Occupational Hazards

Visual Ergonomics in the Workplace

Improving eyecare and vision can enhance productivity

By Jeffrey R. Anshel

VISION IS OUR MOST PRECIOUS SENSE. Our eyes are in constant use every waking minute of every day. Psychologists estimate that 80% of the information people obtain from the external environment is by means of their visual pattern (Manas). Clearly, the way we use our eyes can determine how well we learn, work and perform.

The way we use our eyes each day has changed dramatically in recent years. More tasks are now performed at a close viewing distance and under a wide range of workplace conditions. To perform at maximum potential, a person's visual system must adapt to these changes.

This article examines visual function and its role in workplace productivity. By understanding the connection between comfort, health and productivity, and knowing the options for good visual ergonomics and workplace lighting, readers will gain a better understanding of potential visual stressors in the workplace, and of how vision and visual comfort can affect productivity.

Understanding the Eye & Visual System

A complete eye examination is more than just reading letters on a chart 20 ft away. This is simply one test of the function of one part of the visual system. The eyeball is just the receiver of light and the comparison of the eye to a camera is an inadequate description of how people see. Visual processing is accomplished in the brain where visual perception occurs. "Eyesight" is the process of properly focusing the incoming light to the proper area of the retina, whereas "visual perception" is the process of taking that information into the brain, making sense of it and reacting appropriately (Schapero, et al).

Light travels through the cornea, the anterior chamber, the pupil, the lens and the vitreous body, then to the retina, where light energy is transformed into nerve impulses. It travels out of the eye via the optic nerve, which is made up of about 1 million nerve fibers that extend from the retina to the brain.

When the entire process works normally, the visual state is known as "emmetropia." If the light comes to focus too soon (before striking the retina), it is called "myopia" or near-sightedness. If the light strikes the retina before it has come to a focus, it is called "hyperopia" or far-sightedness. If any distortion is present in the shape of the cornea or other optical structures, then "astigmatism" can occur. This is a common occurrence and an optical correction is often necessary to compensate for the distortion.

One must also consider the fundamentals of binocular vision when assessing the computer-viewing environment. The process of coordination between binocular vision and the accommodative (or focusing) system is a unique process that only occurs in the visual system. Studies have found that the convergence system, where the eyes turn in toward each other as the object moves closer, plays a significant role in vision stress (Jaschinski-Kruza). Additionally, the eyes turn down as well as in when they view a close object. This results in a normal near-viewing posture, which is duplicated optimally with book reading. The viewing of a near object at a raised level or eye-level—typical in computer environments—is awkward and unnatural.

Since people are living and working longer—Bureau of Labor Statistics (BLS) predicts that by 2012, those age 55 and older will make up about 20% of the labor force (Toossi)—the effects of aging on the eye must be addressed as well. In 1900, the average life expectancy of a male in the U.S. was 47 years; today, it is about 76 years (CDC). In essence, people have effectively out-lived many of the useful functions of their eyes.

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Computer Use in the Workplace

Computer use has grown significantly in the last 20 years, and computers are now as commonplace as the telephone in the workplace. According to data from U.S. Census Bureau's Current Population Survey supplements, as of September 2001 (the latest data available), about 76 million working adults 18 and older used a computer at work. The Internet has further ingrained computers into everyday life.

As a result of this increased use, physical problems related to computer use are increasing as well. To date, more public and professional attention has been paid to musculoskeletal disorders, such as those involving the wrist, neck, shoulder and back, than to eye and vision problems. One reason for this is that vision problems are primarily symptomatic in nature and usually are gone by the next day, whereas musculoskeletal problems tend to persist. Furthermore, musculoskeletal problems are typically associated with much higher workers' compensation costs.

However, surveys of computer workers show that eye and vision problems are the most frequently reported health-related problems, occurring in 70 to 75% of computer workers (Smith, et al; Collins, et al; Dain, et al). As a result, the eyecare community has experienced an increase in the number of patients who request eye exams due to symptoms they experience while working at the computer.

Computer Vision Syndrome

American Optometric Association (AOA) has coined the term computer vision syndrome (CVS) to describe "the complex of eye and vision problems related to near work which are experienced during or related to computer use. CVS is characterized by visual symptoms that result from interaction with a computer display or its environment. In most cases, symptoms occur because the visual demands of the task exceed the visual abilities of the individual to comfortably perform the task" (AOA).

