

# What Do They See & How Do We Know?

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Photos by author except where noted

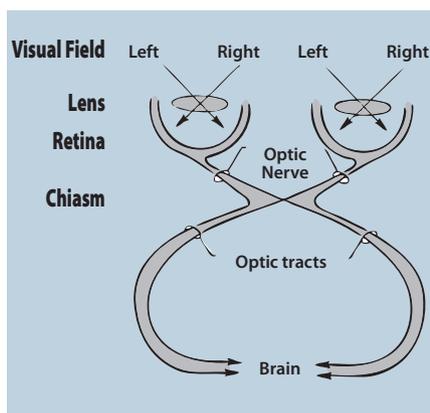


When you go to the eye doctor, you read an eye chart, right? How about your dog? Has he been to the eye doctor? Many dog owners are unaware that some veterinarians specialize in evaluating diseases of the eye and abnormalities in vision. Currently about 300 board-certified veterinary ophthalmologists are available, and most are in large metropolitan areas of the U.S. (Diplomate, American College of Veterinary Ophthalmologists, listed at [www.ACVO.com](http://www.ACVO.com)). As veterinary ophthalmologists we can't ask our patients about their vision. Yet they have many of the same eye problems people have—and a few more! So, how can we tell how well our dogs see? I am asked this question daily in my veterinary ophthalmology practice. As Will Rogers said, "The best doctor in the world is the veterinarian. He can't ask his patients what is the matter—he's got to just know." Fortunately, we have many ways, other than reading an eye chart, to evaluate vision.

To determine what dogs see, it is important to first understand that vision represents a combination of functional elements of both the eyes and the brain. Vision information is transmitted from the eyes to the optic nerves (see **Figure 1**). In the dog, about 75% of the optic nerve fibers cross to the opposite side at the optic chiasm (an X-shaped crossing), located at the base of the brain, near the pituitary gland. From there, the optic tracts go to the centers in the brain that control the pupil and to the large visual cortex. It

is thus possible for a dog with a brain abnormality to have perfectly normal eyes and still be functionally blind. Recognizing that the brain controls how vision information is interpreted is also important. We have all seen examples of optical illusions, where things are not as they appear to us. Dogs experience the same thing, and because the information their eyes record and the way their brain interprets it is different from ours, their perception in both normal and abnormal situations is also different.

Vision represents the total of the eye-brain experience; distinguishing physical eye abnormalities from perceptual abnormalities is the challenge to the veterinary ophthalmologist who is asked to evaluate vision in a performance dog.



*Figure 1: The right and left visual fields strike the opposite halves of the retina in each eye. The optic nerves carry information from the eyes to the optic chiasm where 75% of the fibers cross to the opposite optic tract. The information retains its geographic orientation within the optic nerves and tracts, producing a fused, binocular image within the brain.*

## Behavioral Clues

The first step in assessing vision is to identify behavioral changes; clinicians recognize that the owner is in the best position to do this. Astute owners are often immediately aware of changes in their dog's behavior such as hesitation, startling, or, for performance dogs, altered behavior on course. Different behavior in dim light versus bright light is often an early indicator of impaired vision. Going down stairs confidently requires good vision. A dog that hesitates going downstairs but goes upstairs quickly may have impaired vision; whereas one that goes downstairs quickly but hesitates going upstairs is more likely to be experiencing musculoskeletal weakness or discomfort.

We think of vision as essential for normal navigation. But, a blind companion dog in a familiar and undemanding environment may give the impression of nearly normal vision. I am often presented with a pet whose owners report an apparently sudden onset of blindness. Upon examination, I can see evidence of long-standing blindness. Further questioning reveals that the owners have recently moved (or rearranged the furniture) and their dog (that has been blind for months) is now exhibiting "new" behavioral evidence of impairment. Dogs successfully use their senses of smell and hearing, sensitive in ways that we can only imagine, to help them "visualize" their environment. Our performance dogs are much more dependent on their vision. They are regularly presented with unique situations and must navigate obstacles at high speed; there is no substitute for good vision in the execution of these tasks.

