. With negative polarity, flicker and moiré are less perceptible, legibility is superior for people with anomalous low-acuity vision, and people may perceive characters as larger than they are. Many VDT displays offer a choice between polarities and sometimes both polarities simultaneously in different parts of the screen.⁴³ In addition to these considerations, workers should be encouraged to adjust the contrast to a comfortable level and keep the screen clean to avoid glare from dust and smears.

3. Minimize visual disparity between screen and text

Jobs that involve viewing VDTs and hard copy documents vary a great deal in their structure and visual demands. This section offers general principles for minimizing the visual strain of alternating constantly between two visual media.

- **Find optimum positions for screen and text** The first goal is to use proper positioning to create a comfortable viewing relationship among the eyes, body, screen, and text. Typically when there are two visual targets, one is dominant, and therefore should be placed in the ideal viewing position. The other should be placed in a secondary, but still comfortable position. For example, a person doing data entry transcribes handwritten or typed text to the computer. He or she keeps eyes on the text until the task is finished, then briefly scans the screen for accuracy. For this person, the text is the dominant target and should be placed in a prime position. The screen can be placed just to the side, above, or below the text, keeping within optimum parameters. For a person doing word processing, the targets may be equally important, since checking for accuracy and editing may take longer. This worker may need more equal placement, or the ability to alternate the dominant by moving both targets. The data entry person may need less flexibility but more precise placement, since he or she makes more and quicker eye

movements back and forth between targets. In general, the more demanding the task in terms of speed and frequency of visual alternating, the more important good alignment is.

- **Consider products that allow flexible positioning** Several kinds of products now available offer workers valuable flexibility in positioning screen and document.⁴⁴ Screen-mounted displays affix to the monitor itself and are good for equitable viewing; however, they do not allow alternating the dominant target or bringing the document a little closer to the eye when necessary. A monitor placed on a display armature can be adjusted for height, angle, and lateral position; these are good for equal viewing and for alternating dominant targets. Display stands rest on the work surface and adjust in height and angle; they are helpful when the text needs stable support so that the worker can hand-write information on it.
- **Make sure brightness levels are comparable** To reduce strain on the eyes' adaption mechanisms, the luminance of hard copy documents and the VDT screen should be similar. The IES-RP24 standard suggests that documents have a luminance no more than three times that of the screen, and preferably less. Many vision specialists believe it to be a reasonable control measure to reduce eye discomfort.⁴⁵ To achieve luminance parity between screen and text, provide positive polarity screens (dark characters on a lighter background), since under room illumination typical for a paper-intensive environment, documents and positive polarity screens have roughly the same brightness level.^{46,47,48} Another option is to combine somewhat lower light levels with task lighting directed at documents. The lower light level suits the VDT task, and the task lighting brightens only the visual target that needs it—the document—although this approach may have been most beneficial with older displays that featured text on a dark background. Researchers have found the installation of high-frequency ballasts led to a 50 percent reduction in the reported incidence of eyestrain and headaches in office workers.⁴⁹ Task lighting should be used only when the light level around the VDT screen is below 100 lux (unit of illuminance defined as lumens per meter squared). This low lighting level may be achieved by reducing the brightness from existing fixtures (remove lamps or add louvers) and by using panel systems that block or absorb brighter environmental light. Illuminance levels between 200 and 500 lux are sufficient for standard visual tasks, such as reading printed text or text on a VDT screen.

-
- **Use task lighting where appropriate** Older workers, especially those over 50, may also benefit from task lighting to give paper the extra brightness their eyes need to see without strain. Task lighting comes in a variety of forms, some of which are more useful than others. Fixed task lights attach under shelves and are best for independent reading tasks performed flat on the work surface or to illuminate materials and equipment positioned in a shadowy area. Under-shelf lights are not well suited for VDT-related document viewing. Monitors should never be positioned under a shelf with a task light. Movable task lights include lamps supported by an articulating arm. They are useful for documents positioned below the monitor. The light should fall on the document but not on the VDT screen. Asymmetrical lights can achieve this by aiming light from the side of the document. Document lights mount on the top of the document holder or display stand and are especially useful when the task involves viewing a single document at a time in close conjunction with the VDT screen. They should produce even illumination over the surface of the document (with no more than a one-to-five luminance variation over the surface of the document). Dimmer controls are sometimes available on task lighting and can provide a further, useful degree of control.

