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Two Colors, a Million Smells and Sounds: What a Dog Perceives in Our World

Mankind is a very visually oriented creature. Certainly our senses of smell and hearing are important also, but vision is what gives us a huge advantage in this world. If we close our eyes, our mind is filled with past memories of sights both recent and past, many auditory memories, but rarely memories of many smells. Our dog and cat companions live in a world that is keyed on sounds and smells more than images. Their world is vivid with sounds and smells as ours is with vivid images. The reasons for the differences have to do with both the sensory organs (eye, nose, ear) and the information processing performed by the brain. There are differences between mankind and animals in this regard that explain the sensory perception variations.

A Dog's View of the World

It is wrong to assume that all animals see as we do. First, we must realize that the perspective the environment is viewed from is different between a quadruped and a biped, gaited animal. Try viewing the world from 6" to 24" above ground level to start to understand the difference. A second aspect we often fail to appreciate is the difference in abilities of animals to focus on near or far objects. The lens within the eye is an amazing structure that can actually change shape or position within the eye slightly by adjustment of specialized muscles within the eye. This adjustment is called accommodation. In a normal, relaxed human eye, the lens is shaped to allow incoming, distant light to focus on the rod and cone photoreceptors. This is similar to a camera lens set to infinity focus. If the lens within the eye could not adjust, the image of close objects would be focused on a point behind the retina, resulting in a blurred image. By contracting muscles in a portion of the eye called the ciliary body, the lens shape either becomes more rounded in most animals or the position of the lens shifts in certain animals. This allows the image of close objects to be focused upon the rod and cone cells. For example, a young child can accommodate as much as 14 diopters (one diopter is a lens with a focal length of one meter). This allows objects 3-4 inches from the eye to be focused upon the retina. Dogs have a very limited ability to accommodate and most cannot accommodate more than 2-3 diopters. This is about like a person that must wear bifocals to read with. Anything close\r than 12-18" is more of a blur to a dog.

A third aspect of the vision of a dog relates to the degree of binocular vision. Humans have forward directed eyes with about a 180-degree field of vision, but considerable overlap of the visual field of the right and left eyes. Dogs have eyes that can vary from fairly forward placement to lateral placement (short nose length breeds have more forward facing eyes that longer nosed breeds). Regardless of the nose length, the eyes always tend to aim laterally much more than in humans. As a result, dogs have a wider field of vision (220 degrees), but a narrower binocular vision zone. Thus, it is correct to say that the 3-D vision of a dog is substantially less than that of a human.

The fourth and greatest impact upon vision in dogs has to do with the design of the retina, which is vastly different from humans. Most mammals that we are familiar with have a duplex retina (meaning that both rod and cone photoreceptors are present). The cones function better in bright light and the rods in dim light. The rods and cones respond to incoming rays of light and send the signal information to second processing layer of cells in the retina, where the signal is finally passed on to the ganglion cells. The ganglion cell has a long nerve fiber that runs from the retina to the brain. In humans, there are 1.2 million ganglion cells and nerve fibers versus 170,000 in dogs. In mankind, there is an area of the retina slightly temporal and above the optic nerve head called the fovea. This region contains a very high density of cones. In the dog, there is no fovea, but a visual streak that extends in an oval shape across the top of the optic nerve and to either side. The fovea in man and the visual streak in dogs provide the best vision resolution. For example, in man, one cone cell sends information to one ganglion cell. In dogs, four cones typically send information to one ganglion cell. From the perspective of the ganglion cell, it does not care which of the four photoreceptors sends the information, it responds the same, regardless. Thus, humans will have at least a visual resolution four times greater than a dog.

When visual resolution or acuity is measured a normal person is said to be 20/20. If measurements are made in dogs, their vision corresponds to 20/75 (what a normal person can see at 75 feet, a dog would need to be 20 feet away from the object to see the same approximate detail). By the way, some birds have better than 60/20 vision (they can see at 60 feet what we see at 20).

There are several other differences between the eye of a dog and man that explain the vision differences. Dogs are designed to have sharper night vision than man. The corneal and pupil diameter is greater in dogs than man. This allows the dog eye to gather more light during low light periods. Most dogs, as well as many other animals, have a specialized reflective layer behind the retina called a tapetum lucidum. This layer acts as a mirror to reflect light back across the retina and out the pupil opening. In effect, it gives the photoreceptors two chances to capture a photon of light entering the eye. The trade off is that this design induces a bit more blur as a photon of light would rarely reflect back out the eye along the exact path it entered. Overall, these differences allow dogs to see a low-light world that is two to ten times brighter than what we see.

