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Classroom Demonstration of the Visual Effects of Eye Diseases

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An understanding of the visual system is a fundamental aspect of many neuroscience and psychology courses. These classes often cover a variety of visual diseases that are correlated with the anatomy of the visual system, e.g., cataracts are caused by a clouding of the lens. Here, we describe an easy way to modify standard laboratory glasses/goggles to simulate the various perceptual deficits that accompany vision disorders such as astigmatism, cataracts, diabetic retinopathy, glaucoma, optic neuritis, posterior vitreous detachment, and retinitis pigmentosa. For example, when teaching about cataracts, students can put on glasses that mimic how severe cataracts affect one's vision. Using the glasses will allow students to draw connections between the disorder, its perceptual deficits, and the underlying anatomy. We also discuss floaters in the eye and provide an easy method to allow students to detect their own floaters. Together, these demonstrations make for a more dynamic and interactive class on the visual system that will better link diseases of the eye to anatomy and perception, and allow undergraduate students to develop a better understanding of the visual system as a whole.

Key words: vision; visual disease; vision deficit; retina

INTRODUCTION

The sense of vision is a complex system that is covered in several different neuroscience and psychology courses. A standard course typically mentions the various eye disorders that can occur, as well as the visual deficits that result from them. We describe how to modify standard laboratory glasses to effectively simulate the perceptual deficits associated with three types of impairments: tunnel vision, scotomas, and blurry vision. We also provide instructions to show students how to identify the effects of their own floaters. Experiencing these deficits with our modified glasses will allow students to experience the world as individuals with various eye disorders do. Instructions for modifying simple laboratory glasses are given for each category of disorder after the description of the corresponding disorders.

LEARNING OBJECTIVES

The glasses described here will:

1. Complement lecture material with a hands-on demonstration.
2. Lead to a clearer understanding of the perceptual disturbances that accompany common eye diseases.
3. Lead to better comprehension of the underlying anatomy behind specific eye diseases.
4. Yield a better understanding of the visual system in general.

THE VISUAL SYSTEM

Our experience of the visual world is the result of an intricate process requiring many steps that allow for high sensitivity and acuity. When light first enters the eye, it passes through the cornea, where most of light refraction occurs (Foley and Matlin, 1992). The light then passes through the pupil to the lens, which provides additional refraction. After passing through the lens, light passes through the vitreous chamber, an area that contains vitreous fluid, and finally reaches the retina. The retina lines the back of the eye, and it contains photoreceptor cells (rods and cones) that transduce light into electrical signals. Cones are the color-sensitive photoreceptors and are clustered in the fovea, an area on the retina responsible for perceiving the center of the visual field. Conversely, rods are sensitive to low-levels of light, and are found in the periphery of the retina where they are responsible for perceiving the periphery of the visual field. The retina also contains several other different cell types that communicate with each other in order to send visual information to the brain, including amacrine, bipolar, horizontal, and retinal ganglion cells. The axons of the retinal ganglion cells project form the optic nerve, cranial nerve II, and then projects centrally to the brain. Damage to the structures of the eye may result from trauma, disease, or as a normal part of aging. Specific problems, their anatomical correlate, and finally the resulting perceptual deficits are discussed below.

MATERIALS AND METHODS

Four pairs of laboratory glasses or goggles will be modified to simulate the perceptual experience of individuals with multiple eye diseases. We use retired laboratory glasses that were lightly scratched and no longer used in the lab. Therefore, there was no need to purchase new glasses for this demonstration. In addition to the glasses, the materials used include black electrical tape, semi-transparent tape, a permanent marker, and a few plastic sandwich bags. The glasses are described in more detail in the text below.

