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Reliability of Bloodhounds in Criminal Investigations

ABSTRACT: Anecdotal evidence and legend have suggested that bloodhounds are capable of trailing and alerting to a human by his or her individual scent. This same evidence may be presented to a court of law in order to accuse a particular suspect or suspects of a crime. There is little to no scientific evidence confirming the bloodhound's ability to trail and discriminate the scent of different individual humans. Eight bloodhounds (3 novice and 5 veteran), trained in human scent discrimination were used to determine the reliability of evidence, garnered through the use of bloodhounds, in a court of law. These dogs were placed on trails in an environment that simulated real-life scenarios. Results indicate that a veteran bloodhound can trail and correctly identify a person under various conditions. These data suggest that the potential error rate of a veteran bloodhound-handler team is low and can be a useful tool for law enforcement personnel.

KEYWORDS: forensic science, canine, bloodhound, scent, reliability

There is substantial evidence that dogs, *Canis familiaris,* are able to differentiate humans by their scent (1–5). Police departments in countries such as Belgium, the Netherlands, Poland and Germany utilize dogs to tie a suspect into the scene of a crime using a scent line-up (6,7). In a scent line-up, the suspect is required to hold a stainless steel tube in his hand thereby transferring his unique scent onto the tube. The dog must then match the scent of an object found at the crime scene, the *corpus delecti,* with the suspect's scent on the stainless steel tube. The tube is placed randomly among tubes with the scent of other persons not involved with the crime. Unfortunately, one of the prerequisites for using a scent line-up is the suspect must already be in custody in order to transfer his or her scent to the stainless steel tube. Many times in police work, however, the suspect is able to elude the officers thereby necessitating a manhunt.

Folklore would have it that the best dog to use in a manhunt is the bloodhound. Bloodhounds have been used by law enforcement for many years (8). The various jobs of the bloodhound have included trailing runaway slaves, escaped convicts, criminals at large and even missing children. Today the testimony of the bloodhound is admissible in courts of law in the United States, as well as several countries in Europe. Although the exceptional scenting ability of the bloodhound has been passed down through oral tradition, the efficacy of this legendary animal to trail an individual has never been tried in a scientific setting (9).

The purpose of this experiment was to scientifically validate the success of the bloodhound in matching collected human scent with the correct individual. The study was also carried out under several different settings in order to mimic real-life scenarios. A new scent collection technique was used, which allows for minimal to no intrusion on forensic evidence left at the crime scene.

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Methods

Animals

Eight bloodhounds, similarly trained using the methodology described by William Tolhurst, were selected for this experiment (10). All dogs began their training prior to six months of age with most dogs starting as young as 47 days old. The age of the dogs at the time of the experiment ranged between 10 months and 12 years with an average age of 3.2 years. All individuals handling the dogs during the present experiment were also involved in the training of their own bloodhound. The handlers were either police officers or civilian volunteers affiliated with one or more local police and/or sheriff's departments.

Dogs were placed into two separate categories depending on their prior training and trailing experience. If the dog had less than 18 months of training it was entered into the category of novice dog. When a dog had received 18 months or more of training and had run one or more trails for a law enforcement or search and rescue agency, it was placed in the veteran category.

Scent Collection

Scent was collected from every individual who laid trails for the dogs utilizing the following methodology. A scent transfer unit (STU-100) was used in order to transfer each person's unique scent to a 5 in. $\times$ 9 in. gauze pad, which was then sealed in a zip-loc freezer bag and given to the handler. The STU-100 is a low pressure, hand-held vacuum device with a large head attachment. On the attachment a gauze pad can be secured into place and then held over an area where scent is located. In this study, the STU-100 was held approximately 1 in. from the person's body. The vacuum was then slowly moved over the torso, arms and hands of the individual trail layer both on the anterior and posterior surface. No one particular area of the body was used to collect scent. The bloodhounds used in this study have been trained to identify scent from various places on an individual's body. Prior to each use, the vacuum was cleaned with 70% ethanol. All scent pads were presented to the dog within 30 min of collection.

Trailing

Both male and female trail layers of various ethnic groups were selected for the present study. The age of the trail layers ranged between 8 and 70 years (avg. age 25.2 ± 2.9 years). The trail layers were provided a map to follow and asked to walk with a partner from point A, the start of the trail, to point C, the end of the trail. Approximately 50 ft prior to arriving at point C, the trail layer and partner split at point B, creating a "Y" shaped pattern. The trail layer and partner then hid for approximately 10 min behind a nearby object (for example a tree or side of a building) at point C. Each trail was no less than 0.5 miles and no more than 1.5 miles in length. The trail layer and partner were then picked up and driven away from point C, being certain not to cross over the trail already laid. After waiting approximately 48 h, the trail layer and partner were brought back to point C to hide. Again all precautions were taken not to cross over and contaminate the original trail.

