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Learning in Canines: A Comparison of Visual and Olfactory Cues

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This Thesis for honors recognition has been approved for the Department of Psychology - human-animal bond.

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Abstract

Humans and canines have shared a partnership that extends through history for centuries. Today, dogs are being utilized in many jobs ranging from assisting people with disabilities to search and rescue or bomb detection. Many of these jobs focus on canine olfactory abilities. Much research has been conducted that focuses on canine olfactory precision. However, learning through olfaction has not been measured in comparison to other cues. The hypothesis for this project is that dogs will learn olfactory cues at a faster rate than other types of cues. This outcome is predicted because olfaction is considered the dog’s superior sense. To test the hypothesis eight dogs were taught to associate two visual and two olfactory cues with the commands “sit” and “down.” The research design was a counterbalanced 2x2 factorial. Rates of learning were recorded and compared using ANOVA. The results show a major interaction effect of 3.81E-06 for the “Sit” command and .042 for the “down” command. This suggests that there are not differences in the rates of learning between visual and olfactory cues but that the order in which the animal learns the cue has an effect. Order of learning plays a role because it implies that canines developed a learning set; in other words, the dogs’ rates of learning improved through exposure to training.
Literature Review

History

Throughout history, dogs have played an integral role in human society. The dog’s keen senses have been used to aid humans in various ways; these include the traditional uses of hunting and shepherding, as well as modern uses such as bomb detection and search and rescue. Dogs are intelligent and highly trainable, which has allowed humans to tap into dog’s visual acuity and impressive olfactory abilities.

Images of dogs have appeared in art for thousands of years. Dog-like animals appear on cave paintings in Spain that date back twelve-thousand years. Egyptian hieroglyphics from six thousand years ago show distinctive breeds of dogs working alongside the human. In more recent times, such as the Renaissance, dogs, especially hunting hounds, are showcased in detailed portraiture. These pieces of art act as historical documentation of the intimate working relationship that dogs and people have shared throughout history (Fogle, 1995).

One of the earliest uses of dogs was in the sport of hunting. By the thirteenth century, European nobles were gathering packs of dogs to be used in the hunt. Over time, specific breeds were developed to hunt different types of game. Each of these breeds specialized in a unique method of hunting. For example, the small hounds from which the beagle is descended were capable of accompanying a rabbit hunter on foot. Other breeds were developed to hunt different types of game, such as rats, deer, and foxes. The primary advantage of using dogs was their ability to follow scent trails and lead the hunters to the game. However, dogs also were also used to flush out game, retrieve game,
and in some cases, kill game (Ibid).

Another traditional role that dogs played in aiding humans was that of guard dog. Originally, shepherds kept small flocks of livestock. It was necessary to protect the livestock from predators. Breeds were developed specifically to serve this purpose. Breeds such as the Mastiff were developed as early as the 1500s to guard livestock. These dogs used their vision and olfaction to detect predators and then act to protect the flock (Fogle, 1995).

Over the centuries, it became more common for people to keep larger herds of livestock. It is more difficult to control a larger herd and individual animals sometimes stray. To help manage the livestock herding breeds were created. Many of the collie breeds were developed during this time. Some of the oldest herding breeds date back as far as 920 A.D. (Ibid)

This partnership between humans and canines has progressed into the present. There are several modern jobs that allow people to take advantage of the dog’s impressive senses. Most of these jobs rely on dogs’ olfactory abilities. Many governmental agencies are using canine search teams to detect explosives and illegal substances. These ‘sniffer dogs’ are trained to recognize specific scents and alert the handler to their presence. Dogs are also being trained to follow human scent. These dogs can serve as search and rescue dogs to locate missing individuals, or they can be used by the police to apprehend run away criminals. Another interesting job that the canine is being trained for is to find corpses (Correa, 2005).