1. Tunnel Vision: Tunnel vision is a perceptual deficit in which the range of an individual's visual field is narrower than the visual field of a healthy individual. In this condition, the individual's peripheral vision is impaired, so that person is only able to see objects that fall in the center of their line of sight. Tunnel vision is often experienced as a result of glaucoma, a condition that occurs when the aqueous humor (fluid in the anterior chamber of the eye) does not drain properly, increasing intraocular pressure that compromises the periphery of the visual field (Porter et al., 2009). Alternatively, this buildup can also occur if the anterior chamber is too small, as is the case in closed-angle glaucoma. The increased pressure caused by excess fluid results in damage to the photoreceptors responsible for peripheral vision and thus causes tunnel vision (Leske and Rosenthal, 1979).

Another disorder that causes tunnel vision is retinitis pigmentosa, a heritable degenerative disease. This disorder results in degeneration of photoreceptors in the retina, and causes the formation of retinal pigment deposits (Hamel, 2006). Retinitis pigmentosa primarily affects the rods, which are responsible for perception of light in low-light situations. For this reason, in early stages of the disorder, retinitis pigmentosa leads to impaired night vision (Porter et al., 2009). Unlike cones, rods are mainly located in the outer regions of the retina, and therefore damage to this area leads to impaired processing of information in the peripheral areas of the visual field. For this reason, retinitis pigmentosa is another eye disorder that results in tunnel vision.

Demonstration: We altered a used pair of laboratory glasses for an in-class demonstration of the perceptual effects of tunnel vision. To make the glasses, we placed black electrical tape around the edges of the lens so that only a circle in the middle of the lens (approximately 2.5 cm in diameter) was left uncovered. Next, we used two layers of semi-transparent tape to cover the outer 0.4 cm of this circle in order to simulate the gradual change from normal vision in the center to darkness in the periphery. When the glasses are worn, individuals should not be able to use their peripheral vision and will only be able to see objects in the central region of the visual field. See Figure 1*A*

2. Scotomas: In some eye disorders, damage to a specific part of the retina prevents the transmission of information from just that area of the visual field. When this occurs, the individual perceives a dark spot or area in the visual field that corresponds to the region of the damaged retina. One example of an eye disorder that results in a blind spot is age-related macular degeneration (Zur and Ullman, 2003). The macula is the region that surrounds the fovea and corresponds to the center of the visual field (Porter et al., 2009). In this disease, the cells that make up the macula become damaged and cease to process information from the center region of the visual field. This disease results in the production of drusen, which are extracellular deposits that accumulate around the macula (Klein et al., 2005). Thus, light information cannot be passed to the optic nerve and the person perceives a blind spot, or scotoma, in the center of his or her visual field.

Another disorder that can cause scotomas is optic neuritis. Optic neuritis involves inflammation and damage to the optic nerve, the bundle of cell axons that deliver information from the eye to the brain (Brodsky et al., 2008). Damage to the optic nerve can result in a blind spot in the visual field, or in some cases, may cause complete blindness.

A third disorder that can cause scotomas is diabetic retinopathy (Wisznia et al., 1971). High glucose levels in diabetes can weaken the walls of blood vessels in the choroid (the vascular network behind the retina), making them more susceptible to damage and hemorrhaging (Porter et al., 2009). The vessels then start to bulge and may begin to leak blood, which damages the retina and the individual's ability to perceive the corresponding part of his or her visual field. In some cases, new blood vessels form in response to retinal damage, but these new blood vessels may also start to leak and cause scarring. The damage may be very specific, resulting in blind spots rather than complete blindness, because only a certain part of the retina is damaged. The area of the retinopathy may occur anywhere along the retina depending on where the ischemia is located in the choroid. If the damage continues throughout the choroid, the individual may eventually become completely blind.

Demonstration: Laboratory glasses were modified to demonstrate how scotomas impact visual perception. A circle was cut out of black electrical tape and placed on the lens of the glasses. The exact region of the scotoma differs depending on the specific disease and the location of the damage, so placement of the dark circle is somewhat arbitrary. One option is to place the blind spot in the center of the lens to mimic the effects of macular degeneration and to demonstrate difficulties that can arise when central vision is impaired. Additionally, several small black circles can be put on the glasses to mimic the patient's symptomology. We should note that when one is wearing these particular glasses, they should fix their gaze relative to the glasses, rather than move their gaze around while keeping the head still. This way, the black circles are continuously impacting the same portion of the field of view. See Figure 1*B*.