4. Address inappropriate lighting conditions

Creating good lighting conditions in the work environment is probably the most important as well as the most complex challenge facing organizations concerned about vision problems. The typical office facility is undergoing a period of transition that complicates lighting design in several ways.

Growing understanding of ergonomic issues has made us realize that people need to move around even while they remain seated at their desks. Thus lighting cannot be designed to create ideal light conditions for people in one particular posture or viewing angle. New work styles have also complicated lighting design. The increasing use of project teams as a way of organizing work means that workers move around to different work arenas during the day. Sometimes they even move furniture around as projects and team processes evolve. So once again, in many environments, a lighting system designed for a neighborhood of static workstations or static workers just won't do. Where and how people do their work is less predictable than in the past.

Finally, the increasing population of workers with special needs affects lighting design as well. The growing number of workers over age 45, for example, may indicate a need for overall brighter light in work environments where older workers are in the majority. In other environments, the older workers may simply need task lighting to brighten their individual workstations. It is also increasingly likely that workers with vision disabilities or other conditions may require an atypical lighting arrangement.

With all these factors to contend with, facility managers thinking about improving office conditions should certainly consider a comprehensive solution. A lighting re-design, planned and implemented with the assistance of an environmental lighting consultant, is the best way to make sure all relevant factors have been addressed. Fortunately, new, more efficient lighting systems can pay for themselves in cost savings alone.⁵⁰ For instance, a VDT work environment lighted at 1,000 lux will likely present reflection and glare problems. A lower light level of 300 lux, augmented with task lighting, would provide enough light for half the cost, and eliminate the need to buy glare filters. If state-of-the-art, energy-efficient lighting is used, another 25 percent of the energy cost can be cut.

The following section offers some general principles and suggestions that will help introduce decision-makers to the issues involved in lighting systems for the VDT environment. There are four basic objectives for creating appropriate lighting conditions in the VDT work environment: 1) provide appropriate general illumination levels for the VDT tasks; 2) augment light for reading tasks or for people with special needs using localized light; 3) balance brightness levels in the worker's field of view; and 4) control reflection problems.

In attempting to achieve these objectives, facility planners can informally evaluate their current lighting system, looking for ways to do away with the three most common lighting pitfalls: over-lighting, bright peripheral light, and reflected light.

-
- **Avoid over-lighting** Too much light for the VDT task causes discomfort glare and reduces the image contrast. Most offices designed to support paper-based tasks have general illumination levels of 200 to 500 lux. How strictly one should follow these guidelines depends on several mitigating factors:
 - Older workers do need a bit more light.
 - Negative polarity screens (dark characters on lighter background) can tolerate more light.
 - The more predominant and difficult VDT tasks are in the environment, the more strictly the guidelines should be followed.

These guidelines are a basic rule of thumb: low document/high computer use 100 to 200 lux; medium document/medium computer use 200 to 500 lux; high document/low computer use 500 to 1,000 lux. There are several possibilities for lowering light levels, and all can be effective if done properly. Short of installing a new lighting system, organizations can remove some lamps in overhead fixtures, install parabolic louvers, or use office architecture strategically so that VDT workstations are strategically designed to cut illumination levels significantly within the “field of view.”

- **Avoid bright peripheral light** Some variation of brightness in the environment is not only unavoidable, it’s also good for vision as it provides visual stimulation and interest. So the goal is not uniform brightness but avoiding distracting extremes that annoy workers and degrade visual performance. Bright light that enters a worker’s peripheral vision can produce discomfort or even disabling glare. The most troublesome sources of bright peripheral light are misplaced task lighting and overhead fixtures and windows. Here are some suggestions for dealing with problem peripheral light:
 - Remove under-shelf task lights from behind monitors.
 - Keep ceiling brightness low and uniform by following IES standards.
 - Configure workstations at right angles to windows and light fixtures so that bright light does not enter the worker’s field of vision.
 - Use window treatments like curtains, blinds, awnings, tinted glass, or a dark film covering to shield daylight.
 - Use panels to block out ceiling or window brightness.