These are prime examples of how dogs have been used by humans throughout history and in the present. In many of the canine jobs, from hunting to bomb detection,
olfaction has been the key mechanism. Humans have come to rely on the dog’s superior sense of smell. It is assumed that among all the senses, dogs take in the most sensory information through their noses. Although dogs also have a good sense of hearing and can see well, most literature has pointed at olfaction as the most important sense.

**Development**

Dogs have a highly superior sense of smell compared to humans. People generally have about five million scent receptors in their noses, whereas dogs have around two-hundred and twenty million. Also, dogs are very adept at detecting minute amounts of a substance through smell (Fogle, 1990).

Scent is so important in the canine brain that puppies are born using scent as a survival tool. Young pups are born with no vision and poor hearing. However, the sense of smell is quite well developed (Fogle, 1999). In one study, aniseed was added to a pregnant bitch’s diet. When her puppies were born they preferred the aniseed to a novel scent. This indicates how dogs use scent as a means to learn and understand their world (Wells and Hepper, 2006).

In the weeks following a pups birth, the other senses develop and vision and hearing become more acute. Pups begin to see and hear at two weeks of age, but these senses are not fully developed until four to five weeks old (Fogle, 1999). Although vision and hearing are important senses, it is often assumed by canine experts that dogs primarily use olfaction to gather and interpret information about their surroundings.

The inner-workings of a dog’s nose are very complex. The dog has two nostrils, or nares, that are mobile, which allow the dog to better determine the direction of the scent. The dog takes in scents through regular breathing as well as through sniffing.
Sniffing is an interruption of regular breathing that consists of one to three successive trains of rapid inhalation, with each train consisting of three to seven sniffs. Air that is sniffed passes over a bone-like structure called the subethmoidal shelf and then onto the lining of the nasal membranes. When the dog breathes normally, the air passes down into the lungs, however, when the dog sniffs, the air is left resting in the nasal chambers (Fogle, 1990).

As shown in figure one, the canine olfactory system is full of complex structures. Maxilloturbinate bones provide skeleton structure for the nasal membranes. These bones have numerous folds that are designed to create airflow patterns that allow odors to strike smell receptor regions. The odor molecules are dissolved and concentrated into nasal mucous which adheres to the receptor cells. Because mucous is an integral part of olfaction, dogs produce a lot of it (Ibid). Normally humans produce around a pint of mucous per day, dogs produce considerably more proportionately. The mucous membrane is laden with connections to the olfactory portion of the canine brain. Once the odor is in the mucous, it sticks to microscopic hairs on the receptor cells of the mucous membrane. Then the chemical smell signal is converted into an electrical signal that is transferred to the cerebral cortex and limbic system. Scent can also be captured and converted by the vomeronasal organ which is above the upper mouth behind the upper incisors. The vomeronasal organ is likely involved in perception of pheromones (Correa, 2005).

As in olfaction, there are several structures that function together to allow dogs to see. The eyeball is globe shaped and sits within the orbit, a bony cavity that serves to protect the eye. Eyelids protect the eye from foreign material and maintain lubrication.
The inner surface of the lid is covered in conjunctiva, which is a vascular tissue that creates a pocket on the front of the eye that prevents foreign material from slipping behind the eye. The eyeball itself is a spheroidal body composed of three distinct layers that enclose the aqueous humor, crystalline lens, and vitreous humor. The first layer is tough and fiberous. It is what makes the eyeball rigid and strong. It is made up of the cornea, a clear layer on the outside of the eye and the sclera, a white connective tissue.

