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Vision & Work

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INTRODUCTION

To perform most occupational tasks efficiently and comfortably, employees need some degree of visual skill. The most common measurement of visual skill is visual acuity. In addition, many other aspects of vision are at least equally important to the performance of occupational tasks. These other aspects of vision include accommodation (eye-focusing ability), depth perception, oculomotor balance (ability to keep the two eyes aligned), color vision, and visual fields (peripheral vision).

The employee's visual skills should match the visual requirements of the tasks he or she needs to perform. Not only does this promote good job performance and productivity, it also prevents employees from experiencing symptoms of discomfort associated with the use of their eyes. The issue of worker discomfort has become more evident in recent years with the numerous visual complaints of workers at video display terminals (VDTs).

VISION AND JOB PERFORMANCE

Adequate visual skills are so important to some occupations that job candidates must have minimal levels of visual skill before the hiring authority will consider them for the job. One such occupation is that of the police officer (Sheedy, 1980, 1986; Sheedy et al, 1983; Good & Augsburger, 1987). Police officers need a minimum level of visual acuity for proper observational skills and intense driving requirements. They need a minimum level of uncorrected visual acuity, since they must continue to perform, even after someone has knocked off their glasses. They also need good depth perception so they can maneuver in complex environments, minimal levels of color vision for identifying suspects and evidence, and proper visual fields for intense driving and general awareness and observation. Other occupations with strictly defined visual requirements include fire fighters (Sheedy, 1984), antiterrorist units (Sheedy, 1990b), air traffic controllers, pilots (Dehaan, 1982), and train and boat operators.

For each of these and similar occupations, the minimum visual standards should be those that the hiring authority can show are required for performing that job. In numerous court cases involving vision standards, the plaintiffs who are denied employment claim a visual disability, thereby bringing suit under the "handicap" laws. This places the burden of proof on the employer to show that the visual requirements are needed to perform the job safely and efficiently. The 1990 Americans with Disabilities Act places further requirements on the employer to accommodate, where possible, the limitations of a disabled individual. Formal vision standards are often necessary for safety and/or other job requirements, but they must be carefully established with full knowledge of the legal environment.

Although many kinds of jobs have stringent vision standards, many others depend highly on minimal visual skills for their optimal performance. For example, many employees are involved in assembly line and other manufacturing jobs that require good depth perception and binocular vision. Forklift operators and

Table 13–A. Common Visual Symptoms.

- Headaches
- Eyestrain (sore eyes or eye fatigue)
- Eye irritation (burning, dryness, redness)
- Glare (light) sensitivity
- Near blurred vision
- Slowness in focusing from distance to near and back
- Intermittent double vision
- Transient distant blur
- Neck, shoulder, and back pain

Table 13–B. Visual Conditions that Can Result in Visual Symptoms with Visually Demanding Work.

- Astigmatism
- Hyperopia
- Presbyopia
- Esophoria
- Exophoria
- Accommodative dysfunction
- Tear deficiency
- Contact lens wear

crane operators also need good depth perception. Many occupations require a basic level of color vision ability (such as basic color identification), whereas other employees, such as color inspectors, graphic artists, interior designers, need much higher levels of color discrimination ability.

In many cases, the organization has not established stringent standards for jobs with minimal vision requirements. Usually the standards are not developed because the public safety is not involved. However, workers whose visual skills do not meet job requirements will perform their jobs poorly. Therefore, it is in the employer's best interest to identify employees without the necessary visual skills, and to arrange proper visual examination and correction for them.

VISUALLY RELATED SYMPTOMS

Visually related symptoms are one of the most common problems of workers with visually demanding jobs—usually jobs that involve a lot of work at close viewing distances. The most common visual symptoms are shown in Table 13–A.

Visually related symptoms have come to the forefront in recent years because of the large-scale introduction of VDTs into the workplace. In fact, visually related symptoms are the most frequently reported ones among VDT workers (Dain et al, 1988; Dainoff et al, 1981; Daum et al, 1988).

A recent survey of optometrists showed that 14.25% of their patients have scheduled the eye examination primarily because of visual problems they are experiencing at a VDT (Sheedy, 1992). Since over 70 million eye examinations are given annually in the United States, this indicates that 10 million are primarily because of visual problems at the VDT. These same symptoms have been reported for many years by workers who use their vision at close distances.

Whether a person experiences symptoms depends upon the visual status of that person and upon the visual demands of the task. Many people have visual disorders such as oculomotor deficiencies, accommodation deficiencies, or small, uncorrected refractive errors that will not cause symptoms if the visual task is an easy one. A history of such conditions is in Table 13–B.

However, the same visual disorder will cause symptoms when the employee has to perform a task that is highly visually demanding. Examples of such tasks include microscopy, visual inspection work, small assembly work, or any job category involving extended near work such as accounting, drafting, legal, etc. Therefore, a highly visually demanding task will cause symptoms among a greater percentage of workers than will a less visually demanding task.

It is advantageous to employer and employee alike to solve these symptoms of discomfort. It is usually unnecessary to experience these symptoms, and they certainly diminish efficiency and productivity. Ways to minimize these symptoms include improving the visual characteristics of the workers, providing good vision care, and reducing the visual demands of the task by improving the visual environment and design.

VISUAL PROBLEMS AND CORRECTION

Visual problems can significantly affect work performance. The occupational health and safety specialist should be familiar with visual acuity and refractive error and how to best correct such errors.

