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# Visual Ergonomics in the Workplace

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## Vision and Lighting

Vision is our most precious sense. Our eyes are in constant use every waking minute of every day. The way we use our eyes can determine how well we learn, work, and perform throughout our lifetime. Over 80 percent of our learning is mediated through our eyes, indicating the important role our vision plays in our daily activities. The way we use our eyes in our daily routine has changed dramatically over the past number of years. More and more tasks are done at a close viewing distance, and we are working under a variety of workplace conditions. Our visual system must adapt to these changes in order for us to function to our maximum potential.

Lighting is one of the most overlooked and under-emphasized components of our workplace. Whether working at the computer or in a warehouse arena, our field of vision needs to be free of reflections and sources of glare. Our lighting needs to prevent problems, not cause them. Lighting is workplace-effective when it allows the worker to see the details of a given task easily and accurately. Comfort in lighting is a very individual concern and must be addressed on a one-to-one level; no one lighting pattern will work for every working situation. Those in charge of workplace lighting need to learn what is available to help them make the right choices for their employees. Lighting and vision are interdependent factors and must both be considered when designing a working environment for maximum efficiency.

This session is designed to give the participants awareness and knowledge of how lighting can and will affect workplace well being. It is also an interactive information session that will enlighten the participants about the area of visual function and its role in workplace productivity. By understanding the connection between comfort, health, and productivity and knowing the many options for good ergonomic workplace lighting, attendees will learn how to achieve worker-oriented lighting to insure that the task can be easily and productively accomplished. They will also learn how to become sensitive to potential visual stress that can affect all areas of performance.

## The Eye and Visual System

A complete eye examination is more than just reading letters on a chart 20 feet away. That 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 limited in understanding how we really 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 “vision” is the process of taking that information into the brain, making sense of it, and reacting appropriately.

The pathway of light through the eye travels through the cornea, the anterior chamber, the pupil, the lens, the vitreous body, and then to the retina where the light energy is transformed into nerve impulses. It travels out of the eye via the optic nerve, which is a mass of about one 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 there is any distortion in the shape of the cornea or other optical structures, then “astigmatism” can occur. This is a common occurrence and often needs an optical correction to compensate for the distortion.

We should also discuss the fundamentals of binocular vision, with emphasis on the computer-viewing environment. The process of coordination between binocular vision and the accommodative or focusing system is presented in a unique forum. 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. 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, or eye-level as is often seen in computer environments, is awkward and unnatural.

The history of visual demands puts our current-day viewing conditions in a historical perspective. The origin of the visual system and its’ design shows how our visual system demands have changed. When Homo sapiens first appeared- about 40,000 years ago- we were hunters/gatherers, limiting our time to survival skills. Visually, these included hunting, making weapons, cooking, and little else. Since we are living longer and leading more active lifestyles, the effects of aging on the eye must be addressed. In 1900, the average life expectancy of a male in the US was 47 years. Now, just over one hundred years later, it is about 76. We have effectively out-lived many of the useful functions of our eyes. The Bureau of Labor Statistics predicts that by 2030, the group aged 55 or over will make up over 20% of the labor force, compared to 12.4% share in 1998. Aging in the workplace is certainly an issue that needs to be addressed, especially in the area of vision.

## Computer Vision Syndrome

Computer use has grown significantly in the last 30 years. Since the first computer was developed in about 1950 (when it occupied an entire room), it is now as commonplace as a telephone in our workplace. There are currently over 195 million Americans using computers regularly in the workplace. Children between the ages of 8-18 years old spend over 7½ hours a day looking at digital images. And the growth of the Internet has engrained computer use as a way of life; about one-quarter of the earth’s population uses the Internet!

The symptoms of physical problems that computer users are experiencing are increasing. The eye care community has also seen a jump in the number of patients who request eye examinations due to symptoms they experience at the computer. This has led to the American Optometric Association (AOA) designation of Computer Vision Syndrome (CVS).