The middle layer of the eye is composed of several separate parts. First, the iris which is the colored portion of the eye that controls the opening and closing of the pupil to adjust for different amounts of light; second, the ciliary body which adjusts the shape of the lens to focus; and finally, the choroid which supplies blood and nutrients to the eye. The retinal layer is the third and innermost layer of the eye. It is connected to the brain by the optic nerve. It houses two types of receptor cells, rods and cones. Rods are involved in light and dark vision, whereas cones are involved in color perception. Behind the aqueous humor and iris is a transparent mass called the crystalline lens. The lens is supported by ligaments. Posterior to the lens is the vitreous humor, a clear, jelly-like substance. So the image passes through the cornea and aqueous humor, onto the lens. The lens changes shape through a process called accommodation. This puts the image into better focus. It then passes through the vitreous humor onto the retinal layer. The retinal layer is connected to the optic nerve which sends the image to the brain where it is translated allowing an organism to see (Swenson, 1977). For a visual representation of these structures, refer to figure two.

Dogs have more rods than cones, so they can see well in the dark, but they have a duller perception of color. Dogs also cannot distinguish between different shades of gray
very well. In a study measuring dog’s brightness discrimination ability, dogs were tested on whether or not they could distinguish between varying shades of gray, from white to black. The results of this study indicate that humans are roughly two times better at brightness discrimination than dogs (Pretterer, Bubna-Littitz, Windischbauer, Gabler, & Griebel, 2004).

Learning

Understanding how a dog learns is critical to understanding how best to train the animal. Conditioning is a key aspect of learning. There are two types of conditioning, classical and operant. Often, when training a dog both classical and operant conditioning techniques are used in combination. Classical conditioning can be defined “the simplest mechanism whereby organisms learn about relationships between stimuli and alter their behavior accordingly.” (Domjan, 2006)

The most famous example of classical conditioning is Ivan Pavlov’s original experiment with his dogs in the nineteenth century. In this experiment, Pavlov paired meat with a sound. It is natural that a dog salivates when meat is presented. In Pavlov’s study, the meat was presented at the same time as a tone. After several repetitions of the meat and the tone paired together, the animal would salivate at the tone alone. In this study, the meat was an unconditioned stimulus, a stimulus that naturally elicits a response. The unconditioned response to the meat was salivation. The tone was the conditioned stimulus, a stimulus that was originally neutral until associated with the unconditioned stimulus. Finally, the conditioned response was the salivation; however, instead of salivating at the presentation of meat, the dog would salivate in response to the tone.
Operant conditioning is also very important in dog training. Operant conditioning involves modifying the occurrence and form of a behavior through consequences. Different consequences will increase or reduce the likelihood of a behavior’s reoccurrence. Positive reinforcement, such as a food reward or praise, will increase the probability that the behavior will occur again. Punishment, such as a jerk on the collar or a stern “no,” will reduce the occurrence of the behavior. Negative reinforcement, or the elimination of an aversive stimulus, will also increase the behavior. Finally, omission training or extinction will initially increase the response rate, and then suppress it completely. This occurs when a behavior is followed by a consequence for several repetitions and then no consequence is provided. At first, the response rate will increase as the organism struggles to elicit a response, but eventually it will decline as no response is given (Domjan, 2006).

The most basic example of operant conditioning is B.F. Skinner’s study. Skinner used an operant conditioning chamber or “Skinner box.” He would place the animal, usually a rat or pigeon, inside of the chamber. The chamber was free of stimuli, but had some sort of manipulative inside of it that the animal could trigger, such as a lever. The animal was placed inside and would have to push the lever to activate or deactivate something. In this way, skinner could give positive reinforcement, negative reinforcement, or punishment. For positive reinforcement, the animal would receive a food reward for pushing the lever. As punishment, the animal would be given an electrical shock when it pushed the lever. Finally, for negative reinforcement, the animal would be in a state of constant electrical shock and when it pushed the lever, the shocking would cease. Through this simple device, Skinner was able to successfully study operant
conditioning in a controlled environment (Iverson, 1992).

A basic example of classical conditioning in dog training is the use of a clicker. A clicker is a simple tool in which the user presses a button and a salient noise, or click, is emitted. In this example, the sound of the click is paired with food. The dog eventually associates the click with getting a treat. Operant conditioning is also involved in clicker training. The dog will perform a behavior and a click will follow to mark that the behavior was correct; then a food reward will be given. This training technique is also referred to as bridge training because the click is a “bridge” between the correct behavior and the reward.