The complete visual experience combines field of view, depth perception (ability to judge distances), perception of light, motion, and color, and acuity (clarity). All these functions must then be interpreted and integrated by the brain to produce useful vision. Although we cannot ask our dogs to read an eye chart, through comparative anatomical and behavioral studies we can make some educated assumptions about their vision. There are species variations in all the elements described. Our discussion will be limited to our knowledge of vision in dogs.

## Field of View

Field of view varies greatly among different species and, within dogs, among different breeds. Placement of the eyes determines the “panorama” or width of the visual field and the size of the forward field that is seen by both eyes simultaneously (binocular field). Binocular vision assists in judging distances (depth perception). We humans have a 200° visual field of which 140° is binocular. In dogs, the eyes are usually placed more to the sides, giving them a wider visual field with a smaller portion that is binocular. Most dogs have a 240° to 270° visual field of which 30° to 60° is binocular (see **Figure 2**). The very near, lower, central visual field in most dogs is blocked by the nose. In some breeds, long hair and ears can further reduce the field of vision. Brachycephalic breeds (Pug, Boston Terrier) have a shorter nose, but more widely spaced eyes; thus they have a smaller binocular field. The visual perspective is also affected by the height of the dog (and the eyes) (see **Figure 3**).

## Depth Perception

The ability to judge distances is critical for performance dogs. They must accurately assess jump height and length, and instantly translate this assessment into stride length, speed, and height. Depth perception requires a mental comparison of the image created by each eye. Thus, an object must be visible within their relatively small binocular field and in accurate focus for each eye simultaneously. The range over which an object is in focus is dependent on

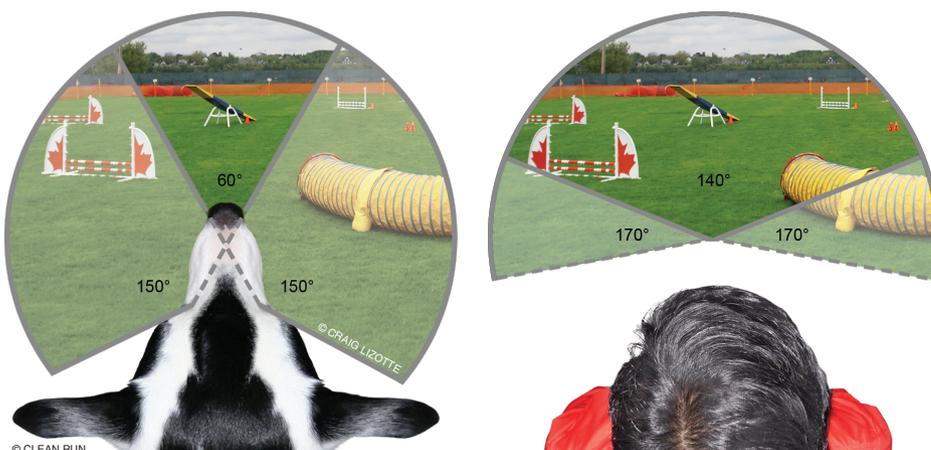


Figure 2: The width of the visual field and the amount of binocular overlap is determined by the placement of the eyes within the head and varies between breeds. Dogs have a much smaller binocular field than humans do.