In order to mimic real life situations the first two sets of trails were run in two different regional parks. The third set of trails was run on a college campus that was in session and the fourth and fifth set of trails were run in a busy downtown urban environment (San Bernardino, CA). Each setting was chosen due to the high probability of individuals walking over the trails and creating a contaminated environment. For example, 24 h prior to running the dogs on the second set of trails, the recreation department hosted a trout fishing contest. It was estimated that over 1000 people walked across the already set trails.

The final two sets of trails were held in a busy downtown area. The trails were laid over busy streets and in areas where people drove, as well as walked overtop of the trails each day.

During each group of trails every dog ran a separate trail and no dog ran the same trail twice. Each set of trails was held three weeks after the last set.

The terrain for each individual trail consisted of a combination of grass, asphalt, cement or dirt. However, some trails also covered surfaces such as wooden bridges, mud, packed dirt and water (a stream). During each trail, measurements were taken for total length of trail, ambient air temperature, wind speed, and humidity.

Identification of Trail Layer

To begin the trailing process both the handler and bloodhound were taken to point A, the start of the trail once the trail layer and partner were back in place. The handler then put the dog in harness and introduced a sterile gauze pad to the dog. The pad was used as a "negative check" on the dog. If the dog did not begin to trail after receiving the negative check, then the handler presented the gauze pad containing the trail layer's scent to the bloodhound. The dog was then given the command to trail. The trail was terminated when the handler signified that his or her dog had made an identification or the dog had lost the trail. Neither the handler nor the researchers on the trail knew the correct trail layer at the time.

Statistical Analysis

If a dog was wrong because it was not able to find and/or identify the trail layer or if the dog identified the partner walking with the trail layer a number "one" was assigned. The number "two" was assigned if the dog was correct and made an accurate identification of the trail layer. The overall differences between the dogs were tested using χ^2. A probability of $p < 0.05$ was considered statistically significant. Percentages for correct and wrong finds were calculated. A *t*-test was used to calculate differences in temperature and humidity between trails.

Results

Overall Trailing Performance of Novice and Veteran Dogs

One assumption made in police work is that all bloodhounds are equal in their ability to trail. With this in mind we tested the difference in performance of novice versus veteran bloodhounds (Table 1). Overall, novice dogs were successful with a 53.3% find rate and one false identification. The veteran dogs had an overall find rate of 96% with no false identifications. The combined total correct finds for the novice and veteran dogs was 77.5% (random score = 50%; $\chi^2 = 12.9$, df = 7, $p < 0.05$).

Effects of Weather on Trailing Performance

Prior to running the first set of trails a storm dropped 1.5 in. of rain. During the trailing trials wind blew at approximately 15 mph. The temperature ranged between 23 and 24°C. The humidity was 22%. The trails were laid in a park up to 48 h prior to running the dogs. The overall performance of the novice dogs on this day was only 33.3%. Nevertheless, the veteran dogs successfully identified their trail layers 100% of the time (random score = 50% correct; $\chi^2 = 8.0$, df = 1, $p < 0.05$, Table 2).

During the second set of trails the temperature ranged between 18–26°C. The night before the trails, the wind blew at speeds up to 60 mph. On the day of the trails the wind speed was minimal, between 0 and 2 mph. The humidity was 14% (Table 3). All trails were laid 48 h prior to running the dogs. The success of the novice dogs was again only 33.3%. Veteran dog success in identifying their trail layers was 80% (random score = 50% correct; $\chi^2 = 3.0$, df = 1, $p > 0.05$).

When the dogs were run on the third set of trails the weather was mild with a temperature range of 21–24°C (Table 4). The wind blew at 2 to 5 mph with 25% humidity. Novice dogs recorded a 0% find rate and veteran dogs again made (100%) all of their finds (random score = 50% correct; $\chi^2 = 8.0$, $p < 0.05$).

Again the weather was mild on the fourth set of trails. The temperature was between 23 and 24°C with wind speeds at 3 to 5 mph (Tables 5 and 6). Humidity was 11%. During the trailing session both novice and veteran dogs found the trail layers every time (random score = 50% correct; $\chi^2 = 2.5$, $p > 0.05$).