There are many reasons that clicker training is effective. First, the click can be given at the exact point that the correct behavior is performed; therefore it marks the correct behavior. When using treat rewards alone, the treat is usually given following the behavior; this can make it difficult for the animal to pinpoint exactly what the correct behavior was. Also, clickers are salient. Unlike the voice, they do not change based on inflection, emotion, or individual. Anyone can use a clicker and it will sound the same every time. Finally, the click is a distinct noise that will stand out to the dog. It is short, and different from other sounds, it will get the dogs attention to tell them that the right behavior has been executed (Bailey, 2008). Clicker training is being used by many professional dog trainers today. It can help to train a dog to perform nearly any task in a clear concise manner.

One trainer who is tapping into the dog’s incredible senses is Bonita Bergin. Bergin is the President and CEO of the Assistance Dog Institute (ADI), an organization focused in researching and teaching ways to “help dogs help people.” Prior to starting the
Assistance Dog Institute, Bergin founded Canine Companions for Independence, an organization which trained and placed dogs with people suffering from mobility impairments. After recognizing a great need for more trainers in the service dog field, Bergin opened the Assistance Dog Institute to educate others on how to train service dogs. Assistance dog institute conducts research in Human-Canine Studies, as well as offering a Master of Science degree to students (Assistance Dog Institute, 2003).

Bergin’s research has led to an interesting discovery: dogs can decipher complex visual cues and learn to associate them with a behavior. Bergin has written a book entitled *Teach Your Dog To Read*, in which she describes the methods to train your dog to associate written words that spell out spoken commands with the behavior itself. For example, a dog who had been trained to pair the written visual cue with the behavior, or “read” as it is referred to in Bergin’s book, would be shown a sign with the word “DOWN” written on it, and would respond by laying down. This demonstrates that the dog has enough visual acuity to differentiate and decipher complex cues and associate them with a specific behavior. Dogs not only learned English print letters, but also learned Japanese text (Bergin, 2006).

**Hypothesis:**

It is apparent that dogs are able to decipher complex visual cues and associate them with a behavior. However, most sources cite the dog’s vision as an inferior sense to its olfactory abilities. Throughout history, humans have been using the dog’s impressive nose to aid them in various tasks. Dogs have been trained to track and search out scents such as drugs, humans, or game. However, the dog’s ability to associate specific scents with individual behaviors has not been measured. This study will compare the canine’s
ability to decipher and associate complex visual cues with behaviors to their ability to
decipher and associate scents with behaviors. The hypothesis is that dogs will learn to
associate commands at a faster rate when the cue is olfactory than when it is visual.

Methods

Participants: eight dogs of varying breeds, ages, and abilities. All dogs solidly
knew the two verbal commands “sit” and “down” prior to participation in study. They
were also familiar with a clicker. Each dog was randomly assigned to a group. Group one
learned to respond to a visual cue first, then an olfactory one, then a second visual one,
and finally a second olfactory cue. Both groups learned the commands in the same order
of “sit, down, down, sit.” Participants were trained and tested individually in their homes.

A training session proceeded as follows: Participant dog stood in front of the
tester. The same tester held an 8.5” x 11” laminated card behind her back. The visual cue
cards had either “sit” or “down” written in large black letters on the front. The olfactory
cue card was blank, but on the back contained a scent pouch which was opened when the
testing session began. The olfactory cue for “sit” was mint extract and the cue for “down”
was anise extract. Tester would give the command while simultaneously displaying the
coordinating cue card at the dog’s level. When the dog performed the command correctly
the tester clicked and offered a food reward and verbal praise.