Visual Acuity and Refractive Error

One of the many measures of visual skill is how accurately the eye naturally focuses when looking at distance. Any inaccuracy in this focus is a *refractive error.* Another basic measure is the ability to resolve detail, or *visual acuity*. If an eye is not properly focused, the visual acuity will be reduced. Visual acuity and refractive error are two of the most commonly measured aspects of vision and are most frequently used in establishing occupational vision requirements.

Measurement of visual acuity

Visual acuity can be measured in many different ways. For example, it could be measured in terms of the minimally detectable separation of two lines, two bright points, two dark points, or the lines in a grating. Unquestionably, however, the most common way of measuring visual acuity is to determine the minimal angular size of standardized letters that the person can identify. This measure is referred to as *Snellen visual acuity.* Normal visual acuity is considered to be the identification of letters that subtend 5 minutes of arc at the eye. A measurement of 20/20 indicates that vision was tested with a chart at 20 feet (the numerator) and the patient read a letter that subtended 5 minutes of arc at 20 feet (the denominator). Thus, the normal, expected visual acuity of an individual without pathology and without refractive error is 20/20 (English units) or 6/6 (metric units). A measurement of 20/60 indicates that vision was tested at 20 feet and the patient read a letter that would subtend 5 minutes of arc at 60 feet. In other words, the person with 20/60 vision could read at 20 feet what a person with 20/20 vision could at 60 feet. A correlate of this is that at 20 feet, letters need to be three times as large to be detected by a person with 20/60 vision as for a person with 20/20 vision.

In most states, a person whose best corrected visual acuity is poorer than 20/200 can be considered legally blind for tax and other benefits. In nearly all states, a visual acuity of 20/40 is required for an unrestricted driver's license. Most people who have an uncorrected visual acuity of 20/40 or worse will choose to wear glasses or contact lenses habitually in order to see better. But some people are particularly averse to wearing glasses or have minimal visual requirements, and may choose to tolerate blur of 20/50 to 20/80 before wearing corrective lenses. However, there are probably more people who choose to habitually wear spectacle correction for uncorrected acuities of 20/25 to 20/30. Some people with 20/20 vision even choose to wear glasses habitually in order to see 20/15. In highly visually demanding jobs, employees with acuities of 20/25 to 20/30 should obtain and wear appropriate correction.

Types of refractive error

For some people, the optics of the eye do not properly focus an image of the distant world onto the retina. Such conditions are known as *myopia, hyperopia,* and *astigmatism,* as shown in Figure 13–1. With myopia, commonly referred to as "nearsightedness," the image is formed in front of the retina, so light rays are out of focus when they arrive at the retina. Myopia can be thought of as resulting from the optics of the eye being too strong or the distance from the optics to the retina being too great. Hyperopia, commonly called "farsightedness," results in the image of the distant world being focused behind the retina. The rays of light intercept the retina before they come to focus, resulting in a retinal image that is out of focus. Thus, hyperopia can be thought of as being the result of optics that are too weak or an eye in which the distance from the optics to the retina is too short.

Astigmatism results from the optics of the eye not being the same power for different meridians (orientation of the light entering the eye). A common example of this is that the refractive power of the eye would be different for vertical lines and horizontal lines. This would be because the refractive power of the eye in the horizontal meridian would be different from that of the vertical meridian. Astigmatism can exist independently or in conjunction with hyperopia or myopia.

Detecting problems

By far the most common reason for decreased visual acuity is an uncorrected refractive error. Other causes include irregularities of the cornea, lenticular opacities (opacities in the crystalline lens of the eye) such as cataract, central retinal disorders, amblyopia (reduced vision due to lack of proper neural development), and tumor. The relationship between visual acuity and magnitude of refractive error is quite, but not perfectly, predictable (Peters, 1961). Since visual acuity is the more direct measure of visual ability, is more easily measured in a nonprofessional setting, and will also identify some pathological conditions, it is more commonly used for occupational vision standards than is refractive error.

One way to measure visual acuity in the workplace is with visual acuity charts, which are either hung on a wall or projected onto a screen. Visual acuity can also be measured with industrial vision testers. The test must take care to measure the acuity at the proper testing distance, with proper chart design, proper technique, and proper illumination. Although 20/20 visual acuity is considered normal, many persons with proper refractive correction obtain a visual acuity of 20/15.

Refractive error is more difficult to measure in industrial screenings. One method that lends itself well to screening purposes is retinoscopy, which must be performed by a trained optometrist or ophthalmologist. Automatic refractors can be used to measure refractive error with a minimum of personnel training, but they are often too expensive for a business to purchase.

Correcting Refractive Error

In nearly all cases, refractive errors of the eye can be optically corrected to obtain a focused image on the retina. In the absence of other problems, the corrected visual acuity will be 20/20 or better. The most common means of correcting refractive errors is with spectacle lenses or contact lenses. Myopia is corrected with a minus-power lens to reduce the total optical power, whereas hyperopia is corrected with a plus-power lens to effectively increase the power of the eye. Astigmatism is corrected by providing appropriate but different refractive powers in different meridians (orientations of the light). In addition, a recently introduced means of correcting myopia is with a surgical procedure called radial keratotomy.

Corrective lenses

Spectacle lenses can usually provide a more precise correction of astigmatism than contact lenses. Because the correction of astigmatism requires a different power in different meridians, the correcting lens must be in a known rotational position. It is difficult to control the rotational position of a contact lens, whereas a spectacle lens does not rotate. On the plus side for contact lenses, they avoid restricting the visual field as does the frame of a spectacle lens. Also, contact lenses move as the eyes move, so they do not cause peripheral distortions as the eye rotates.