Typical symptoms of CVS are eyestrain, headaches, blurred distance or near vision, dry or red eyes, neck and/or backache, double vision and light sensitivity. Contributing factors are a combination of improper workplace conditions, poor work habits and existing refractive errors. Lighting, vision and posture are all interrelated concepts. People are visually directed and they will alter posture to alleviate stress on the eyes. Therefore, alterations in body posture may be indicative of a visually stressful situation.

The Toll of Visual Demands

Because of the high visual demands of computer tasks and the visual shortcomings of many operators, vision problems and symptoms are common among computer workers. Most studies indicate that visual symptoms occur in 75 to 90% of computer workers (Smith, et al; Dain, et al). A study by NIOSH showed that 22% of computer workers have musculoskeletal disorders as well.

A survey of optometrists indicated that 10 million primary care eye examinations are conducted annually in the U.S. because of visual problems at computers (Sheedy and Parsons). The most frequent visual problems reported in that survey (listed by frequency) are:

- eyestrain;
- headaches;
- blurred vision;
- dry or irritated eyes;
- neck and/or backaches;
- photophobia (light sensititivy);
- double vision;
- after images (Sheedy and Parsons).

Vision-related symptoms occur whenever the visual demands of the task exceed the individual's visual abilities. Many people have marginal vision disorders such as difficulties with accommodation (eye focusing) or binocular vision problems (eye coordination) that do not cause symptoms when performing less-demanding visual tasks.

Workers who require bifocals or reading glasses often have special problems at the computer since the optical prescription and spectacles worn to meet everyday visual needs do not work well at the computer. Think about the awkward position people with bifocals often adopt to read something above eye level—such as a book on a shelf. This also occurs at a computer since the screen is located higher in the field of view and farther away from the eyes than are common reading tasks for which most bifocals are designed.

Numerous aspects of computer work make it a more demanding visual task than others. Therefore, more individuals fall beyond their threshold for experiencing symptoms. The visual symptoms can largely be resolved with proper management of the environment and by providing proper vision care

Common Workplace Lighting Problems

Problem: Display is placed on a desk in front of a window.
Solution: Windows should be off to the side, not in front of or behind the employee

Problem: Image of overhead ceiling light visible on screen.
Solution: Use a parabolic louver to direct the ceiling light straight down; and/or cover the screen with an antiglare filter.

Problem: Task lighting is used but shines into employee's eyes.
Solution: Proper task lighting is directional and should be directed to the hard copy, being careful not to spill onto the display screen or into employee's eyes.

Problem: Employee uses a new LCD flat panel display and gets headaches.
Solution: LCDs can be extremely bright. Display should be dimmed slightly to match surrounding room illumination.

Lighting Evaluation

To perform a lighting evaluation, specific tools include a luminance meter, a general lighting meter, a tape measure and possibly a camera.

First, consider the general room illumination—placement of luminaries in relation to workstations.

Second, look at monitor position on the desk and sources of glare around the display.

Third, check lighting on the desk and see whether task lighting might be appropriate.

Fourth, talk to the employee to learn whether there are any subjective complaints.

Including pictures in a report is an effective way to demonstrate visual stress concerns to management.

for the employee. Key aspects of the work environment that may contribute to eye problems include:

- lighting geometry and quantity;
- screen reflections;
- glare from windows or overhead lights;
- higher viewing angle of monitor;
- dry office environment;
- poor screen design (e.g., contrast, polarity);
- poor visual arrangement of the workstation (Sheedy).

The Role of Lighting

Lighting is one of the most overlooked and underemphasized components in the workplace. Whether working at the computer or in a warehouse, one's field of vision needs to be free of reflections and sources of glare. Lighting is workplace-effective when it allows the worker to see the details of a given task easily and accurately.

Comfort in lighting is an individual concern and must be addressed on a case-by-case level; no one lighting pattern will work for every working situation. Therefore, those responsible for workplace lighting need to learn what is available to help them make the right choices for employees. Lighting and vision are interdependent factors and must both be considered when designing a working environment for maximum efficiency.

The quality of light greatly affects a person's ability to see well in the workplace. Good quality light creates good visibility and visual comfort. This can be accomplished with attention to brightness, contrast, quantity and color of light. Contrast between a task object and its immediate background must be sufficient to enable the worker to clearly view the task. Contrast ratios should maximize productivity without increasing eyestrain. In general, a 1:3:10 ratio is ideal; that is, the task area should be less than 3 times as bright as its immediate surroundings and 10 times brighter than the peripheral area (IESNA).