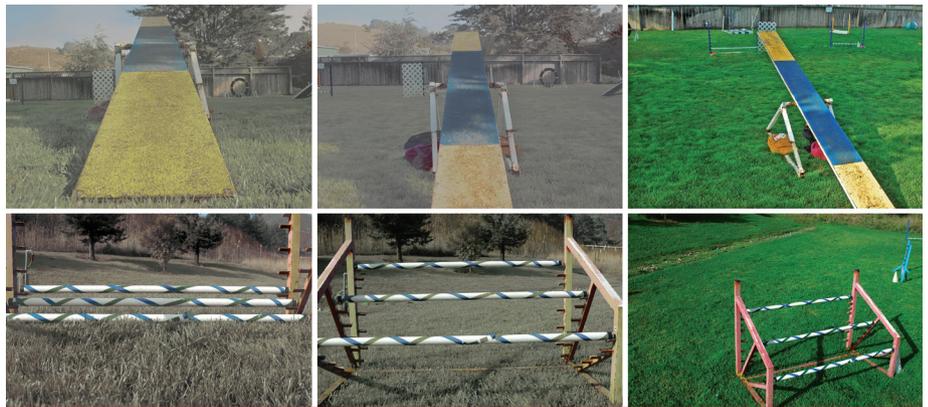


Figure 3: Comparison of vision between an 8" dog (left photos), 22" dog (center photos), and human (right photos). These photos simulate the more muted colors seen by dogs as well as the variation in height.

pupil size and the eyes' accommodative ability. Much like a camera, a smaller pupil (aperture) results in a greater depth of field. Dogs have relatively large pupils enhancing their dim-light vision at the expense of their depth perception. Accommodation is the ability of the eye to alter its focal point, generally by changing the shape of the lens, which is discussed in the section below on acuity.

## Light

Dogs have greater dim-light sensitivity than humans do for several reasons. Their eyes are larger and can dilate more widely for maximal light capturing ability. It is interesting to note that the size of the globe of the eye as a whole varies remarkably little over the large range of sizes of adult dogs. The eyes of a Chihuahua and a Great Dane are nearly the same size.

Dogs also have a specialized, reflective layer behind the retina called the tapetum. The color of the tapetum in dogs ranges from blue-green to yellow and results in the characteristic “eye shine” when their eyes are seen in car headlights. Although the tapetum greatly enhances light sensitivity, it also results in a scattering of light that may reduce visual acuity.

The photoreceptor cells in the retina consist of rods and cones. In general terms, cones are responsible for bright light and color vision; rods are sensitive to low intensity, dim light. Rods are the predominant type of photoreceptor in dogs and these rods are more sensitive to low light levels than human rod cells.

## Motion

Dogs appear to be neurologically sensitized to preferentially react to moving objects, as would be expected of a predator species. Owners often tell me that their dog (with normal vision) does not appear to recognize them until they move or speak. Many dogs ignore stationary objects but reflexively chase them if they move. Their large peripheral field of vision, in combination with their rod-rich retina, makes dogs well suited to detection of movement (prey) in dim light.

## Color

Although the common belief is that dogs see only in black and white, evidence suggests that they have some degree of useful color vision. The perception of color is determined by the presence of cone photoreceptors within the retina. Humans have a regional area, called the macula, consisting entirely of cone photoreceptors. This is the area

of the retina used for nearly all visual tasks. Dogs lack a true macula but do have a slightly greater concentration of cone photoreceptors centrally and in a horizontal band. In this “area centralis” cones still comprise only 10-20% of the photoreceptors. Yet, dogs may be better able to differentiate between subtle shades of gray than people can because of the dogs’ larger number of more sensitive rod photoreceptors.

The limited numbers of cones that dogs have are of only two types with sensitivity to violet (429 nm) and yellow-green (555 nm). Thus, dogs have dichromatic color vision (similar to color-blind humans) compared with normal human trichromatic vision. Wavelengths ranging from 500 to 620 nm (seen as green, yellow, and red by humans) would all appear as yellow to dogs. Light that appears blue-green to people probably appears as blue-gray to dogs. Behavioral tests in dogs suggest that they can distinguish red (which appears yellow) from blue but often confuse red and green. Thus, it is likely that guide dogs for the blind interpret traffic lights based on the position of the light rather than by differentiating red from green. Since red, green, and yellow all appear similar to dogs, blue is the best color to contrast with the yellow agility contact zone (see **Figure 4**).