Contact lenses have some other shortcomings. In some people, the contact lens does not center well on the cornea, thus resulting in poor correction. This can be especially difficult for someone with a large pupil. Also, since the contact lens fits directly onto the cornea, the wearer can suffer discomfort, pain, and/or tissue damage. Contact lenses are not recommended for employees who work in environments with a lot of dust, fumes, or other airborne contaminants. Contact lenses often will cause the worker discomfort if the environment is particularly dry, as on planes and also in many offices.

Without getting into a discussion on the relative merits of contact lenses and spectacles, it is safe to say that many people can obtain 20/20 corrected visual acuity with either spec-

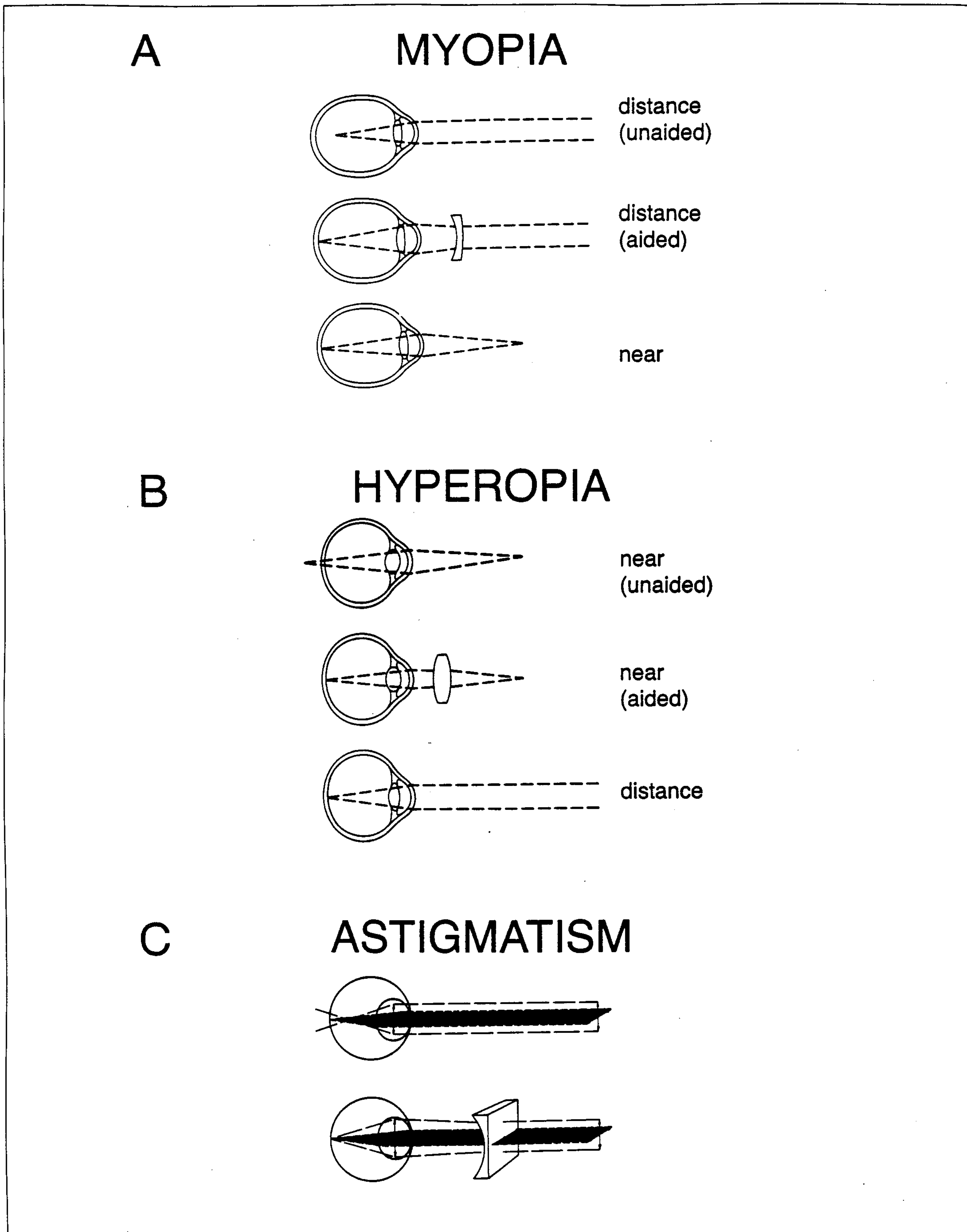

Figure 13–1. Illustrations of myopia (A), hyperopia (B), and astigmatism (C).