Too much or too little light can inhibit a worker's ability to effectively see the task. Comfortable light levels will vary with the individual. For example, a 60 year old needs 2 to 3 times as much light as a 20 year old to achieve the same visual performance (Toomey). Comfortable light levels will also vary with the task. The more rapid, repetitive and lengthy a task, the more important it is to have enough light. When performing such tasks, a person's eyes are more vulnerable to fatigue, thereby reducing productivity.

Different colors of light can create different moods or atmospheres that will affect a worker's sense of well being and productivity level. "Full spectrum" fluorescent lights come closest to natural light, imitating the color rendition of the midday sun and adding a sense of well being to the office environment. Altering the lighting sources, or installing a special filter that can be placed between the lens and lamp of a fixture or fitted as a sleeve over each lamp can achieve this (Dutson, et al).

Lighting for the workplace of today is distinctly different from what has been acceptable in the past. Older offices were designed to illuminate paper-based tasks rather than self-illuminated computer displays. As a result, the average ambient light levels in most offices are too high, inefficient and costly.

The current trend calls for reduced ambient lighting supplemented by adjustable task lighting, which helps to illuminate work surfaces and tasks without creating veiling reflections or glare on computer screens or work surfaces. Recommended light levels for today's computerized workplace is closer to 40 to 50 foot-candles for ambient light, as compared to 100 foot-candles or more in noncomputerized offices (IESNA). Task lighting can also help older employees who often need additional light.

With respect to the best colors for working on a computer, the actual color of the letters and background on a display is a secondary consideration. The contrast between the letters and the background is more significant. The combination that offers the maximum contrast is black letters on white background (like paper). Workers should be cautious of working with pale letters (poor contrast) or very dark backgrounds in an environment that is too bright (exceeds the recommended 1:3:10 contrast ratios).

Although lighting a workplace for maximum efficiency is ideal, cost must be considered. Costs related to factors such as energy, new lighting fixtures, retrofitting and remodeling are all significant considerations that must be balanced to achieve the most for the money spent. Approximately 86% of the cost of lighting is energy consumption, while only 3% of the cost is the price of the lamp (DOE). Therefore, purchasing cheaper lamps does not necessarily translate into a cost savings. A more prudent method is to purchase lamps that consume power more efficiently.

Lighting control is also critical. For example, are light fixtures equipped with standard prismatic lens or grid-type lens (parabolic louvers) that project the light outward and downward in the most efficient manner? Lighting designers or ergonomists should make checklists to ensure that all lighting is ergonomically supportive of worker productivity before beginning work. Helpful reminders and current options should focus on the ultimate goal: to achieve worker-oriented lighting which will ensure that the task can be comfortable and easily seen, and that the employee is working productively.

Ensuring effective workplace lighting encompasses three key steps:

1) Learn to observe the types of lighting available to the worker and to develop ongoing awareness of how this may/may not be working.

2) Identify risk factors, such as glare and reflections, and understand the options for correcting these factors.

3) Develop solutions that involve worker responsibility, administrative cooperation and caring, as well as realistic, cost-effective improvements.

Other Potential Eye Health Hazards

Eye-related health hazards have been a potential concern for many years. To date, however, no proof has been offered that computer use causes any type of eye health hazard. The electromagnetic radiation that comes from a CRT computer monitor is well below all international standards and recommendations. Newer LCD flat panel displays emit much less radiation than the older CRT models (Elliott, et al). Some have also contended that UV protection is necessary while working at a computer; however, no research has confirmed that UV radiation has any effect on the computer user. Most UV radiation drops off at about 4 in. from the front of the screen.

One study conducted in Japan suggested that excessive computer use among myopic individuals can lead to visual field defects, most often associated with glaucoma. It should be noted, however, that this study's population was mostly male and the numbers of glaucoma suspects related closely to that number which often go undetected in the general population (Tatemichi, et al).

Another concern surrounds the wearing of contact lens while using a computer. Such concerns can be easily addressed, however. For example, blinking is an issue for most computer users—and even moreso for those who wear contact lens. People tend to blink less often while performing computer tasks, likely because of a combination of concentration on the task and monitor position (usually higher in the visual field of view). This requires one's eyes to be open wider, which is not a natural reading posture, and causes the eyes to dry out faster with less blinking. Therefore, those who wear contact lens should use rewetting drops periodically during the day while using a computer.