## Acuity

Visual acuity is defined as the “clarity of vision”: the ability to distinguish two separate objects. It represents the sensitivity of the eyes (ability to bring an object into precise focus on the retina) and the interpretative faculty of the brain (the number of visual receptor cells that converge to form an image in the brain). We commonly hear our own visual acuity expressed as a Snellen fraction 20/x. The numerator or upper number in this designation represents the

distance in feet from which an individual can distinguish two objects, compared to the denominator or lower number, the distance at which an individual with normal acuity (20/20) could distinguish two objects. The fraction 20/100 is used to describe an individual who can distinguish two objects at 20’ that can be seen by a normal individual at 100’.

Refractive power is measured in diopters (D), the reciprocal of the focal length in meters. For example, a 3 D lens would bring parallel rays into focus at 1/3 meter. Convex lenses are measured in positive diopters and are used to treat hyperopia (farsightedness). Concave lenses are measured in negative diopters and are used to treat myopia (nearsightedness).

The refractive power of the eye as a whole represents a combination of the length of the globe, curvature of the cornea, and position and refractive power of the lens. In an ideal situation, the image falls accurately onto the photoreceptors (rods and cones) of the retina. The refractive state of the eye can be measured using retinoscopy (described below). There are several terms used to describe various refractive states.

**Emmetropia:** being able to focus clearly, in a relaxed state on an object at a distance (>20’).

**Myopia:** near objects are in focus and distance objects are blurred. This is most often the result of an eye that is longer (axial length = front to back) than normal.

**Hyperopia:** close objects are blurred; usually caused by a globe with short axial length.

**Anisometropia:** the two eyes do not focus equally. This will affect binocular vision and depth perception.

**Astigmatism:** the horizontal and vertical planes of focus are different; not commonly seen in dogs.

**Presbyopia:** reduced ability of the lens to change in shape; occurs with increasing age and density of the lens.

Surveys of the refractive state of dogs reveal that most are near emmetropia. One survey of 240 “normal” dogs revealed that some breeds (German Shepherd and Rottweiler) had a higher incidence of myopia; however, German Shepherd guide dogs were likely to be significantly less myopic. This leads to speculation that screening of dogs for use as guides may have eliminated those for whom vision-dependent behavior was considered unsatisfactory.

Besides the ability of the optical features of the eye to cause an image to fall accurately on the retina, acuity is also determined by the density of the photoreceptors and the proportion of cells that are sensitive to small amounts of light (rods) versus those that are sensitive to color and require larger amounts of light (cones). Continuing with the camera/film analogy, the rod photoreceptors are similar to high-speed film; the image produced in low light conditions tends to be grainy with lower resolution (acuity).

Information from the photoreceptors is transmitted in a series of cellular connections; first to the bipolar cells, then to the ganglion cells, the axons of which form the optic nerve. The number of cells that converge in this chain affects acuity. In the human macula, there is a nearly 1:1 ratio of cone photoreceptors to ganglion cells, meaning that information from each small area in the retina is represented by a corresponding communication in the brain. In non-primate mammals, including the dog, many photoreceptors transmit to a single bipolar cell and then many bipolar cells to a single ganglion cell. This situation creates a more “dilute” visual image in the brain.

When considering acuity, it is important to recognize the role of accommodation, where contraction of the lens changes its refractive state to adjust for near vision. Muscle within the ciliary body



Figure 4: Comparison of the view of the same scene by a human (A, C) and a dog (B, D); for the dog yellow, green, and red appear similar.

(see **Figure 5**) contracts resulting in the lens becoming more rounded to allow better focus on near objects. Dogs have very poorly developed ciliary muscles and limited accommodative ability. In people, the range of accommodation progressively decreases with age and the onset of presbyopia. Children have a range of accommodation of 14 diopters, decreasing to 2 diopters by age 50. In dogs, the weaker ciliary muscle means that accommodation occurs to a much smaller degree in dogs throughout life with a maximal range in young dogs of 2 to 4 diopters.