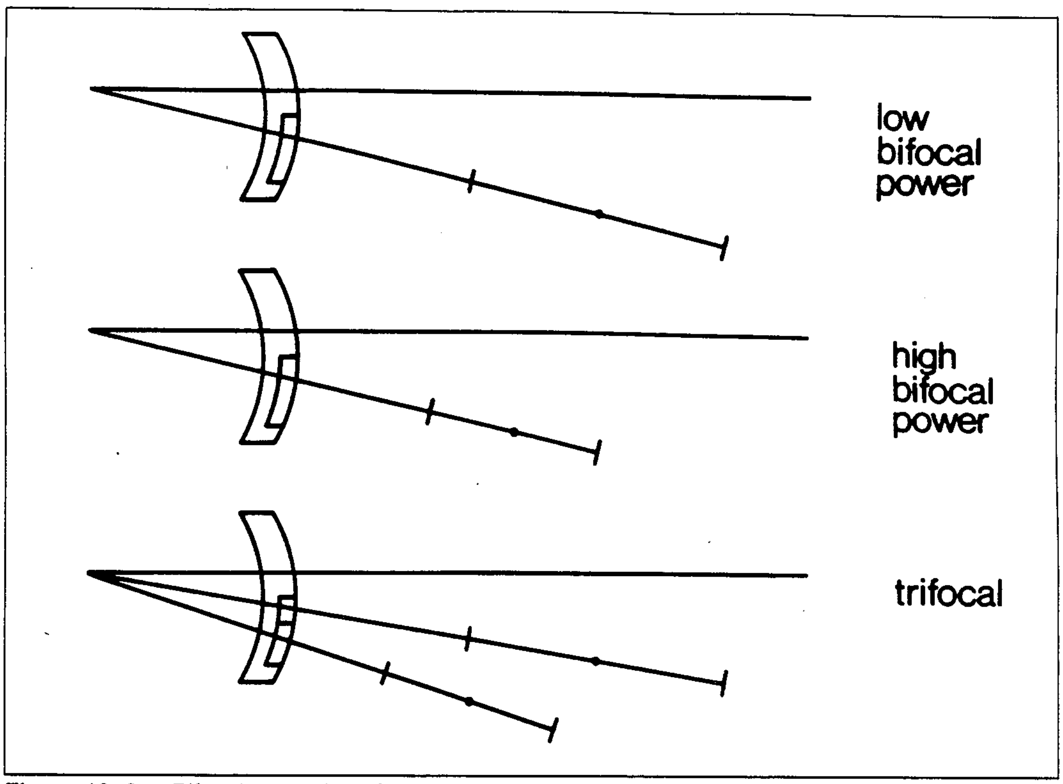

Figure 13–2. Bifocal correction of presbyopia.

tacle lenses or contact lenses. Most people can be corrected to 20/20 vision with spectacles, and some people may have better vision with contact lenses. Individual characteristics determine which type of correction will be best for a specific person.

Surgery

To correct myopia with radial keratotomy, the surgeon makes a series of incisions radiating out like the spokes of a wheel away from the central optical zone of the cornea. The incisions do not infringe upon the central section of the cornea, since this portion is most critical in forming the image on the retina. The peripheral incisions flatten the curvature of the center of the cornea. The flattening of the center of the cornea reduces the optical power of the eye, thereby correcting the myopia.

The vision obtained with radial keratotomy is usually not as good or nearly as predictable as with spectacles or contact lenses. Among persons who have undergone radial keratotomy, a large number (at least 58%) need to wear spectacles or contact lenses to obtain 20/20 vision after surgery (Waring et al, 1987). Also, the refractive error of the eye can continue to change for years after the surgery, and some patients experience significant variation in the refractive error during the day. The incisions on the cornea can scatter light, resulting in an increased sensitivity to glare, such as occurs with oncoming headlights (Atkin et al, 1986).

Refraction corrective techniques using lasers and other techniques are in the development stages. These offer some promise of accurate refractive correction without some of the negative visual effects of radial keratotomy.

Presbyopia

A predictable change that occurs with age is the onset of *presbyopia.* This gradual loss of accommodation (ability of the eye to change its focus for near-viewing distances) creates difficulties in the near vision of most people beginning at about 40 years of age. The result is the need for a near prescription in the form of reading glasses, bifocal glasses, or special contact lens correction.

In a vision screening situation, the measurement of near visual acuity (usually at a distance of 16 in. (40 cm) from the eyes) is the best way to identify employees who need a correction for near viewing distances. The need for a near-point correction depends upon the visual demands of the task and the person's remaining accommodative abilities. For example, a jeweler who needs to work at distances very close to the eye will require a near-point correction at an earlier age than someone working on an assembly line with objects at arm's length.

Reading glasses (single-vision lenses) provide the necessary correction for near-working distances, but they result in blur when the person looks at far distances. Single-vision lenses work well for employees who perform nearly all of their work at near working distances and who require a wide visual field. Single-vision lenses often work well to correct presbyopia in VDT workers who require a wide field of vision, whose VDT screen is situated above eye level, and who don't need to look in the distance very frequently while working.

Bifocals

The most common way to correct presbyopia is with bifocals (Figure 13–2). The distant prescription is contained in the top portion of the lens, and the bifocal segment contains the near prescription. The bifocal segment is usually placed in the lens for a downward viewing angle of approximately 25°. The selection of bifocal type and size depends upon the needs of the individual employee. Wider bifocal segments are needed for more extensive near tasks, and a higher placement of the bifocal segment is required for near-point tasks that are higher in the field of view. The drawback is that wider segments and more highly located segments make distant-viewing general orientation more difficult. The specific power in the bifocal depends on the accommodative abilities of the employee and the near distance at which the employee needs to see clearly.

The optometrist or ophthalmologist who examines the employee's eyes must be aware of the viewing distances and locations of the near tasks the employee is required to perform. Many employees will need trifocals or even quadrifocals. Some jobs require near vision in the superior field of view. Such jobs include drapery hangers, mechanics, librarians, and druggists looking at items on shelves. Job performance and comfort for these employees benefit when bifocal segments are placed in the top portion of their lenses.

A common example of improper spectacle design for a particular task is that of the VDT worker. The most commonly prescribed bifocal is for a 40-cm near-viewing distance and a downward viewing angle of approximately 25°–30°. However, the typical VDT screen is located 50–55 cm from the eye and only 10°–15° below the straight-ahead position of the eyes. Therefore, the VDT worker who uses a typical bifocal prescription at a VDT workstation will need to assume an awkward posture, resulting in blurred vision and also neck and back strain. Such employees usually need spectacles specifically designed for the VDT workstation.