3. Blurry vision: Cataracts and astigmatism can produce generalized blurry vision. The severity of blurriness varies with the type and severity of the disorder. Unfortunately, almost all people experience at least some blurring of vision as they age, due to inevitable cell death and changes in parts of the visual system over time. While corrective lenses or contacts can help in many instances, some cases are only treatable with medication or surgery.

Cataracts are characterized by a general clouding of the lens—the transparent part of the eye that helps refract light onto the retina and changes shape to accommodate for focusing on details both close and far away. The clouding of the lens experienced with cataracts is due to irregularity of the crystallins in the lens (Wolfe et al., 2009). The crystallin protein starts to build up in the lens, which prevents light from passing through. Because the light is unable to reach the retina, the person's vision will become blurry. Cataracts are more likely to develop as age increases; by age 80, nearly half of the population has cataracts. Additionally, a small portion of the population is born with congenital cataracts, and these may cause blindness at an early age. Corrective glasses or contacts can treat less severe cataracts, but severe cataracts may require surgery to remove the clouded lens and replace it with an artificial one.

Generalized blurred vision may also result from astigmatism, a very common disorder in which the cornea is slightly misshapen (Foley and Matlin, 1992). The cornea is the outermost, glassy, transparent surface of the eye and is responsible for about 2/3 of light refraction. Ideally, a normally shaped cornea helps focus light onto the correct spot on the retina. However, for patients with astigmatism, the abnormal shape of the cornea causes light to bend so that it is focused either in front of or behind the retina, causing blurred vision. This is the most common cause of both myopia (nearsightedness) and hyperopia (farsightedness). In both cases, the astigmatism causes blurred vision when looking at either near or distant objects (Wolfe et al., 2009).

Demonstration: A clear plastic sandwich sized bag was cut to fit around the outside of the glasses and taped in place. This causes the visual field to become blurred when wearing the glasses. Two or three layers of the plastic bag may be used to create significant blurriness that is associated with severe cataracts. These will cause the individual to detect light and movement, but little or no detail in the visual field. See Figure 1*C.*

4. Floaters: Most normal sighted individuals experience floaters, and they are a normal part of aging (Roufail and Polkinghorne, 2006). In between the lens and the retina is a chamber filled with vitreous humor, a gel-like fluid that helps maintain intraocular pressure. As we age, collagen fibers in the vitreous humor shrink and become stringy (Wolfe et al., 2009). These stringy bits often break off and float in the vitreous fluid. Perceptually, floaters are often unnoticed, but may appear as small floating strings that move around the eye. The number of floaters may increase with age, but most individuals do not notice the floaters in their visual field unless they are looking at a uniform bright surface such as a light-colored wall or a bright blue sky. Floaters are usually small enough that any shadow they might cast on the retina is too small to be detectable.

The buildup of floaters is usually gradual as age increases, but the sudden increase in floaters may be indicative of a more serious problem. The sudden onset of floaters was found to be from posterior vitreous detachment in 83% of cases (Murakami et al., 1983). This detachment occurs when the vitreous separates from the retina, which can be a very serious problem. The separation of the vitreous from the retina can cause stringy bits of the vitreous to break and become floaters.

Demonstration: Floaters are best demonstrated by viewing a uniform bright blue slide from a projector. We have found that approximately three fifths of undergraduate students can see their own floaters under these conditions, but sometimes they are only visible from one eye. For the glasses that mimic floaters, we drew squiggles on the outside of the glasses with an indelible marker. See Figure 1*D*.

DISCUSSION

There are numerous diseases that can compromise visual processing. In a classroom setting, one can take advantage of the fact that many different disorders can cause similar perceptual deficits. By grouping disorders into the types of visual deficits they cause, it is easy and cost efficient to create a set of glasses that can effectively demonstrate these visual deficits.