As testing progressed, the tester repeated the process. However instead of saying
the command immediately, the tester first displayed the card. If the dog performed
correctly, it was rewarded with a click and treat again. However, if the dog did not
perform the command shortly after the card was displayed, the tester gave a verbal
prompting and repeated the command. This process was repeated until the dog could
perform the command three times consecutively without any verbal prompting. At this point the behavior was assumed to be learned.

Testing took place as frequently as possible until the dog demonstrated that it had learned all four sensory cues and corresponding commands. Dogs were tested for ten minutes per training session, or until they demonstrated that they had learned the current cue. So, training would progress until the dog performed the first cue three consecutive times without verbal prompting. Group one learned visual “sit” first and group two learned olfactory “sit.” During the following testing session, the dog must repeat the process and again perform the first cue correctly and without prompting three consecutive times. If it did so, then the second cue was introduced. For group one, the second cue was olfactory “down” and for group two the second cue was visual “down.” Training progressed for the remaining time (defined as the time left in the ten minutes following the first cue) or until the subject could perform the second cue three consecutive times without verbal prompting. Then, at the next testing session, the dog had to perform the first two cues successfully before the third was introduced.

This process repeated until all four cues were learned. On the final testing day, the dog had to correctly perform each of the four cues and commands three consecutive times without verbal prompting. At that point, the tester displayed randomly selected cue cards eight times. If the dog performed the correct behavior each time, then it was assumed that the dog had successfully learned all cues and testing ended.

Testing sessions were video-taped to ensure accuracy in counting the number of trials it took each dog to learn the command. It was also possible to make observations when watching the video tape that may not have been obvious during the training session.
After each session, the number of repetitions for each cue was recorded. At the end of the training period, each dog's total for each cue was calculated for analysis.

Results

The study was a two-by-two factorial design. Results were analyzed using analysis of variance with replication. The order was counterbalanced as a research control. Results show no main effects. This indicates that there is no difference in learning time between visual and olfactory cues. However, there is a significant interaction effect of 3.81 E-06 for the “sit” command and .042027 for the “down” command. For detailed results, reference figures three, four, and five.

Discussion

The results of the study suggest that dogs learn to learn. As the canines are exposed to training, they lower the number of repetitions needed to learn to pair a specific behavior with a sensory cue. In other words, the dogs form a cognitive set. This study implies that the type of sensory cue that is paired to the behavior is not important and it does not influence the rates of learning.

The interaction effect is significant. This is because as the dog learns how to learn to pair cues with commands, their learning rates decrease. The interaction effect was higher for the sit command than the down command because of the order learned. Both groups learned commands in the order of “sit, down, down, sit.” The interaction effect was stronger for sit because the dogs learned “sit” first and last. The dogs learned “down” second and third. As dogs formed a cognitive set, and learned to learn, they’re learning rates decreased. Therefore, the difference in learning rates between the two “sit” commands were more substantial than the learning rates between the two “down”
commands.

These results are important because they help us to understand how the canine brain works, and add to our knowledge of canine learning and cognition. The implications of this study may also be helpful to those training dogs. This study has made it clearer that as training progresses, the dogs’ rates of learning will likely improve. In simpler terms, as the dog is trained, it will better learn how to successfully perform and learning will occur more quickly.

This knowledge may be especially important to those training dogs used in service to humans. These dogs usually need to learn extremely high numbers of commands. By understanding how dogs learn, people may be able to train them more effectively.

There were several interesting behavioral observations that were made during the experiment. For example, several of the dogs targeted on the cue cards in different ways. A few of the dogs repeatedly poked the card with their snout. Other dogs used their paws to touch the cue card. This behavior may simply suggest that the dogs were interested in the card. It may also be a trial and error behavior which they exhibited to see if it would earn them the reward. Almost all of the dogs displayed some form of targeting towards the card when the study began. Most of them stopped this behavior as training progressed and they learned how to successfully perform. However, a couple of the dogs continued this behavior throughout the duration of the study.