Binocular Vision

Visual skills include the coordination of the two eyes in binocular vision. If the eyes are not aligned, the person is said to have *strabismus*. The condition is called *exotropia* if the eyes are misaligned outward, and *esotropia* if the eyes are misaligned inward. Patients with either form of strabismus lack *stereopsis*, which is a critical form of depth perception. In the absence of stereopsis, employees perform occupational tasks less efficiently (Sheedy et al, 1986). Some occupations exclude individuals with strabismus (Sheedy, 1980, 1984). Some industrial jobs, such as assembly work, work through binocular microscopes, dentistry, and jewelry, require stereopsis for good job performance. Individuals with binocular vision should be selected for such jobs. Tests of stereopsis are available separately or in industrial vision screeners. Negative results should be confirmed by professional optometric or ophthalmologic examination.

Many people with binocular vision find comfortably maintaining the alignment of the eyes difficult. Even though they normally keep their eyes aligned, the natural position of the eyes is either inward *(esophoria)* or outward *(exophoria)* and they must continually exert effort to keep the eyes aligned (Figure 13–3). These conditions can result in fatigue, eyestrain, headaches, eye irritation, and intermittent double vision (Sheedy & Saladin, 1983). These symptoms result when a person with a clinically significant esophoria or exophoria performs visually demanding tasks for extended periods. The occurrence of symptoms will depend upon the relative severity of the condition and the magnitude of the visual demands of the task. These conditions are especially likely to manifest as symptoms with extended critical near work; VDT work is one example.

Many vision screeners give estimates of the *phoria measurement* (the amount of esophoria or exophoria). A professional must evaluate the estimate to determine whether the binocular muscle balance is adequate for the task.

Accommodative Disorders

Accommodation is the ability of the eye to change its focus for different working distances. This is accomplished by contraction of the ciliary muscle, which surrounds the crystalline lens inside the eye. Contraction of this sphincter-like muscle releases the normal outward pulling tension on the lens and allows it to "fatten," thereby adding refractive power (Figure 13–4).

Workers younger than the age of 40 years (prepresbyopia) should have an adequate amount of accommodation to properly perform their near work without a near optical prescription. However, many of these younger workers have accommodative dysfunctions whereby the eyes cannot accommodate as quickly (facility) or as fully (amplitude) as they should. These disorders result in an inability to focus comfortably at near-working distances for extended periods of time. When performing demanding near-visual tasks, this causes eyestrain, fatigue, headaches, and intermittent blurred vision. This can also result in distance blur after termination of near work. These accommodative disorders occurred in 33% of prepresbyopic VDT users with visual symptoms (Sheedy & Parsons, 1990). The facility and amplitude of accommodation should be measured when screening workers with near-visual tasks.

Color-Vision Deficiency

Deficiencies of color vision occur in 8% of the male population and 0.5% of the female population. Approximately 25% of color-deficient persons have *dichromacy*, meaning the person appears to be completely missing one of the three cone receptor systems. The ability to discriminate colors is severely limited compared to normal. People with this condition are unable to discriminate saturated red, orange, yellow, and green from one another. They confuse blue-greens with grays and desaturated violets. They have difficulty discriminating many of the basic colors. Approximately 75% of color-deficient persons have anomalous trichromacy, a condition in which one of the receptor systems appears to be weak. These persons are able to identify and discriminate all of the basic colors but have difficulty discriminating smaller changes in color.

Some jobs, such as interior designers, photographers, artists, and colorists, require a high level of color discrimination, and any form of color deficiency would be a detriment, even anomalous trichromacy. Many other occupations, such as electricians and police officers, require only that the person be able