According to the AOA definition, CVS is “the complex of eye and vision problems related to close work that are experienced during or related to computer use”. The symptoms that most often accompany this condition are eyestrain, headaches, blurred distance or near vision, dry or red eyes, neck and/or back ache, double vision and light sensitivity. The factors that most often contribute to CVS are a combination of improper workplace conditions, poor work habits, and existing refractive errors. Lighting, vision and posture are all inter-related concepts. We are visually directed creatures and will alter our posture to alleviate stress on the eyes. Therefore, paying attention to body posture may be indicative of a visually stressful situation. Some of the symptoms of CVS actually concern the head, neck and shoulder areas of the body.

## Workplace Lighting

An important factor that affects our ability to see well in the workplace is the quality of light. Good-quality light creates good visibility and visual comfort. This can be accomplished with attention to brightness, contrast, and 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. You must set up contrast ratios to 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 less than 10 times brighter than the peripheral area.

Too much or too little light can inhibit the worker's ability to effectively see the task. Comfortable light levels will vary with the individual. For example, the 60-year old worker requires many times more light to achieve good visibility and contrast than the 20-year old worker. Comfortable light levels will also vary with the task. The more rapid, repetitive and lengthy the task, the more important it is to have enough light. With these types of tasks, the eye is more vulnerable to fatigue and the worker to declined productivity.

Different colors of light will create different moods or atmospheres that will affect a worker's sense of well-being and level of productivity. “Full spectrum” fluorescent lights come closest to nature’s light, imitating the color rendition of the noonday sun and adding a whole new 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 fit as a sleeve over each lamp, can achieve this condition.

Lighting for the workplace of today is distinctively different from what has been acceptable in the past. Most offices were designed to illuminate paper-based tasks, instead of the self-illuminated computer display. The average ambient light levels in most offices are too high, too inefficient and too costly. The trend now calls for reduced ambient lighting supplemented by adjustable task lighting. Recommended light levels for today’s computerized workplace are 40-50 foot-candles for ambient light, as compared to 100 foot-candles or more in previous non-computerized offices. Many offices have no task lighting, yet task lighting systems are advanced,

versatile and available to illuminate work surfaces and tasks without creating veiling reflections or glare on computer screens or work surfaces.

Many people inquire about the “best” colors for working on a computer. The actual color of the letters and screen are a secondary consideration in this respect. More important is the contrast between the letters and the background. The combination that offers the maximum contrast is black letters on white background (like paper). This is very disappointing for many people, especially considering that they often have 16 million colors from which to choose! Be cautious of working on pale letters or very dark backgrounds in too bright of an environment.

Lighting a workplace for maximum efficiency is a nice concept. However, in the real world of budgets and bottom-lines, cost effectiveness is also a major consideration. The cost of energy, of new lighting fixtures, of retrofitting, of remodeling and more are all significant considerations which must be balanced to achieve the most for the money spent. Approximately 86 percent of the cost of lighting is energy consumption, while only 3 percent of the cost is the price of the lamp. Therefore, purchasing cheaper lamps does not necessarily indicate a cost savings. A more prudent method is to purchase lamps that consume power more efficiently. These and other considerations will be discussed in depth to allow for a thorough working knowledge of lighting within budget constraints.

The concept of lighting control is critical. For example, are the light fixtures equipped with standard prismatic lenses or grid-type lenses (parabolic louvers) that project the light out and down in the most efficient manner? Tips for achieving balance in creating effective task/ambient light levels for computer work are detailed. Checklists should be made to ensure that all lighting is ergonomically supportive of worker productivity before beginning work. Helpful reminders and current options should be reviewed while focusing on the ultimate goal: to achieve worker-oriented lighting; lighting that will insure that the task can be comfortably and easily seen...and that the worker is working well.

Recommendations regarding good workplace lighting are offered, with attention given to constructive and realistic problem solving. The focus is threefold: 1) Learning to observe the types of lighting available to the worker and to develop ongoing awareness of how this may or may not be working; 2) Identifying risk factors, such as glare and reflections, and the many options for correction of these factors; 3) Developing solutions that involve worker responsibility, administrative cooperation, and caring, and realistic cost effective improvements.