There were also some behaviors that became obstacles to collecting data. One behavior that was difficult was that many of the dogs had a solid “automatic sit.” The dogs would sit automatically without being given a command. This made it difficult to
collect data because the dog is supposed to be in a standing position for the training. If the dog automatically sits, then it is impossible to know whether it is sitting in response to the cue card or not. In future studies, it would likely be best to use a less obvious command.

Another interesting behavior that occurred was when the dogs played “the guessing game.” This means that the dog tries to perform every command it could in an attempt to earn the reward. This makes research difficult because if the dog performs correctly, then it must be rewarded. Sometimes, if the dog is a particularly good guesser or gets lucky, then it will perform the correct behavior multiple times and meet the criteria for a learned behavior. However, this was rectified quite easily because the dog would not correctly perform in the following training session, so training on that cue would continue until the dog would respond based on the cue card.

A major limitation of the study was the total number of dogs used. Originally, there were ten participants, but two of them did not complete the study. One dog was not food motivated and was generally disinterested in training. The dog only progressed to the second cue in the allotted time period for data collection. The other dog was not motivated by food either and also had a fear of strangers. This dog did not complete the study because his fear of the tester prohibited him from learning during the training session.

A larger number of subjects would allow for better research on learning of different types of cues. For follow-up research it would be best if there were enough subjects so that they could be divided into two groups, one to learn olfactory cues and one to learn visual cues. Within a small number of dogs, they must learn both and serve
as their own controls. This convolutes research in learning of different cue types because, as demonstrated in this study, interaction effects occur between variables. It would be possible to divide them into two separate groups if there were enough subjects to avoid having individual variations affect results.

Another limitation of this study was the small number of commands that the dogs learned. The dogs only had to associate the commands “sit” and “down” with visual and olfactory cues. Because one command may be a different difficulty level than another, the dogs had to learn to associate each command with both a visual and olfactory cue. Teaching the dogs to do this is very time consuming. Due to time constraints, it was impossible to use more than two commands in this study. In future research it would be better to use more commands. Also, it would be best if the commands were a less common than “sit” and “down.” Those commands are often the “default tricks” of the dogs and they perform them immediately without any direction. If there were more uncommon tricks, such as “spin,” “bark,” or “bow,” it would be easier to see when the dog performs in response to the cue alone.

An additional possible limitation of the study is the influence of the tester. It is possible that she may have unknowingly been hinted the correct answer to the dog. The dogs could have been responding to unintended body cues instead of the cue cards. Although this cannot be completely ruled out, it is very unlikely. Probable evidence that researcher influence did not occur is that at some point during the study, all of the dogs oriented towards the cue card by targeting it with their snout or paw. This indicates that they were likely making some sort of connection between the cue card and the appropriate behavioral response. Also, when the tapes were reviewed, the dogs’ body
language was observed; dogs spent most of their time gazing at the cue card after it was presented, rather than at the researcher.

Despite the limitations of the study, there is a lot of value to be gained from it. Based on the results, we have better insight into how the canine brain functions and learns. We better understand how training is processed by the dog. This experiment demonstrated the development of a cognitive set, or learning how to learn. We can apply this understanding to training of dogs in all fields. This helps to explain why learning rates may improve as dogs are exposed to more and more training.
References

Bailey, B. Intro to clicker/bridge training. Retrieved April 7, 2008, Web site:


Figure 1. Canine olfactory structures (Correa, 2005).

Figure 2. Structures of the canine eye (Fogle, 1999).
Formation of Cognitive Set: Group Comparison

Figure 3. Group comparison of learning rates.
Figure 4. Individual learning rates for each subject.
### Group 1: Visual

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**Totals:** 66 37 19 8 43 42 26 19 62 43 26 13 50 180 19 12

### Group 2: Olfactory

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**Totals:** 44 42 20 8 66 115 20 12 39 30 22 16 61 51 26 29

*Figure 5.* Individual daily learning data and totals.