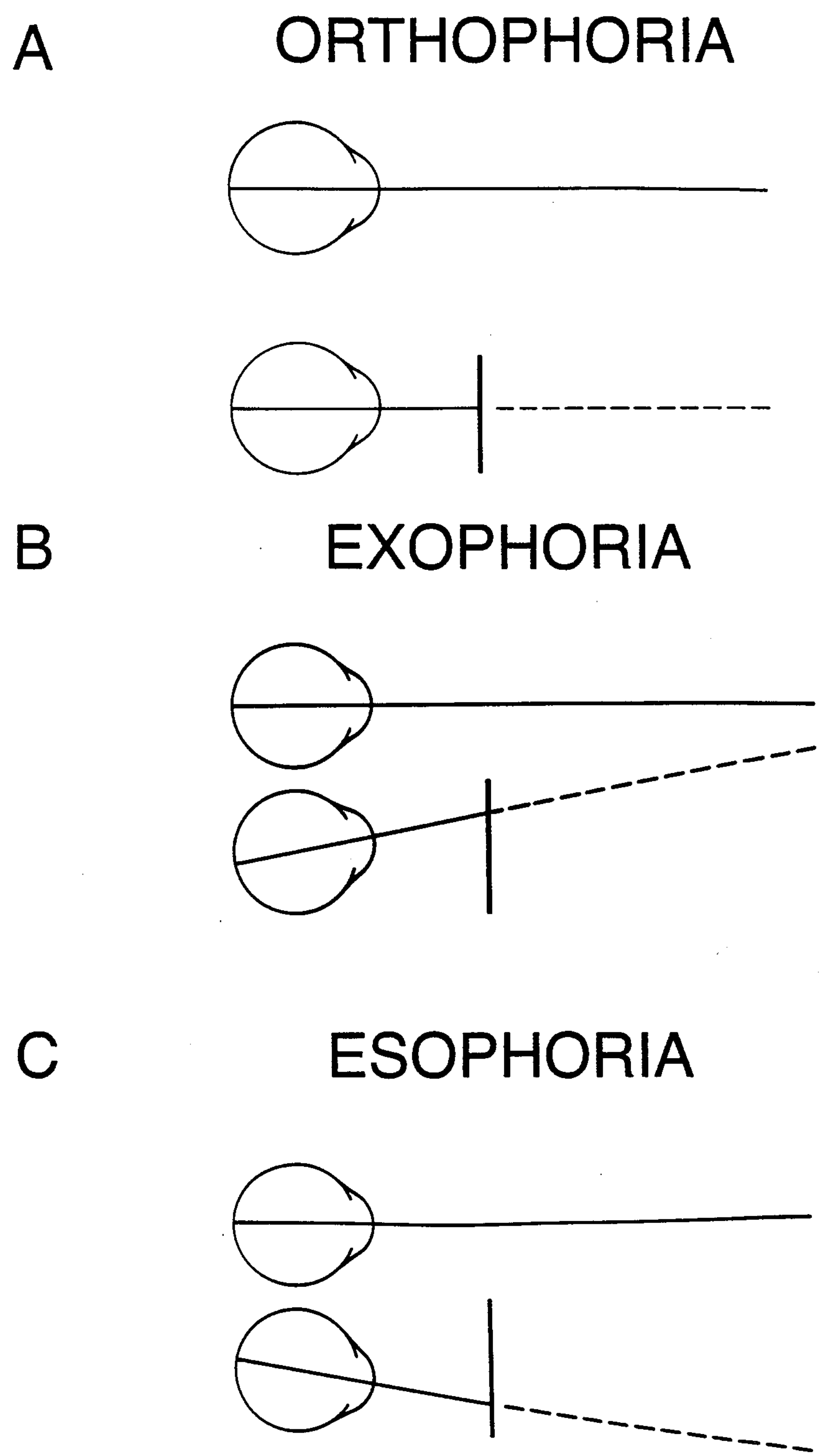

Figure 13–3. For individuals with binocular vision, both eyes are aligned on the target (A). Many of these individuals have an exophoria (B) or an esophoria (C) whereby the eye deviates from alignment when it is occluded—demonstrating the "resting" relationship of the eyes.

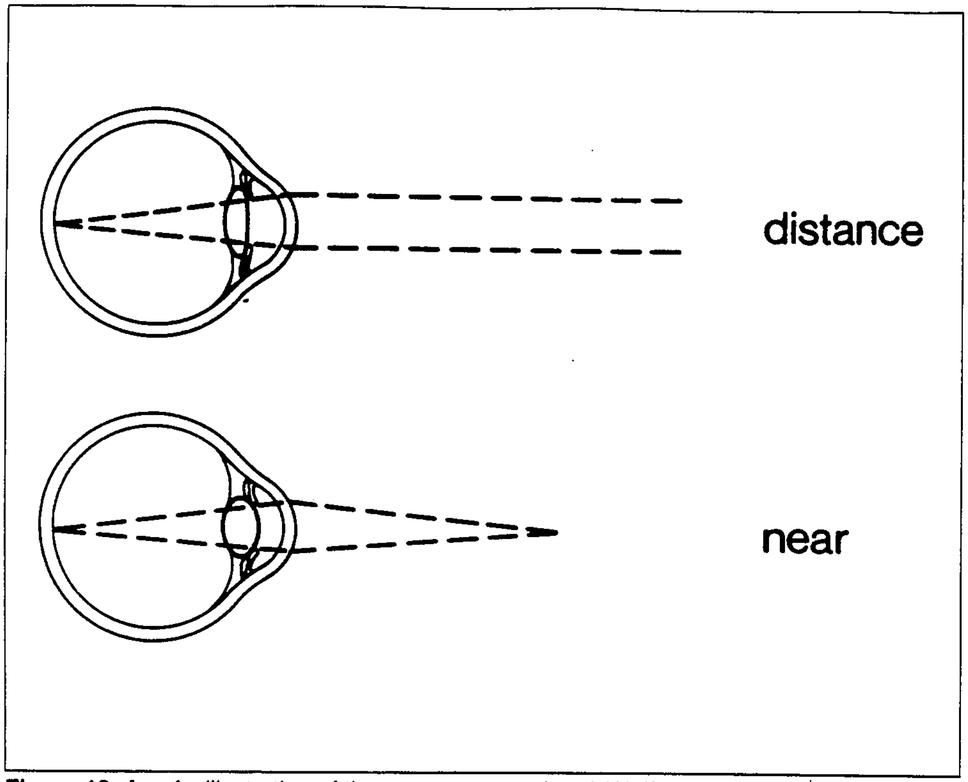

Figure 13–4. An illustration of the eye accommodated (A) (focused) for distant viewing, and accommodated for near viewing (B).

to discriminate basic colors. For these types of jobs, only dichromacy would result in deficient job performance.

For most purposes, the *pseudoisochromatic plates* or the D-15 test are easy to administer and adequately test color vision. The pseudoisochromatic plates, which involve identifying numbers or symbols on a color printed page, will identify most forms of color deficiency, with the severity of the defect being indicated by the number of plates missed. The D-15 test, which involves arranging color chips in an ordered color progression, will identify dichromats and the more severe forms of anomalous trichromacy. Those with normal color vision and milder forms of anomalous trichromacy will pass the test. The 100-hue test is a better test for identifying individual ability at discriminating small changes in color. Even among normal persons, the ability to discriminate colors will vary. This test is a good one for identifying persons to perform jobs that require a high level of color discrimination.

Lantern tests are good color-vision occupational tests. They measure the ability to identity the color of small spots of light. This type of task is required for pilots, boat captains, and railroad engineers.