- **Avoid annoying reflected light** Reflections, particularly those that degrade the VDT screen image, are probably the most intransigent vision problem in the office environment. Diffuse reflections degrade the image contrast by washing out the background. Specular reflections place ghost objects on the screen and confuse the eyes’ focusing and light adaption mechanisms. While glossy or shiny surfaces in the task surround can produce annoying reflected light, the object with the greatest reflection potential is, of course, the VDT screen. To achieve the healthiest vision and posture conditions, workers should be able to position the VDT screen several ways within optimum parameters. This makes the reflection problem even more challenging since the VDT should be reflection-free not just in one position, but in a range of positions. The two basic ways to achieve this are to address reflected light at its source and to treat the monitor itself.

- **Consider filters or screen treatments** A number of different glare filters and screen treatments provide a straightforward, inexpensive solution for all but the most extreme glare problems. They all reduce brightness to some degree, so they work best if the screen has excellent resolution and contrast to begin with. Also, they may not necessarily represent the most cost-effective solution. If enough VDTs need a filter, the cost of a whole new lighting system might be comparable.⁵¹ Filters that carry the American Optometric Association Seal of Acceptance enhance screen contrast and increase character legibility. Polarized glass also reduces brightness, but it is especially effective at reducing specular reflections. Film coatings are available to spray right onto the monitor, or a pre-treated filter can be fit onto the monitor; these reduce diffuse and specular reflections well, but can be easily scratched. Several screen treatment options are available from screen manufacturers. Matte finishes, which actually involve etching the glass, do break up specular reflections, but the etching can distort characters and reduce the resolution quality. Hard film coatings are equally effective in reducing reflections, but do not degrade the sharpness of the characters. Finally, flat screens, now readily available, are less susceptible to reflections than the concave surface of earlier VDT screens.

While many different lighting systems can work well for a VDT environment, a few principles about the two basic ways to light an environment—with direct or indirect lighting—may be helpful in evaluating current or proposed systems. Direct lighting casts light downward from ceiling fixtures. Indirect lighting casts light upward

from hanging or standing fixtures, reflecting the light off the ceiling and then downward. Neither is more expensive as a rule; one can install either system affordably or extravagantly—although a particular building’s geometry may make one or the other more feasible.

Most buildings can support a direct lighting system. Light fixtures are usually mounted in a dropped ceiling grid, so the ceiling can be placed at virtually any height above eight feet. Direct lighting systems can cause discomfort resulting from glare off the display screen entering the eyes directly or from specular reflections that appear on display screens when they are tilted upward. To avoid this, use parabolic louvers in the direct lighting fixtures to direct light straight down rather than at oblique angles into the room. Also, place fixtures on the ceiling so that light reflected on the ceiling completely overlaps from one fixture to the next, creating an even effect. When possible, lamps should be positioned to the side of the worker. Diffuse reflections tend to be less of a problem with direct lighting systems as long as the light level is kept low. Louvers should have a cut-off angle or lens that casts light downward below screen and eye level.

Installing an indirect lighting system usually requires a ceiling higher than nine-and-a-half feet, because good reflection off the ceiling requires that the ceiling be a certain distance from the fixtures. An indirect lighting system might produce less-pronounced shadow effects within workstations than a direct system would, and therefore require fewer task lights. A ceiling-mounted indirect system can also provide better flexibility for offices with a high rate of change in workstation configuration. Indirect systems are less likely than direct systems to produce specular reflections since the light sources are directed at the ceiling.

However, it’s possible that the fixture itself, if finished in a dark color, can create specular reflections on VDT screens. In this case, the reflection would appear as a dark blob against a generally brighter background. (Indirect fixtures should be white or have a mirror-like finish to avoid this.) Diffuse reflections can be a problem with an indirect system since indirect systems tend to be a bit brighter than direct systems. If the light level is kept low, however, the small amount of light reflected off the ceiling into the VDT screen should not degrade contrast significantly. Organizations with high concern for aesthetics as well as function may find that an indirect system to their liking is more expensive than a comparable direct system.

In short, both direct and indirect systems can provide suitable lighting when well designed for the architecture and task set in question. It is also possible to implement a combination direct/indirect system that, if well designed, could achieve the advantages of both.