## General Eye Care Tips

Some of the practical recommendations regarding computer viewing are:

• General eye care— 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 are introducing lenses that are designed for the intermediate distance-viewing situation. The newest versions of these are called Occupational Progressive Addition Lenses (OPALs). Your eye care professional will be able to

guide you to the lens that is most effective in your particular viewing situation. There are also eyeglass frames which can be adjusted to provide an easier viewing area for computer work;

• Glare—there are many types of anti-glare screens for the computer monitor. The glass models generally tend to be the best and most expensive. The circular polarized models are absolutely the best type of screen to use on the CRT type of monitor. Privacy screens are also an excellent way to reduce glare and keep on-screen information secure. Mesh screens should be avoided. While a flat-panel display may not appear to have the same glare as a polished-glass CRT, there is still often enough glare to cause a loss of contrast of some of the display.

• Working conditions— our eyes must adapt to our viewing environment. A poorly laid out workspace can lead to visual fatigue and eyestrain. Be sure that all items in the work area are easily seen and without excess glare or poor lighting;
• Breaks— taking visual breaks is easy to do and very effective in reducing eyestrain. I usually recommend the "3-B" approach: Blink, Breathe, and Break!" For breaks, a good rule of thumb is the 20/20/20 rule: every 20 minutes, look 20 feet away for 20 seconds!

Eye health hazards have been touted for many years as a potential concern. As of today, there has been no proof 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. There is more of a concern for this radiation that is emanated from the sides and rear of the monitor. The newer LCD flat panel displays emit much less radiation than the older CRT models. Some eye care professionals feel that a UV protection is necessary for safety while working at a computer. However, the research has failed to confirm that UV radiation has any effect on the computer user. Most UV radiation drops off at about four inches from the front of the screen.

A study out of Japan in 2004[14] has seemed to indicate that there is a possibility that excessive computer use in myopic- or nearsighted individuals can lead to visual field defects, most often associated with glaucoma. While there were many people covered in the study, the population was mostly male and the numbers of glaucoma suspects relates closely to that number that often go undetected in the general population as well.

Contact lenses are also considered a concern for computer users. There are some concerns for contact lens users; however with very little attention those concerns can be easily addressed. Blinking is a concern for general computer users and even more so if contact lenses are to be worn. Studies have shown that people blink less often while performing visually intensive tasks, and even less yet while viewing a computer task. These results are probably a combination of concentration on the task and the position of the monitor. Most often monitors are higher in the visual field of view, therefore requiring the eyes to be open wider. This position is not our natural reading posture and will allow the eyes to dry out faster- with less blinking. This is even more critical for contact lens wearers. The use of lens re-wetting drops is recommended periodically during the day while using a computer. It your doctor feels that wearing contact lenses is right for you, then it should be fine for computer use.

The information presented here is very difficult to obtain for most employee populations. Eye doctors generally don't have the time, knowledge, or inclination to discuss these issues while examining a patient in an office setting. Additionally, performing eye examinations in an office setting bears very little relationship to the working environment of today's office worker. A unique and popular software program that actually performs a vision screening on the user's own computer screen is discussed with the attendees.

The effectiveness of the worker is dependent on adequate visual function, and visual function is dependent on appropriate lighting. The two areas are essentially inseparable in their interaction and critical in their effect on workplace performance. Knowledge in these fields is still growing, and many professionals are poorly informed about this information that is essential for workplace effectiveness and productivity.

## Providing Eyecare for Employees

The visual symptoms that computer workers experience are the most obvious expression of the shortcomings in the ergonomics and visual characteristics of the worker. Because of the high visual demands of the computer task and the visual shortcomings of many operators, vision problems and symptoms are very frequent among computer workers. Most studies indicate that visual symptoms occur in 75-90% of computer workers[1, 2, 4], by comparison a recent study released by NIOSH[4] showed that 22% of computer workers have musculoskeletal disorders. A large survey of optometrists[5] indicated that 10 million primary care eye examinations are annually given in this country primarily because of visual problems at computers— not a small public health issue! The most frequent visual problems reported in that survey are shown in Table 1.