THE VISUAL ENVIRONMENT

Visually related symptoms occur when the demands of a visual task exceed the visual abilities of a particular individual. To the extent that a particular visual task—for example, work at a VDT—is more visually demanding than other tasks, a greater percentage of workers will experience such symptoms.

Intensive near work, such as extensive viewing of paper work, mail sorting, filing, assembly work, and work at a VDT is particularly demanding upon the visual system (Yekta et al, 1989; Sheedy & Parsons, 1990). This is because near work requires that the two eyes converge, or cross inward, from their normal parallel position used for looking into the distance, and also that the eye accommodate or focus for the near distance. To lessen symptoms and enhance worker performance, the employer can improve aspects of the visual environment in order to lessen the visual demands of the task. In fact, improvement of the visual environment can be as important as improving the vision of the worker. Currently the best example of visual discomfort is that experienced at VDTs, so I will discuss improvements in the visual environment primarily in the context of this particular task (see also Sheedy, 1990a).

Lighting

One of the most essential elements for visual comfort is good lighting. With poor lighting, most employees will be uncomfortable, irrespective of their individual skills and characteristics. Most basically, there must be enough light on the task. The Illuminating Engineering Society (1981) provides information about recommended illumination levels for various tasks. Generally, illumination levels of 10–20 footcandles (fc) are adequate for hallways, 30 fc for reception areas, 70–80 fc for most office work, 100–150 fc for more visually intensive tasks, and even as high as 500–1,000 fc for very fine tasks. The recommended illumination levels for VDT offices (18–46 fc) are lower than for most other office tasks (Human Factors Society, 1987). The primary reason for low illumination levels is that most VDTs display light characters on a dark background. Lower room illumination results in fewer reflections from the dark screen and less of a brightness difference between the screen and the surrounding room.

Although the amount of the illumination is important, it is usually more important that the lighting geometry is proper. Most workplaces today have adequate illumination levels, but many have a lighting geometry that results in discomfort glare. Whenever some areas in the field of view are considerably brighter than others, discomfort glare results (Guth, 1981; Luckiesh & Guth, 1949; Luckiesh, 1944). Bright objects are more likely to be sources of discomfort glare if they are larger, brighter, and closer to central fixation. A common source of discomfort glare is fluorescent lights. To demonstrate the sensation, look straight ahead in a room with bright overhead fluorescent lights, then shield your eyes with a visor or your hand. Shielding your eyes will improve your comfort noticeably. The effect can be cumulative over a workday. Windows and auxiliary light sources are other common sources of discomfort glare. Several options are available for eliminating sources of discomfort glare and are listed in Table 13–C.

Table 13–C. Methods of Mitigating Discomfort Glare.

- Use drapes or blinds on windows.
- Use indirect lighting.
- Put parabolic louvers on fluorescent fixtures.
- Shield auxiliary lights.
- Move or rotate the employee.
- Have the employee wear a visor.

Discomfort glare can be a particular problem for VDT employees, especially those using dark background screens. This is because a VDT worker is viewing more horizontally than other officer workers, so the windows and overhead lights are in the field of view more than for someone looking down at a desk. White-background VDTs have the advantage that the brightness of the task better matches that of the surrounding room. The brightness of the VDT screen should be adjusted to match the surrounding room brightnesses. Also, reference documents usually should not have auxiliary lights, since this creates too large a brightness difference between screen and document.

Reflections

Highly reflective surfaces can result in discomfort glare and decreased visibility of the work object. Horizontal surfaces on which work is performed (such as tables and desks) should have matte finishes with medium reflectance. In some cases, such as in metal assembly tasks, employees must use very reflective materials. In these situations, it is best to use diffuse, indirect lighting. If auxiliary lighting is necessary, orient it so that most of the reflections are headed away from the employee; the light should be aimed primarily in the direction in which the worker is looking.

Reflections are a problem in VDT screens. This problem is most acute with dark-background VDTs in which reflections cause the background to become significantly lighter, thereby reducing the contrast of the work on the VDT screen. To eliminate this problem, install antireflection screens on the VDT. Glass screens usually perform better than mesh screens.

Other Environmental Factors

Visual tasks—especially paperwork and VDT work—should be designed to have good clarity and contrast. Resolution on a VDT screen is crucial. Fonts should be easily visible. Research has shown that workers perform better with black characters on a white background instead of white characters on a black background (Sheedy et al, 1990). On paper or video display, it is easiest to read lowercase letters in which there are *ascenders* and *descenders* (ascender is the part of a lowercase letter that rises above the main body of the letter; descender is the part of a lowercase letter that descends below the main body of the letter).

Also important to clarity, the size of the work must be large enough that the employee can perform it comfortably and efficiently. Generally, the size of the detail in work should be at least three times the minimum size that is required for the worker to be able to resolve that detail. For example, a person with 20/20 vision cannot perform efficiently and comfortably if reading print with 20/20 size letters. Also consider the fact that certainly a person cannot perform at the threshold of his or her visual discrimination ability. Instead, the letters should be three times the size of the 20/20 letters—or the equivalent of 20/60 sized letters. Since the 20/20 letters have an angular size of 5 minutes of arc at the viewing distance, the task letters should have an angular size of 15 minutes of arc in order to optimize performance. As another example, if a reading task is to be designed to meet a population of users who are screened to have 20/25 vision (7.5 minutes of arc), then the letters should be 22.5 minutes of arc (3 x 7.5). If the designed viewing distance is 20 in. (50 cm), then the letters should be 3.3 mm in height (500 tan 22.5 minutes of arc).