5. Provide good vision screening

Because VDT viewing is an unusually demanding visual task, many—perhaps most—VDT workers will not be able to get by without corrective eye wear or with their current eye wear. The American Optometric Association recommends that all computer operators obtain a comprehensive eye examination prior to or soon after beginning computer work and periodically thereafter. The exam should include:

- A general systemic and ocular health history.
- A specific patient history relating to computer use. It is recommended that the patient be prepared to provide the following information:
- Type of computer work and nature of visual demands.
 - Number of hours, continuity and time of day for computer work.
 - Size and color of screen and screen characters.
 - Position and working distances of computer screen and other visual tasks.
 - General characteristics of light sources and their locations within the work area.
 - Nature, severity and frequency of symptoms associated with computer work.
 - Measurement of unaided and aided visual acuity at distance and appropriate near working distances.
 - Evaluation of internal and external eye health, (e.g., ophthalmoscopy, biomicroscopy, tonometry, visual fields, tear analysis, etc.)
 - Refraction at distance and near working distances.
 - Assessment of eye focusing (e.g., accommodative amplitude and facility).
 - Evaluation of eye coordination and eye movement skills (e.g., binocular vision analysis, ocular motility).⁵²

The aging of the North American workforce increases the importance of regular eye exams and appropriate eyeglasses. Presbyopia, the normal age-related loss of accommodation (ability to change the focus of the eye for near viewing distances), results in an inability to comfortably maintain focus on near objects.

Computer workers with presbyopia are at greater risk for the development of symptoms with a conventional prescription versus a computer prescription because general-wear multi-focal corrections often do not provide adequate correction for the viewing distances and angles needed at the computer workstation. Computer glasses, defined by the American Optometric Association, have a different lens design or prescription than general-wear glasses and have shown to be effective in reducing symptoms of presbyopic computer users.⁵³

6. Address psychosocial stress issues

A discussion of stress management programs in the workplace is beyond the scope of this paper. However, it is worth mentioning that many companies have achieved excellent results in controlling the incidence of musculoskeletal disorders by combining medical management and ergonomic training with stress management programs. It is reasonable to assume that vision problems can be managed successfully with the same holistic approach to the problem.

- **Stress management programs** Successful stress management programs attempt to give workers a degree of control and self-reliance in their work and in the management of work-related health problems. They also attempt to identify and address causes of stress. These might include internal factors, such as corporate policy or culture conflicts, or factors having to do with employees' personal concerns.
- **Training and education** A health training and workplace assessment program is one way to reduce psychosocial stress in the workplace, since such programs reassure employees that management is concerned about worker health. Of course, the main purpose of such a program is prevention or early treatment. Management should be involved in training as well, since they may otherwise be tempted to dismiss the importance of proposed health measures.

- **Medical management** Having well-defined procedures for reporting symptoms is another way to reassure employees of management's concern. Workers should be encouraged to report any adverse symptom early and receive treatment immediately in order to reduce the seriousness of potential problems. For VDT workers, a medical management program would have to include routine vision screening. Those who experience symptoms might be assigned to a different job for a time, or have their own jobs redesigned. Finally, scrupulous record keeping helps determine the effectiveness of interventions.

What is the outlook for the future?

Vision problems related to VDT work are gaining the kind of attention already paid to musculoskeletal disorders. This has sometimes proved counterproductive to addressing the problem. On the other hand, lack of information and attention to vision symptoms has allowed many businesses simply to ignore what is a very real problem in their workplaces.

Fortunately, VDT-related vision symptoms seem to be a relatively manageable worker health concern. Organizations who use this paper as a starting point for making ergonomic adjustments in their VDT environments should see excellent results. As a critical business resource, workers' visual health is worth the effort.

What impact do laptops have on the discussion?

At many organizations, laptop, or notebook, computers have become the primary, or only, computer people use, especially if their work requires mobility. The good news is that the advanced screen technology and portable nature of these computers make many of the issues discussed in this paper beside the point.

However, while laptop computers perform much better than VDT screens in relation to vision disorders, they do present a different set of issues for wrists, arms, and shoulders. For example, because the current design of laptops does not provide for separating keyboard from screen, achieving a comfortable eye-to-screen distance may require an awkward reach to use the keyboard. A separate keyboard and mouse can alleviate this issue and allow a person to use a platform to raise the height of the laptop's screen to a comfortable eye level.

As the cost of these computers goes down and their computing power goes up, many organizations will provide their employees with laptops in order to address vision disorders. This approach is fine as long as these organizations also address the ergonomic problems that intensive use of laptops can cause.