Addressing Eye & Vision Problems

Many eye and vision problems can be resolved through management of the visual environment and provision of proper eyecare for employees. Why should an employer invest resources to resolve these problems? Primarily because doing so is good business. Executives are familiar with investing money in processes or equipment that improve efficiency. Although one typically thinks of assembly lines and blue-collar workers when talking about work production, people sitting in front of computer displays are a major part of today's work production. Thus, businesses must improve the efficiency of office workers much like assembly line processes were streamlined in the past.

Vision & Work Efficiency

Beyond the humanitarian aspects of providing eyecare (eliminating employee discomfort), economic factors must be considered. Since working at a computer is a visually intensive task and the sense of vision is used to acquire the information needed for job performance, it is reasonable to expect that improvements in the computer display or in the user's visual capabilities will improve performance efficiency.

Consider the older VGA displays—the most common display format used with DOS-compatible equipment. These displays have a pixel density on the screen of approximately 75 dots per inch (dpi). It has been shown that increasing the pixel density on the screen from 75 dpi to 115 dpi results in 17.4% faster reading performance for 30-minute reading sessions (Sheedy). Likewise reading speed improvements of 4.1 to 19.9% (depending on display type) have been shown for adding a grayscale improvement of image quality (Sheedy and McCarthy). This supports the need to supply better monitors—as well as to provide for better vision of the worker. If subjects with good vision (all study subjects had at least 20/20 vision) can improve reading speed with a better-quality image, it is likely that a person with poor vision will attain better performance as well.

LCD monitors have introduced a new set of circumstances surrounding visual performance. The LCD has many advantages. For example, it is lighter weight, smaller, easier to position on a desk, uses less electricity, generates less electromagnetic radiation and has a finer pixel formation. However, its increased capability of brightness can be detrimental if not properly set. Additionally, LCD pixels are so crisp and clear that they are viewed as a dot matrix pattern rather than a smooth letter. Studies have been conducted to compare computing performance on LCD monitors as compared to CRT and have found them to be at least as good, if not better (Ziefle). However, the performance still does not approach that of paper-based tasks. If an employee is experiencing difficulty with display viewing, simply switching to an LCD display will likely not fully resolve the problem.

Other studies have assessed the effects of different types of visual corrections on occupational task performance [Sheedy and Parsons; Sheedy, et al(a); Sheedy, et al(b); Harris, et al]. For example, instead of wearing bifocals, it is possible to be fitted with various types of contact lens that enable a person to see clearly both nearby and at distance. One approach is to fit one eye with the distance prescription and the other with the near prescription (known as monovision); another example is to wear lens that have both the distance and near power in each lens. Despite the known visual compromises that occur with such corrections, these options can work for many patients.

Although these vision compromises are "acceptable," it has been shown that they result in 4 to 8% slower performance on occupational tasks. If these decreases in vision result in 4 to 8% productivity loss, one would expect that the more common forms of uncorrected vision—which result in larger losses of visual function—would result in even larger productivity losses. A more recent study found a favorable cost/benefit ratio of at least 2.3 for the visual correction of an employee (total cost $268) with a salary of $25,000 per year (Daum, et al).

Does Eyecare Pay?

A high percentage of VDT operators has been found to have uncorrected or undercorrected vision problems that may affect their visual performance and comfort (Rosner and Belkin; Sheedy and Parsons). Uncorrected vision problems in the workforce create more problems than those corrected situations that showed 4 to 8% decreases in task performance. Although these were laboratory studies and the tasks were performed for durations considerably shorter than a full workday, it is likely that similar inefficiencies occur daily for workers with uncorrected vision disorders. One might even expect that 8-hour productivity would be more greatly reduced because of the symptoms and fatigue which accompany the vision problems.

If an employee's compensation is $30,000 (including benefits), a 1% improvement in work efficiency is worth $300. Eyecare can be provided for considerably less than this—and will likely produce a greater than 1% increase in productivity.

Eyecare Programs for Computer Workers

Many companies offer vision care as an employee benefit. However, such care may not be meeting the needs of employees who use computers. As noted, proper care of the computer-using employee requires more than a simple refraction, dilated examination of the inside of the eye and provision of glasses. Many employees require a different pair of glasses for computer work—and some employees may be reluctant to pursue under the company's benefits program.