Even when the characters are clear, the flickering in fluorescent lights and VDTs can be bothersome. There is some evidence that flicker can cause discomfort, even though we can't perceive it. To resolve this problem, use high-frequency ballasts in fluorescent lighting systems and select VDTs with higher refresh rates (Sheedy, 1990a). Spectacle lenses with light pink tints also seem to provide comfort in fluorescent-lit environments.

The visual environment should be designed to require a minimum amount of eye movement and eye focusing. Objects that need to be viewed repeatedly should be located close to one another visually. It is also best for such objects to be located at approximately the same distance from the eyes in order to minimize eye focus changes. An example of this is locating reference documents at a VDT workstation so that they are next to the VDT and at the same distance from the eyes as the VDT.

The preferred position of the eyes is in a somewhat downward gaze. Most of the time, we are looking downward, not only when looking at near tasks, but also when walking in our environment. If visual tasks are located so that they require straight-ahead or upward viewing, the individual often adapts by tilting the head back in order to maintain a downward viewing angle. This problem is common among VDT workers, resulting in neck and back aches. The VDT screen should be located below the straight-ahead position of gaze, preferably 10°–15° (Human Factors Society, 1987).

SUMMARY

Good vision is important for efficiency of job performance and for the visual comfort of the employees. Visual comfort is also related to work performance. Good vision requires proper design of the visual tasks and visual environment in order to reduce the visual demands. It is also important to provide proper visual examination and correction for the work force so that employees have the necessary visual skills and abilities to comfortably and efficiently perform their tasks.

REFERENCES

Atkin A, Asbell P, Justin N, et al. Radial keratotomy and glare effects on contrast sensitivity. *Doc Ophth* 62:129–148, 1986.

Bailey IL, Sheedy JE. Vision screening and driver licensure. In, *Transportation in an Aging Society: Improving Mobility and Safety for Older Persons.* TRB Special Report 218. Washington DC: Transportation Research Board, 1988.

Dain SJ, McCarthy AK, Chan-Ling T. Symptoms in VDU operators. *Am J Optom Physiol Optics* 65:162–167, 1988.

Dainoff MJ, Happ A, Crane P. Visual fatigue and occupational stress in VDT operators. *Human Factors* 23:421–438, 1981.

Daum KM, Good G, Tijerina L. Symptoms in video display terminal operators and the presence of small refractive errors. *J Am Optometric Assoc* 59:691–697, 1988.

Dehaan W. *The Optometrist's and Ophthalmologist's Guide to Pilots' Vision.* Boulder, CO: American Trend, 1982.

Good GW, Augsburger AR. Uncorrected visual acuity standards for police officer applicants. *J Police Sci Admin* 15:18–23, 1987.

Guth SK. The science of seeing—A search for criteria. *Am J Optom Physiol Optics* 58(10):870–885, 1981.

Human Factors Society. *American National Standard for Human Factors Engineering of Visual Display Terminal Workstations.* Santa Monica, CA: Human Factors Society, 1987.

Illuminating Engineering Society (IES). *IES Lighting Handbook.* New York: IES, 1981.

Luckiesh M. *Light, Vision and Seeing.* New York: Van Nostrand-Reinhold, 1944.

Luckiesh M, Guth SK. Brightnesses in visual field at borderline between comfort and discomfort. *Illum Eng* 44:650–670, 1949.

Peters HB. The relationship between refractive error and visual acuity at three age levels. *Am J Optom and Arch Amer Acad Optom* 38:194, 1961.

Sheedy JE. Video display terminals—Solving the environmental problems. In Sheedy JE (ed). *Problems in Optometry—Environmental Optics* 2(1):17–31, March 1990a.

Sheedy JE. Vision requirements: Static guard of the Royal Canadian Mounted Police. *Canadian J Optometry,* Winter 1990b.

Sheedy JE. Contact lenses for police officers. *J Am Optometric Assoc* 57:658–660, 1986.

Sheedy JE. Fire fighter vision standards. *J Am Optometric Assoc* 55:365–374, 1984.

Sheedy JE. Police vision standards. *J Police Sci Admin* 8:275–286, 1980.

Sheedy JE. VDTs and vision complaints: A survey. *Info Display* 8(4&5):20–23, 1992.

Sheedy JE, Bailey IL, Buri M, et al. Binocular vs. monocular task performance. *Am J Optom Physiol Optics* 63:839–846, 1986.

Sheedy JE, Bailey IL, Fong D, et al. Task performance and contrast polarity on hard copy and video displays. *Proceedings of SPIE/SPSE Symposium on Electronic Imaging Science and Technology.* Bellingham, WA: Society of Photo-Optical Instrumentation Engineers, February 1990.

Sheedy JE, Keller J, Pitts D, Miller S. Recommended police vision standards. *J Am Optometric Assoc* 54:925–930, 1983.

Sheedy JE, Parsons SP. The video display terminal eye clinic: Clinical report. *Optometry and Vision Science* 67(8):622–626, 1990.

Sheedy JE, Saladin JJ. Validity of diagnostic criteria and case analysis in binocular vision disorders. In Schor C, Ciuffreda K (eds). *Basic and Clinical Aspects of Binocular Vergence Eye Movements.* Boston: Butterworth, 1983, pp 517–540.

Waring GO, Lynn MJ, Culbertson W, et al. Three year results of the prospective evaluation of radial keratotomy (PERK) study. *Ophthalmology* 94:1339–1354, 1987.

Yekta AA, Pickwell LD, Jenkins TCA. Binocular vision without stress. *Optom and Visual Sci* 66(12):815–817, 1989.