Notes

1. Collins M. J., Brown B., Bowman K. J., "Visual Discomfort and VDT's," Centre for Eye Research, Queensland Institute of Technology, 1988.
2. Sheedy J. E., London R., "VDT's—Solving the Vision Problem," *Problems in Optometry*, Volume 2, No. 1, 1990.
3. Smith M. J., Cohen B. G. F., Stammerjohn L. W., "An Investigation of Health Complaints and Job Stress in Video Display Operations," *Human Factors*, 1981.
4. Godnig E., Halunda J., *Computers and Visual Stress - Staying Healthy*, Grand Rapids: Abacus, 1991.
5. Sheedy J. E., Quotations from Ergonomic Advisory Panel Session, Herman Miller, Inc., January 1992.
6. *Ergonomics Today*, "Computer Workers View Vision Problems," ErgoWeb, accessed April 20, 2004 (available at <http://www.ergoweb.com/news/detail.cfm?id=863>).
7. California Code of Regulations, Title 8, Section 5110, "Control of Ergonomic Hazards," Draft 2, 1992.
8. Chaffin D., "Localized Muscle Fatigue," Definition and Measurement Reprint from *Journal of Occupational Medicine*, Volume 15, No. 4, p. 346 - 354, April 1973.
9. Collins M. J., Brown B., Bowman J., "Task Variables and Visual Discomfort Associated with the Use of VDT's," *Optometry and Vision Science Journal*, Jan., 1991.
10. Collins M. J., Brown B., Bowman K. J., "Visual Discomfort and VDT's," Centre for Eye Research, Queensland Institute of Technology, 1988.
11. Mitra Toossi, "A Century of Change: The U.S. Labor Force, 1950-2050," *Monthly Labor Review* 125 (2002): 15-28.
12. Sheedy J. E., London R., "VDT's—Solving the Vision Problem," *Problems in Optometry*, Volume 2, No. 1, 1990.
13. Occupational Safety and Health Administration. *Ergonomics Program: Proposed Rules* (Washington, D.C.: U.S. Department of Labor, November 23, 1999, accessed April 20, 2004), Federal Register #64:65768-66078, Part XIV.F.6 (available from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=FEDERAL_REGISTER&p_id=16305).
14. Anshel, Jeffrey. *Visual Ergonomics in the Workplace* (Philadelphia: Taylor & Francis, 1998), 18-19.
15. Jaschinski-Kruza, W., "On the preferred viewing distances to screen and document at VDU workplaces," *Ergonomics*, 33 (1990), 1055-1063.
16. Jaschinski-Kruza, W., "Eyestrain in VDU users: Viewing distance and the resting position of ocular muscles," *Human Factors*, 33 (1991), 69-83.
17. James Sheedy, "The Work Environment: Workstation Arrangement," DoctorErgo.com, accessed April 20, 2004 (available at <http://www.doctorego.com/>).
18. NIOSH, Schieffer L., Sauter S., Smith R., "Ergonomic Demands and Visual System Disturbances in VT Work," *Proceedings from Third U.S. Finnish Science Symposium*, October 1986.
19. Grandjean E., Reference from Retrospective Study on Line of Sight entitled "Differing Opinions" in *Ergonomics in Computerized Offices*, 1987.
20. Add reference #39 per Sue
21. Chaffin D., "Localized Muscle Fatigue," Definition and Measurement Reprint from *Journal of Occupational Medicine*, Volume 15, No. 4, p. 346 - 354, April 1973.
22. Sheedy J. E., Quotations from Ergonomic Advisory Panel Session, Herman Miller, Inc., January 1992.
23. Kroemer K. A., Personal Commentary on Viewing Posture, Herman Miller Ergonomics Advisory Panel, October 1991.
24. Rea M., Overette M., Kennedy M., "Lighting and Task Parameters Affecting Posture and Subjective Ratings," *National Research Council Canada IES 13p. (IRC No. 1361) NRCC 25546*, 1985.
25. Sheedy J. E., Quotations from Ergonomic Advisory Panel Session, Herman Miller, Inc., January 1992.
26. Hedge A., "Clear Eyed Computing," *MacWorld*, April 1992.
27. Sheedy J. E., Personal Commentary, University of California at Berkeley Optometry Lab, April 1992.
28. Tanahashi M., Miyao M., Sakakibara H., "The Effects of VDT Work on Fluctuations of Accommodation," *Industrial Health*, 1986.
29. Grieco A., "Sitting Posture: An Old Problem and a New One," *Ergonomics*, 29.3, 1986.
30. Herman Miller, Inc., "Issues Paper - Cumulative Trauma Disorders," p. 39, 1991.
31. Rinalducci E., Dismures K., Reference from guidelines presented in "NRC—Video Displays, Work and Vision," Chapter 9, "Design, Practice, and Standards for VDT Equipment and Work," p. 194, 1983.
32. Loomis V., Church J., "Video Display Terminals: Potential Health Hazards and Possible Solutions," *Journal of Bio Communications*, Volume 17, No. 4, 1990. *Vision and the Computerized Office* 19 I
33. Smith M. J., Cohen B. G. F., Stammerjohn L. W., "An Investigation of Health Complaints and Job Stress in Video Display Operations," *Human Factors*, 1981.