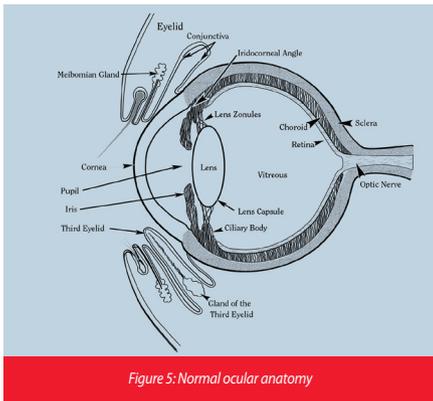


Figure 5: Normal ocular anatomy

## How Vision Is Clinically Assessed

So, if dogs can't read an eye chart, how do we know how well they see? We have several ways to evaluate the eyes and vision, to include both functional and anatomical assessments.

One of the challenges to early diagnosis of vision problems is the ability of dogs to compensate for reduced vision, particularly when only one eye is affected. One eye may be completely blind and behavior nearly normal despite reduced depth perception and limited

peripheral vision on the affected side. For performance dogs, altered behavior may be more readily apparent. In a clinical evaluation, assessing vision in each eye separately can be difficult. Attempts to physically place a patch over one eye are so distracting to the dog that the resulting behavior is often impossible to evaluate. Ophthalmologists use an easily tolerated opaque contact lens to cover one eye and assess function in the other.

When light is directed into the eye, the pupil normally constricts, which is called the direct pupillary light response. Because of the crossing of the optic nerve fibers described previously, both pupils constrict even if only one eye sees light. The response of the opposite eye is called a consensual pupillary light response and is important in assessing vision in an eye when the pupil cannot respond.

An image reaching the retina must pass through several layers (cornea, anterior chamber, lens, vitreous) that are normally completely clear. Any opacity or aberration in these structures will impede or distort the visual image. The clarity of the ocular media is one of the unique and

### Comparison of Dog Vision with Human Vision

- Larger peripheral field of view
- Enhanced sensitivity to motion
- Less depth perception
- Less acuity
- Minimal accommodation
- Better night vision
- Less intense, dichromatic color vision



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essential features of the eye, making it exquisitely sensitive to abnormalities that may be developmental (possibly genetic) or through damage resulting from inflammation or injury.

There are several specialized examinations performed routinely by veterinary ophthalmologists. Most can be easily performed within a 30-minute exam period without causing discomfort or requiring sedation.

Slit lamp biomicroscopy (see **Figure 6**) uses a hand-held microscope and a slit beam of light to detect and localize opacities or imperfections in the ocular media (cornea, aqueous humor, lens, vitreous). Indirect ophthalmoscopy (see **Figure 7**) uses a light source and a condensing lens to visualize the retina and optic nerve. Cloudiness within any of the ocular structures is detected by these examinations. The degree to which the cloudiness affects vision can be estimated by the degree to which visualization of the retina is impaired.

Tonometry is used to measure intraocular pressure (a test for glaucoma). A topical anesthetic is applied and a small pen-like instrument is touched to the cornea to measure the fluid pressure inside the eye. A pressure of 10-25 mmHg is normal in dogs.

Electroretinography (ERG) is used to measure the electrical signal emitted by the retina in response to a light stimulus. This examination is normally performed in a darkened room under general anesthesia and is used to detect forms of retinal degeneration (see **Figure 8**). Some forms of retinal degeneration result in impaired vision before there are any abnormalities detectable by direct examination. These conditions may be diagnosed very early by ERG.

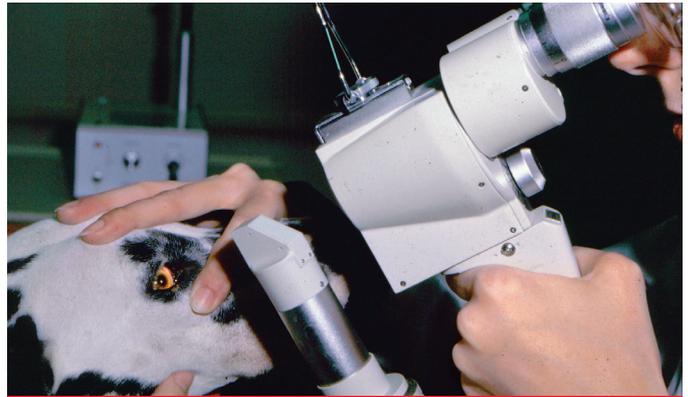


Figure 6: Slit lamp biomicroscopy uses magnification and a slit beam of light to find localized abnormalities within the cornea, anterior chamber, iris, lens, and vitreous.