One final difference between the vision of man and dogs is the ability to detect motion. The photoreceptor-ganglion cell wiring and brain processing of dogs allows improved detection of motion. They may not know exactly what the object was that moved, but they know exactly where it is. A stationary object that can be detected by a dog a quarter mile away, could be spotted in motion a half mile away.

Do dogs see color? Many people would say no, but are definitely wrong. Dogs do possess color vision, but it is very limited. Humans see a full range of colors because of three sets of color receptor cones, each with peak sensitivity to a different wavelength of light. Depending upon the relative strength of the signal coming from each of the three types of cone receptors, the brain can determine the perceived color. Light stimulating blue and green cones equally would appear blue-green. The yellow and green cones sort out whether a color will appear red, orange, yellow, or green. Thus humans can discriminate about 100 different color hues. Dogs, and most non-primate mammals, have only two kinds of cones. In dogs, these cones have peak wavelength sensitivities in the yellow-green and violet range. Dogs can see two basic color groups, red-orange-yellow-green and blue-violet. All the colors within these groups appear the same. But dogs can tell the difference between the two groups and can tell the difference between the two groups and white or gray.

What does this mean to the dog? Many of the things made for dogs, that we think are so colorful, are the wrong color for a dog. A bright red ball in the green grass is not really all that distinguishable to a dog, unless it is moving. A violet object against a green background would be much easier for a dog to recognize. Red, yellow, and green objects would be nearly impossible for dogs to discriminate between, based on color alone. Although this seems a serious disadvantage from our perspective, to a dog sacrificing human-like color discrimination offers profound advantages for life in the dog realm. Basically there is a trade off between detailed color vision and functional low light vision. By having fewer cone cells, the canine retina can contain more rod receptors that are responsive to dim light. Dogs seem to be able to distinguish more shades of gray than the human eye. The vision of dogs reduces the confusion from camouflage to enhance hunting and pursuit abilities.

The Sharp Hearing and Smell Senses of a Dog

Healthy human hearing allows detection of sound up to 20,000 Hz; whereas a dog can hear up to 65,000 Hz. To put this into perspective, dogs can hear approximately two octaves higher than a person. Why would this be important since no dog can produce sound in this frequency range? Think about what dogs love to do. Small rodents make sounds in the 60,000-65,000 Hz range. Dogs can locate the direction such sounds are coming from within 8 degrees. This is due to a combination of the function of the hearing receptors and brain computation of differences in sound intensity and arrival time at the right and left ears. Dogs can discern differences in sound arrival of 55 microseconds between the two ears. They also have the ability to filter out an echo that arrives a millisecond or so later than the primary sound. Thus, it is no wonder that a dog can detect and locate sounds with superb sensitivity and accuracy.

The eye is an extension of the brain, and can be considered a networked PC. The nose is also an extension of the brain, but would be more like a networked supercomputer. The olfactory bulb is dramatically large in dogs than man, and a dog has nearly 20 times the number of primary receptor cells in the nose as a person. Dogs can detect certain organic compounds at concentrations 100 times less than that of a person and for other compounds the dog nose is more than a millions times more sensitive. A controlled study that puts this into perspective, demonstrated that dogs could detect human scent on a glass slide that had been lightly fingerprinted and left outdoors for as much as two weeks, or indoors for as much as a month. But more remarkable than the sensitivity to trace odors is the ability of dogs to pick out particular odors of interest from an ocean of competing smells. This requires not only detection of the odor, but an amazing ability to analyze and compute the intricacies involved in the total olfactory experience.

Dogs can quickly sniff 2-5 footprints of a person and with near perfect accuracy determine within a few seconds which way the person was walking. This is possible because the dog's nose can detect the relative odor strength difference between footprints only a few feet apart. The ability of a dog to determine the direction of a trail tends to fade after the trail is about 3 hrs old, but the trail can still be located for many more hours.

All of this boggles our minds, but by comparison, the human visual system is capable of similar levels of discrimination. Thus, one can truly consider the world of a dog as consisting of two colors but a million sounds and smells.