-
34. "VDT's in the 1990's: Advancing Technologies/Mounting Concerns," Labor Relations Week, August, 1990.
 35. Zlatija V., Toncheva R., "A Search for Ophthalmological Changes from Video Display Units," Institute of Hygiene and Occupational Health, Sofia, Bulgaria, 1989.
 36. Rinalducci E., "VDT's in the Workplace," Occupational Health Meeting, NASA, 1990.
 37. Sheedy J. E., "VDT's: Solving the Environmental Problems," Problems in Optometry, Volume 2, No. 1, March 1990.
 38. Sheedy J. E., "Reading Performance and Visual Comfort on High Resolution Large Monitor Compared to a VGA Monitor," University of California at Berkeley, School of Optometry, 1990.
 39. Alison McCook, "Our Brain Sees Screen Flickers, Even if We Don't," (London: Reuters Health eLine, January 23, 2003 (available at <http://www.reutershealth.com/en/index.html>).
 40. Rinalducci E. Lassiter D., "The Effects of Transient Adaption in Simulated VDT Operations," S.I.D. Digest, 9.4, 1986.
 41. Sheedy J. E., Personal Commentary, University of California at Berkeley Optometry Lab, April 1992.
 42. Jane Berliss-Vincent, "The Boomer Effect: Accommodating Both Aging-Related Disabilities and Computer-Related Injuries," in Proceedings of the 16th Annual California State University, Northridge, "Technology and Persons with Disabilities" Conference, March 19-24, 2001, held in Los Angeles, California (available at <http://rose.iinf.polsl.gliwice.pl/~kwadrat/www.csun.edu/cod/conf2001/proceedings/0194berliss-vincent.html>).
 43. Human Factors and Ergonomics Society, *BRS/HFES100, Draft Standard for Trial Use: Human Factors Engineering of Computer Workstations* (Santa Monica, CA: Human Factors and Ergonomics Society, 2002), 59.
 44. Illumination Engineering Society of North America, IES - RP24, "Recommended Practice for Lighting Offices Containing Visual Display Terminals," 1990.
 45. Sheedy J. E., Personal Commentary, University of California at Berkeley Optometry Lab, April 1992.
 46. Rinalducci E. Lassiter D., "The Effects of Transient Adaption in Simulated VDT Operations," S.I.D. Digest, 9.4, 1986.
 47. Rinalducci E., Dismures K., Reference from guidelines presented in "NRC—Video Displays, Work and Vision," Chapter 9, "Design, Practice, and Standards for VDT Equipment and Work, p. 194, 1983.
 48. Sheedy J. E., "Vision Problems at Video Display Terminals," Society for Information Display, Digest of Technical Papers, 1991.
 49. NRC Lighting Quality Contributors, p. 8, per Sue
 50. Hedge A., Sims W., Belker F., "A Summary of the Cornell University Study: Lighting the Computerized Office," October 1989.
 51. Kohn M., Personal Commentary on Lighting the VDT Work Environment, May 1992.
 52. American Optometric Association, "Recommended Components of an Eye/Vision Examination for Computer Operators" (St. Louis: American Optometric Association); available from <http://www.drsheedy.com/>; accessed April 7, 2004.
 53. S.P. Butzon, James Sheedy, E. Nilsen, "The efficacy of computer glasses in reduction of computer worker symptoms," *Optometry* 73(4) (April 2002): 221-230.