WHAT DO ANIMALS REALLY SEE?

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Introduction
Owners frequently ask questions concerning vision in their dogs and cats. There are also situations in which the owner feels there is a vision defect which is really only 'normal' dog or cat vision. The intent of this lecture is to provide the veterinarian with the knowledge to answer the commonly asked questions. The lecture primarily deals with cats and dogs but some points will be made on other species.

It is important to make the point to the owners, particularly those owners of pets with decreased or loss of vision, that dogs and cats are superior to man in their other senses of hearing and smell. These served animals better in their ancestors initial life style as predators. For example, dogs can hear about 4 times the distance of humans. The average human can hear anything between 20Hz to 20,000Hz while a dog can hear between 40Hz to 60,000 Hz. It is estimated that dogs can identify odors between 1,000 to 10,000 times better than humans. Male dogs can detect a female in estrus 3 miles away!

This explains why even blind dogs can function so well since they rely on these two superior senses. Dogs with decreased vision adapt better than humans as well. While it is true that their vision by human standards in the areas of color vision and visual acuity is poor, it is also true their vision in areas of motion detection, night vision and peripheral vision is superior to humans. These last three areas served them better in their natural environment as predators and prey and as pets which have to navigate room filled with furniture and moving humans.

Retina- "The Difference Maker"
The retina is only the 'receptor' for vision which actually is perceived in the brain. There are differences in the anatomy and physiology of various structures of the human and animal eye. The most significant affecting vision is within the retina and choroid. In the retina the photoreceptor cells called rods and cones process light. Rod receptors are important for night vision and motion detection. They detect brightness and shades of gray. Cones are involved in day vision, color vision and visual acuity. Dogs and cats have a rod-rich and a cone-deficient retina which is the opposite of the human retina.

Not only does the absolute ratio vary but the concentration varies significantly. Humans have a fovea centralis located in the center of the macula, temporal to the disc. This is an area of 100% cones which allows us color vision, visual acuity and day vision. The dog and cat have a poorly developed equivalent the visual streak and area centralis respectively. Certain breeds of dogs and even different strains may have a more pronounced visual streak i.e. more cones and therefore a greater visual acuity.
In addition to the ratio and the concentration of the rod and cone receptors, the synapse within the retina varies substantially. The ganglion cell layer (2nd inner most of the retinal layers) continues to form the optic nerve. The greater the number ganglion cells, the better the visual acuity. The 1:1 ratio of cone cells to ganglion cells in the human compares to the 4:1 in the dog and cat. The dog has 167,000, the cat 116,000 and the human 1,200,000!

A large number of rods eventually synapse on a single ganglion cell. This summation results in the increased vision in dim light but reduces visual acuity. The dog's retina is like a high speed photographic film with a high ISO or ASA number; great in dim light but 'grainy' with less detail (visual acuity) in bright light.

Many owners do no understand the reflection from their animal's eyes. The tapetum in dogs and cats is a cellular structure deep to the retina and is actually a part of the choroid. Reflection and absorption of various light waves account for the apparent color or shine because the tapetum contains no pigment. The color of the reflection may be various shades and combinations of green, orange, yellow and blue. In the dog the color is often breed specific. That reflectivity will be red as in humans in the case of albinoid and atapetal fundus. The purpose of the tapetum has been debated but it is commonly thought it reflects light back through the retina which improves night vision. This could also contribute to decreased visual acuity in dogs and cats. It has also been proposed the tapetum shifts the wavelength of the light in the cat. This brightens a blue-black evening or night sky and enhances the contrast between the sky and objects silhouetted against it. Atapetal individuals have not demonstrated decrease vision.

**Refractive Power**

Part of your personal yearly ocular examination includes refraction. Using a Snellen chart at 20 feet and the phoropter you look through, you doctor tells you if your eye focuses an image directly on the retina (emmetropic or normal), in front of the retina (myopic or nearsightedness) or behind the retina (hyperopic or farsightedness. In dogs, this is done with either streak retinoscopy or autorefraction. Myopic individuals have decreased vision for distant objects; hyperopic individuals have decreased vision for near objects. The extent of the ametropia (either myopia or hyperopia) is measured in diopters. A diopter is a unit of measurement used to identify the optical power or refractive (light bending) capacity of a lens.

The mean refractive state in dogs is reported to be emmetropic; however 25% of all dogs are myopic (-0.5 to-6.0 D). Myopia percentages are greater in the German Shepherd dog, rottweiler, collie, Labrador retriever, miniature schnauzer, toy poodle and English springer spaniel. In one study 53% of the German shepherds in veterinary practices were myopic, where only 15% in guide dog programs were myopic. Myopia increases with age due to nuclear or lenticular sclerosis. Hyperopia is greater in the Australian shepherd, bouvier and Alaskan malamute. Anisometropia exists if the refractive power varies between eyes. This has been reported in 6% of the dogs in one study. Astigmatism results due a variation in the corneal curvature and is seen in only
1% of the dogs. This could be a more significant problem following corneal disease. All working dogs or performance dogs, especially one that has a higher breed incidence of ametropia should be refracted prior to training.

Studies on cats are not as extensive. Kittens less than 4 months old were found to be myopic; adults older than 12 months were emmetropic. Domestic shorthair casts were significantly more likely to be myopic than domestic medium hair or longhair cats.