**COMPUTER EYE-RELATED SYMPTOMS AMONG OPTOMETRIC PATIENTS**

Ranked by frequency

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Eyestrain
Headaches
Blurred Vision
Dry or Irritated Eyes
Neck and/or Backaches
Photophobia (Light sensitivity)
Double Vision
After-Images

**Table 1**

The causes for the inefficiencies and the visual symptoms are a combination of individual visual problems and poor office ergonomics. The symptoms occur whenever the visual demands of the task exceed the visual abilities of the individual. Many individuals 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 (nearly everyone beyond the age of 40) often have special problems at computers, since the optical prescription and spectacle design which they wear to meet their everyday visual needs does not work well at the computer. We have all observed the awkward position that people with bifocals adopt in order to read something above eye level- such as a book on a library 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 the common reading tasks for which most bifocals are designed.

There are numerous aspects of the computer and the work environment that make it a more demanding visual task than others. Therefore, more individuals are put beyond their threshold for experiencing symptoms. The visual symptoms can largely be resolved with proper management of the environment and by providing proper visual care for the employee[6]. Key aspects of the work environment that should be investigated are listed in Table 2.

| Aspects of computer viewing environment that contribute to eye problems |
|---|
| Lighting geometry and quantity |
| Screen reflections |
| Glare from windows or overhead lights |
| Higher viewing angle of monitor |
| Dry office environment |
| Poor screen design— contrast, polarity, etc. |
| Poor visual arrangement of workstation |

**Table 2**

Despite the greater frequency of the vision and eye problems, more public and professional attention is usually given to the musculoskeletal disorders such as wrist (e.g., Carpal Tunnel Syndrome), neck, shoulder and back problems. One reason for this is that the vision problems are primarily symptomatic in nature and usually are gone by the next day, whereas the musculoskeletal problems generally persist for a longer period of time. However, the main reason that musculoskeletal problems are given more attention in the corporate world is that they have greater worker's compensation costs associated with them.

## Why Should Employers Solve These Eye and Vision Problems?

The eye and vision problems can largely be resolved through management of the visual environment and by providing proper eye care for employees, as will be discussed later in this paper. But, why should an employer invest resources to resolve these problems?

The primary reason is that it is good business to do so. Business executives are familiar with investing money in processes or equipment that improves efficiency. Although we typically think of assembly lines and blue-collar workers when we talk about work production, we must recognize that people sitting before computer displays are a major part of work production today. Yesterday's blue-collar assembly line worker has become today's computer worker. It is important that businesses improve the efficiency of the office worker today, just as assembly line processes were streamlined in the past.

## Vision and Work Efficiency

For the sake of argument, let's put aside the humanitarian reasons for providing eye care, i.e., eliminating the vision and eye symptoms of discomfort in order to make employees feel better. Let's just consider whether it makes economic sense.

Since working at a computer is a visually intensive task, and the sense of vision is used to acquire the information need for job performance, it is reasonable to expect that improvements in the computer display or in the visual capabilities of the user will work towards improving performance efficiency. There are several studies that show that better displays or better vision result in improved efficiency.

Most of us are familiar with 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/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[7]. Likewise reading speed improvements of 4.1% to 19.9% (depending on display type) have been shown for adding a gray scale improvement of image quality[8]. This argues for providing better monitors—but it also argues for providing better vision of the worker. Certainly if subjects with good vision (all study subjects had at least 20/20 vision) can obtain reading speed improvement with a better quality image, a person with poor vision will attain better performance by improving their vision. Similarly, a better display technology will make the display characters easier to see, but this will only manifest in better performance if the employee's visual abilities are up to the task.

There have been other studies into the effects of different types of visual corrections upon occupational task performance. For example, instead of wearing bifocals (for the person over 40) it is possible to be fitted with various types of contact lenses that enable a person to see clearly at distance and at near. One example is to fit one eye with the distance prescription and the other with the near prescription; another example is to wear lenses that have both the distance- and near power in them. Despite the known visual compromises that occur with these types of visual corrections, these correction modalities can be successful for many patients. Even though these vision compromises are "acceptable," it has been shown that they result in 4-8% slower performance on occupational tasks. [9-11]. If these "acceptable" decreases in vision result in 4-8% productivity loss, we 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 by Daum, et. al.[3] found that 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.