The temperature for the final set of trails was between 19 and 20°C. While the dogs were running their trails, the wind blew at approximately 30 mph with 22% humidity. Both the novice and veteran dogs successfully found their trail layers 100% of the time (random score = 50% correct; $\chi^2 = 2.0$, $p > 0.05$). When looking at a comparison of weather conditions between the five sets of trails, there was no significant difference in temperature or humidity ($p > 0.05$).

TABLE 1—*Performance of individual dog and handler team.*

Dog	Handler	No. of Trails Run	Trails Run to Completion	Correct Finds
Shelby	police officer	5	2	40%
Shiloh	deputy, retired	5	3	60%
Sadie	police officer	5	2	40%
Edna	civilian volunteer	5	5	100%
Trace	police reserve	5	4	80%
Dana	police officer	5	5	100%
Tinkerbell	police reserve	5	5	100%
Sable	police officer	5	5	100%

TABLE 2—*Environmental and weather occurring during trails, Set 1.*

Dog	Environmental Conditions	Weather	Comments
Shelby	Grass, dirt and asphalt road Crossed over a wooden bridge	Light gusty winds 15 mph, 24°C, 22% humidity	Dog missed the bridge, but was able to come back and find the turn to make the tag. Not considered a find
Shiloh	Dirt, dried grass field Crossed over asphalt road back onto grass	Light gusty winds 15 mph, 24°C, 22% humidity	Dog had no problem making the tag
Sadie	Grass, around a pond with ducks	Light gusty winds 15 mph, 24°C, 22% humidity	Dog found the two trail layers, but made the tag on the wrong person
Edna	Dirt, dried grass field Crossed over asphalt back onto grass	Light gusty winds 15 mph, 23°C, 22% humidity	Dog made tag without difficulty
Trace	Followed a dirt road around a pond, across a wooden bridge onto cement sidewalk, back onto grass	Light gusty winds 15 mph, 24°C, 22% humidity	Dog made tag without difficulty
Dana	Dirt to gravel and up a dirt path on side of a hill. Back onto grass and across asphalt	Light gusty winds 15 mph, 23°C, 22% humidity	Dog made tag without difficulty
Tinkerbell	Grass to cement sidewalk and onto asphalt road. Over grass to cement again and down to a duck pond	Light gusty winds 15 mph, 23°C, 22% humidity	Dog made tag without difficulty
Sable	Dirt, dried grass to four lane asphalt road	Light gusty winds 15 mph, 24°C, 22% humidity	Dog made tag without difficulty

TABLE 3—*Environmental and weather conditions occurring during trails, Set 2.*

Dog	Environmental conditions	Weather	Comments
Shelby	Dirt road to asphalt, through cement wash, up side of hill through high brush	0–2 mph winds, 26°C, 14% humidity	Dog began trail and headed in the wrong direction. Dog was brought back to start of trail and made to go in right direction. After this she made the tag. Not considered a find.
Shiloh	Asphalt road onto a parking lot, across cement sidewalk	0–2 mph winds, 20°C, 14% humidity	Dog passed a turn, but came back and then made the tag. Not considered a find.
Sadie	Dirt road into cement wash, across wooden bridge down dirt path across asphalt	0–2 mph winds, 20°C, 14% humidity	Dog had no difficulty making tag
Edna	Asphalt road to dirt, down into a cement wash, over a wooden bridge down dirt	0–2 mph winds, 18°C, 14% humidity	Dog had no difficulty making tag
Trace	Grass to dirt road past a dump site, onto grass	0–2 mph winds, 23°C, 14% humidity	Dog would not trail, wanted to go into dump. When dog was walked 100 ft away from dump, made tag. Not considered a find.
Dana	Through grass along a stream, up a canyon, followed a trail up hill onto grass	0–2 mph winds, 26°C, 14% humidity	Dog took several extra minutes to find trail up side of hill, but once up had no difficulty making tag
Tinkerbell	Asphalt road to grass to a pond, back to asphalt road, over cement steps	0–2 mph winds, 20°C, 14% humidity	Dog had no difficulty making tag
Sable	Asphalt road to cement, across dirt and grass field	0–2 mph winds, 21°C, 14% humidity	Dog had no difficulty making tag