In order to show that this activity was an efficacious learning tool, a pre- and post-assessment questionnaire

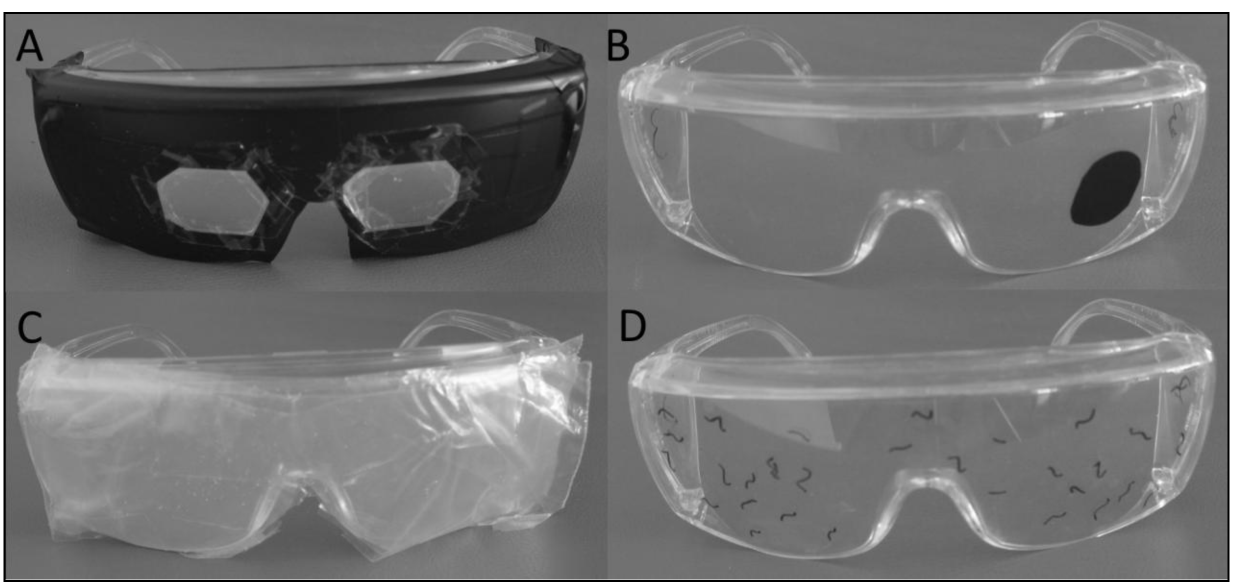

Figure 1. Laboratory glasses modified to mimic the effects of (*A*) tunnel vision, (*B*) a scotoma, (*C*) cataracts, and (*D*) floaters.

was given to students. Students were pseudo-randomly presented with one of two counterbalanced versions of this assessment before the classroom activity, and were given the other version after the activity. The questions were true/false and multiple-choice questions and aimed to assess the level of understanding of the perceptual disturbances that accompany each eye disorder. The numbers of multiple-choice and true-false questions were equal between the two tests. A sample multiple-choice question was: "Macular degeneration causes a) tunnel vision, b) scotomas, c) blurry vision, or d) floaters." A true/false question was "Cataracts and astigmatisms result in similar perceptual problems."

Scores on the pre-assessment (M=0.44, SD=0.12) were significantly lower than the post-assessment (M=0.82, SD=0.20), $t(42)=-7.5$, $p<0.001$, suggesting that students gained significant understanding of the eye disorders following the classroom activity. Additionally, a final question at the end of the post-assessment asked students how useful they thought the glasses were in helping them understand the perceptual deficits associated with the eye disorders. The average response was 5.65 on a 7-point Likert-type scale.

Neuroscience and perception classes in particular can benefit from this type of demonstration, as can high school students or other individuals interested in temporarily experiencing the effects of damage to the visual system.

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