**Accommodation**
Accommodation is the ability to change the shape or position of the lens for near vision. This ability is limited in the dog and cat owing due in part to the lack of ciliary body musculature compared to man. Presbyopia is the age-related loss of accommodation in man. This is due to loss of elasticity of the lens capsule. It is not a noteworthy problem in animals since the lens does not significantly change shape. A human child can accommodate to within 2.8 inches. By the age of 30, adult's ability to accommodate falls to 5.6-4.9 inches. A dog can accommodate to 20-13 inches while a cat is good at 10 inches. A near point reflex occurs when an animal accommodates. In addition to the change in the shape of the lens, the globes converge and the pupils become miotic. This is difficult to demonstrate but could explain why older animals with nuclear sclerosis or dogs with axial cataracts may lose some vision for near objects. It would also explain why an older dog could no long catch a ball.

**Color Vision**
The old belief that dogs are color blind has been proven wrong. Humans have three types of cones and are referred to as trichromats. Each cone has a peak absorption at the wave length represented by red, green and blue. Dogs are termed dichromats and have two cones types. One is basically the same as the human's blue cone. The second cone has peak sensitivity in the red to green spectrum. This makes dogs' red-green color blind and unable to distinguish red from green. In fact, stimulation of this cone may result in what we would call yellow. This color vision is similar to Caucasian men with X-linked colored blindness termed deuteranopia. Dogs fail to differentiate green, yellow, orange or red objects. They also cannot distinguish blue-green from gray.

There is more controversy concerning color vision in the cat. It has been demonstrated that they have three cone types but the number of each color type varies. Behavioral testing, however, does not confirm they are trichromats like man. Some believe their color vision is limited to blue and grays while others believe it is similar to dogs but with less richness of hues and saturation of the colors.

**Visual Acuity**
Visual acuity is the ability to see an object as separate and unblurred. This is affected by anterior segment factors and how the image is processed in the brain. The latter we cannot easily determine in dogs and cats. The most limiting factor in animals is the retina as previously discussed. Since glasses only focus an image on the retina and most dogs are already emmetropic, glasses will not improve their vision. Visual acuity
in the average human is 20/20. The dog's acuity is 20/75 which means a dog has to be at 20 feet to see what an average human can see at 75 feet. Different investigators have reported that dogs' have a range of 20/50 to 20/140; the cat's range is 20/100 to 20/200; and horse is estimated to be 20/30 to 20/60.

**Motion Detection**
Early German studies demonstrated that a dog could discriminate a moving object at 810-900 meters (885-984 yards). But, they could only discriminate the same object when stationary at 585 meters (637 yards) or less. This would explain why a person may recognize a rabbit or deer at a distance, but the dog does not respond until the animal moves.

Again, due to the rod and cone ratio and distribution, there is a significant variation in the motion detection between the species. Humans have 10-12 times better motion detection in bright light than the cat or dog since bright light vision is a cone function. Dogs and cats see better in dim light since this is a rod function. While humans, dogs and cats all detect motion in the peripheral visual field, the dog and cat are superior. The peripheral retina in all species is primarily composed of rods, great for movement and night vision; but poor for acuity and color vision!

**Night Vision**
Due to the rod and cone ratio and the presence of the tapetum, both the dog and cat have superior night vision compared to man. The cats' is believed to be superior to the dogs' as a result of its thicker tapetum, large cornea and posteriorly placed lens. It has been suggested the cat requires 8X less light than humans.

**Vision Field**
Visual field perspective refers to the distance forward and animal can see. Contrary to popular thought, hunting breeds such as the German shorthaired pointer and sight hounds such as the Borzoi do not have superior vision. They can, however, see over tall grass and brush due to their height. The position of the globes affects visual fields and binocular depth perception or stereoptic vision. Frontal placed eyes result in a large binocular field, small monocular field and a large blind area of vision. This difference is obvious in dogs as you compare the skull type of a pug to a collie. The length of the nose also affects the visual fields. Humans have an average of 180° field of vision with both eyes. The average dog's field is 240-250°; the cat's is 200°; and the horse is 357°. Binocular depth perception in man is 140° as it is in the cat. The dog's field is 30°-60° and the horse's is 65°.

**Addendum of Interesting Facts**
An aphakic dog would have a +14D hyperopia and be severely farsighted with a reduced visual acuity of 20/800. (20/200 is legally blind in humans).

A shallow anterior chamber as in feline aqueous humor misdirection syndrome has a -14D myopia and is severely nearsighted.
Cetaceans (whales, porpoise, dolphins,) pinnipeds (walrus, seals, sea lions) and some nocturnal animals such as raccoons, rodents and flying squirrels are monochromats. With only one cone, which is sensitive to the red-green spectrum, they are colorblind.

Horses, cattle and deer are more orange-blue color blind, while dogs are red-green color blindness.

Deer, rodents, and reptiles can see ultraviolet light.

**Birds**
All avian have a greater number of receptors per mm² of retina than humans. In diurnal birds, 80% of the photoreceptors are cones; in nocturnal birds, almost 100% of the receptors are rods.

54% of all birds have 2 fovea. Examples include diurnal birds of prey, as well as kingfishers, swallows and hummingbirds.

Barn owls vision is estimated at 20/75; kestrels at 20/15; and wedge-tailed eagles at 20/4.

Nocturnal birds have a tapetum.

Most birds are tetrachromats with an additional cone that is sensitive to ultraviolet light.

Pigeons and butterflies have a fifth cone and are termed pentachromats. In theory they could see 10 billion colors and hues!

**Fish**
Some species of tropical fish are tetrachromats and can see ultraviolet light.

Most fish are nearsighted and see best in the red-orange and yellow-green spectrum. Trout and carp have a broader range of color vision. Carp and goldfish can see ultraviolet light.

Walleye and shark have a tapetum.

Sharks have eyelids, but do not blink. Some shark species have only rods and many species are farsighted.

Deep water fish, and some aquatic animals including octopus, squid and some whales have primarily rods and few non-functioning cones. Other species of whales, the truly deep divers, are true rod monochromats with no cones.