## Does Eye Care Pay for Itself?

Uncorrected vision problems in the work force create worse vision than those situations above that showed 4-19% decreases in visual task performance. Although they were laboratory studies, and the tasks were performed for durations that are considerably shorter than a full work day, it is likely that similar inefficiencies occur daily for workers with uncorrected vision disorders. We 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. Eye care can be provided for considerably less than this—and likely results in much more than a 1% increase in productivity.

## Eye Care Programs for Computer Workers

Many companies already offer vision care to their employees as a benefit of employment. Even if a company offers vision care to all employees, it may not necessarily be meeting the needs of their computer employees. As discussed below, proper care of the computer employee requires more than a simple refraction, dilated examination of the inside of the eye, and provision of glasses. Also, many computer employees require a different pair of glasses for their computer work than that which is

required for their other daily visual needs. The employee is reluctant to use their employee benefits for a pair of computer glasses; they feel that the benefits should be used to provide for their general glasses.

The backbone of any care program is the capability of the doctors who are providers for that program. For proper computer eye care, it is important that the providers understand the eye and vision problems of computer users, be able to diagnose the underlying conditions, and be able to implement proper care for those conditions. The most common diagnosable vision conditions that can result in compromised visual function and symptoms of discomfort are listed in Table 3. A successful managed eye care program for computer workers will have a panel of providers who are skilled at diagnosing and treating these conditions.

**Vision and Eye Conditions**
**That Cause Symptoms at Computers**

Accommodative (Eye Focusing) Disorders
Binocular Vision (Eye Coordination) Disorders
Hyperopia (Far-sightedness)
Astigmatism
Dry Eyes
Contact Lens wear
Improper multifocal spectacle design

**Table 3**

The American Optometric Association[12] has issued a list of recommended components of an eye examination for computer users. In addition to those tests which are commonly part of all eye examinations, they recommend that examination of a computer patient 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 (eye focusing) abilities, assessment of ocular coordination, refractive determination for the required viewing distances at the computer work station, design of occupational lenses if required, and counseling regarding the visual environment at the workstation. The panel of doctors in a computer eye care program should provide these services in addition to full-scope eye examinations.

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

## Who Pays for the Glasses?

In the interest of work efficiency, everyone who needs a visual correction should wear one. The best way to insure this is for the employer to provide the eyewear for all computer employees (or others with visually demanding jobs). However, many employers feel that employees should be responsible

for providing their own general eye wear, and that it should be the employer's responsibility only if the glasses are different from the general eye wear of if they would not otherwise be required. This can be accomplished, with cost savings, by establishing a list of diagnostic/treatment conditions (such as in Table 4) for which glasses will be provided. In order for glasses to be provided under the program, panel doctors 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.

| Diagnostic Conditions That Can Warrant Special Glasses for Computer Use |
| --- |
| Presbyopia |
| Accommodative disorders |
| Hyperopia |
| Binocular vision disorders |

**Table 4**

## Other Cost Controls

Establishing limitation on the frames and spectacle lenses that are provided can also control costs. Single vision and bifocal lenses are a necessary program option. General progressive addition lenses should not be provided, nor even allowed as employee options, since they do not function well for computer workers. Trifocal and specially designed occupational progressive addition lenses can be very useful for many computer workers. While it is desirable to provide these lens options, most users' visual needs can be properly managed with single vision lenses, thereby resulting in cost savings. Tints and coatings provide little additional help in solving the problems that computer users have and are not necessary for the program. If only the basic lens options are to be covered, then employees should be able to pay the difference if they want more expensive options.

Another important cost-control element is to provide good ergonomic assessment and correction where indicated. It is clear that many of the eye and vision problems that computer users experience can be resolved buy evaluating and improving the visual work environment. Visual ergonomic evaluation and correction will help reduce the utilization of eye care services.

Vision screening can help to reduce over utilization by identifying those employees who are most likely to benefit from an eye examination. Professionally managed vision screenings are costly and it is questionable whether the savings in utilization overcome the costs of performing the screening. Self-analysis tools are available which more cost effectively enables employees to screen themselves for vision problems and also to educate them about proper use of their eyes and their computer environment.

## Should You Provide Eye Care for your Computer Workers?

Providing good vision for computer employees makes economic sense. It results in increased work efficiency and happier, more comfortable employees. It is a win-win proposition for employers to provide eye care for computer workers.

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