Figure 7: Indirect ophthalmoscopy uses a condensing lens to visualize the retina and optic nerve.

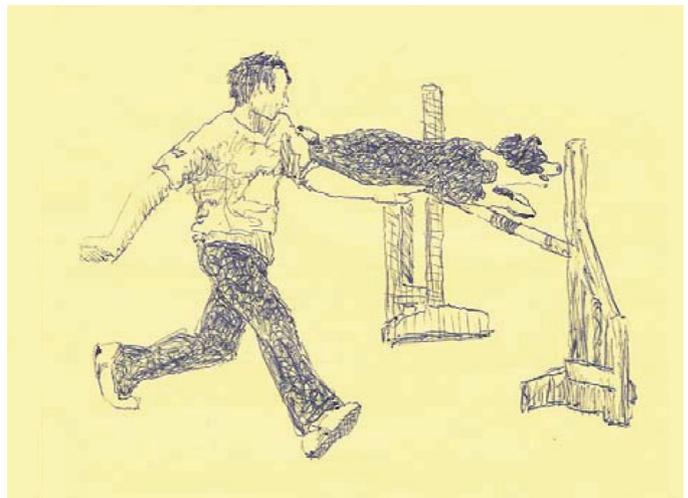


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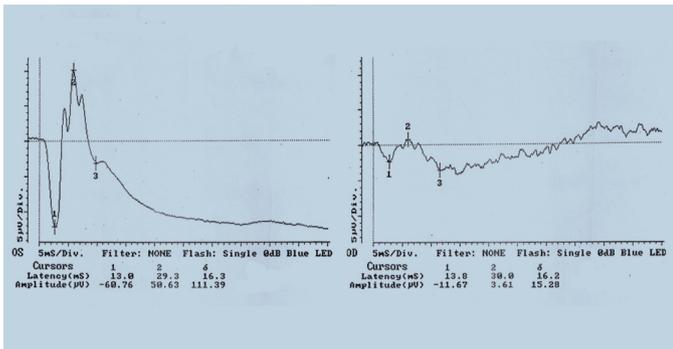


Figure 8: Electroretinography measures the electrical signal created by the retina to a flash of light. The left tracing illustrates normal retinal function; the right is from a dog affected with retinal degeneration. ERG is most useful to determine if the retina is healthy in cases where it cannot be directly visualized, usually due to opacification of the lens (cataract) and is used most commonly before cataract surgery.



Figure 9: Retinoscopy is a means of determining if there is a refractive error in the eye. This is similar to the procedure used for people to determine the correction required by glasses or contact lenses.

Retinoscopy is a method of evaluating the refractive components of the eye and is a measure of visual acuity (see **Figure 9**). This examination is painless and easily performed without sedation. The retina is visualized through a specialized instrument and a series of lenses are interposed until emmetropia is achieved. Refractive errors of 2 diopters or less are probably of minimal significance to function. Yet, when the refractive error or difference in refraction between the eyes is greater than 2 diopters, difficulties with depth perception can occur.

In the next article, we will discuss causes of impaired vision, including genetic conditions such as cataracts, glaucoma, lens luxation, and retinal degeneration. We will also discuss which behaviors to look for that might indicate a vision problem, as well as diagnosis and treatment for these conditions and refractive errors. 🐾

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Cynthia Cook, DVM, PhD, Dip. ACVO, is the founder of Veterinary Vision, with offices in San Carlos, and San Francisco, California, and a staff of three other veterinary ophthalmologists. Besides her clinical practice, she is active in lecturing, research, and consulting activities in academia and industry. Dr. Cook is also an agility enthusiast. More information about animal vision and eye diseases is available at [www.VeterinaryVision.com](http://www.VeterinaryVision.com).