The key to this program is the ability of the eyecare providers to understand eye and vision problems common among computer users. These providers must be able to diagnose the underlying condition; and implement appropriate care in response. The most common diagnosable vision conditions that can result in compromised visual function and symptoms of discomfort are accommodative disorders; binocular vision disorders; hyperopia; astigmatism; dry eyes; contact lens wear; and improper multifocal spectacle design (Sheedy and McCarthy).

A successful managed eyecare program for computer workers will feature a panel of providers who are skilled at diagnosing and treating these conditions. AOA has developed a list of recommended components of an eye examination for computer operators. In addition to tests that are part of all eye examinations, AOA recommends that the exam of a computer user should include:

- a detailed history (symptoms, nature of computer work, position and working distance of screen and other materials, and other visual characteristics of the work environment such as lighting and reflections);
- assessment of accommodative abilities;
- assessment of ocular coordination;
- refractive determination for the required viewing distances at the computer workstation;
- design of occupational lenses if required;
- counseling regarding the visual environment at the workstation.

Vision training for accommodative and/or binocular vision disorders should also be considered in an eyecare program; it is the treatment of choice in some situations (especially for convergence insufficiency). Treatment of dry eye should also be provided as part of the eyecare program.

Who Pays for Eyewear?

In the interest of work efficiency, everyone who needs a visual correction should wear one. The best way to ensure this is for the employer to provide the eyewear for all computer-using employees (or others with visually demanding jobs). However, many employers feel that employees should be responsible for providing their own general eyewear and that vision correction becomes the employer's responsibility only if the glasses are different from the general eyewear an employee would otherwise require.

This can be accomplished by establishing a list of diagnostic/treatment conditions for which glasses will be provided. These might include presbyopia; accommodative disorders; hyperopia; and binocular vision disorders (AOA). For glasses to be provided under the program, panel providers would need to arrive at one of the listed diagnoses and determine that the glasses are different in prescription or design than those required for other daily visual needs.

Limiting frame and lens selections can help to control costs. Single-vision and occupational lens are a necessary option. In the author's experience, general progressive addition lenses should not be provided as an option since they do not function well for computer workers. Trifocal and specially designed occupational progressive addition lens can be useful for many computer workers. However, while it is desirable to provide these options, most users visual needs can be properly managed with single-vision lens thereby resulting in cost savings. Tints and coatings do little to solve the problems reported by computer users and are not a necessary program component. If only basic lens options are covered, employees should have the option of paying the difference should they want more expensive options.

Another way to control costs is to conduct an effective ergonomic assessment where indicated. As noted, many eye and vision problems experienced by computer users can be resolved by evaluating and improving the visual work environment. Such evaluation and corrective action will help reduce the use of eyecare services.

Vision screening is another tool that can help to reduce overuse by identifying those employees who are most likely to benefit from an eye examination. However, professionally managed vision screenings are expensive and it is questionable whether the savings in use overcome the costs of performing the screening. Self-analysis tools are available that more cost effectively enable employees to screen themselves for vision problems and also to educate themselves about proper use of their eyes in the computer environment.

Conclusion

Providing for good visual health for computer employees makes economic sense. Computers are used in almost every aspect of life, including work. Many users experience eye and vision-related symptoms and discomfort, which can negatively impact their productivity. Often, these problems can be addressed by using effective workstation design practices, providing adequate lighting and lighting control, and ensuring that employees receive appropriate eyecare. ■

General Eyecare Tips

Practical recommendations regarding computer viewing include:

- **General eyecare.** Recognize the importance of regular and routine eye examinations, with emphasis on the computer-using environment and working distances.
- **Computer eyeglasses and frames.** Many optical companies offer lens designed for the intermediate distance-viewing situation. The newest versions of these are called occupational progressive addition lenses. An eyecare professional can guide the selection of the lens that is most effective in a given viewing situation.
- **Glare.** Many types of antiglare screens are available for computer monitors. The glass models generally are the best and most expensive. AOA provides a list of those that have passed its qualification standard as being an effective screen.
- **Working conditions.** Each person's eyes must adapt to his/her viewing environment. A poorly designed workspace can lead to visual fatigue and eyestrain. Therefore, all items in the work area must be easily seen and without excess glare or poor lighting.
- **Breaks.** Visual breaks are effective at reducing eyestrain. One recommended strategy is the "3-B" approach: blink, breathe and break. For breaks, consider the 20/20/20 rule: Every 20 minutes, look 20 feet away for 20 seconds.

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