TABLE 4—*Environmental and weather conditions occurring during trails, Set 3.*

Dog	Environmental Conditions	Weather	Comments
Shelby	Asphalt parking lot, cement sidewalks, grass field	Light winds 2–5 mph, 21°C, 13% humidity	Dog missed an opening in the wall and had to be directed, after this she made the tag. Not considered a find.
Shiloh	Grass field across dirt field to cement patio area and into building	Light winds 2–5 mph, 22°C, 13% humidity	Dog hesitated to make tag because someone was taking flash pictures. Not considered a find
Sadie	Cement sidewalk, asphalt road, and grass	Light winds 2–5 mph, 21°C, 13% humidity	Dog found direction of travel, but did not make tag
Edna	Asphalt road to cement sidewalks and back to asphalt parking lot	Light winds 2–5 mph, 23°C, 13% humidity	Dog found trail layer with no difficulty
Trace	Cement sidewalk, grass, asphalt road	Light winds 2–5 mph, 21°C, 13% humidity	Dog had no difficulty making tag
Dana	Cement sidewalks, over asphalt road, across grass and dirt lot	Light winds 2–5 mph, 24°C, 13% humidity	Dog had no difficulty making tag
Tinkerbell	Asphalt parking lot to cement sidewalks	Light winds 2–5 mph, 21°C, 13% humidity	Dog had no difficulty making tag
Sable	Followed asphalt road across dirt and gravel field	Light winds 2–5 mph, 21°C, 13% humidity	Dog had no difficulty making tag

TABLE 5—*Environmental and weather conditions occurring during trails, Set 4.*

Dog	Environmental Conditions	Weather	Comments
Shelby	Cement sidewalks, across asphalt streets through intersections to parking lot	Light winds 3–5 mph, 23°C, 11% humidity	Dog made tag without difficulty
Shiloh	Asphalt street, across intersections, cement sidewalks	Light winds 3–5 mph, 23°C, 11% humidity	Dog made tag
Sadie	Grass lawn, cement sidewalks, asphalt streets	Light winds 3–5 mph, 23°C, 11% humidity	With all the traffic the dog had a difficult time finding trail-layer. Not considered successful trail
Edna	Cement sidewalk, asphalt road, into building	Light winds 3–5 mph, 24°C, 11% humidity	Dog had no difficulty with tag
Trace	Cement sidewalk, across asphalt street	Light winds 3–5 mph, 24°C, 11% humidity	Dog made tag
Dana	From inside building, out onto cement sidewalks, followed asphalt street	Light winds 3–5 mph, 24°C, 11% humidity	Dog made tag with no difficulty
Tinkerbell	Asphalt street, across grassy lawns, across parking lot onto cement sidewalk	Light winds 3–5 mph, 24°C, 11% humidity	Dog made tag
Sable	Followed asphalt street into parking lot, across sidewalk into grassy field	Light winds 3–5 mph, 24°C, 11% humidity	Dog had no hesitation in making tag

TABLE 6—*Environmental and weather conditions occurring during trails, Set 5.*

Dog	Environment Conditions	Weather	Comments
Shelby	Asphalt streets, down cement sidewalks	Gusty winds 30 mph, 20°C, 22% humidity	Dog had no trouble making tag
Shiloh	Asphalt streets, down cement sidewalks	Gusty winds 30 mph, 19°C, 22% humidity	Dog had no trouble making tag
Sadie	Grass field, across cement sidewalks, down asphalt street	Gusty winds 30 mph, 19°C, 22% humidity	Dog had no trouble making tag
Edna	Grass field, across dirt lot, to asphalt parking lot	Gusty winds 30 mph, 18°C, 22% humidity	Dog had no trouble making tag
Trace	Asphalt streets, down cement sidewalks	Gusty winds 30 mph, 18°C, 22% humidity	Dog had no trouble making tag
Dana	Across asphalt parking lot, through dirt field, down cement sidewalk	Gusty winds 30 mph, 20°C, 22% humidity	Dog had no trouble making tag
Tinkerbell	Across asphalt parking lot, through dirt field, down cement sidewalk	Gusty winds 30 mph, 19°C, 22% humidity	Dog had no trouble making tag
Sable	Asphalt streets, down cement sidewalks	Gusty winds 30 mph, 19°C, 22% humidity	Dog had no trouble making tag

Discussion

A number of studies have demonstrated the ability of dogs to identify an individual in a scent line-up using a *corpus delecti*. However, to our knowledge, these are the first studies demonstrating the use of mantrailing bloodhounds in real life scenarios. Our data indicate that bloodhounds are able to scent discriminate between two individual trail layers on a trail that is 48 h old. Bloodhounds can match human scent collected from random locations on the human body with the correct individual. Our results also indicate that age of the dog, as well as training may have an affect on the capability of a bloodhound to correctly find the trail layer. The ability of a bloodhound to locate a perpetrator on a highly contaminated trail that may be up to 48 h old is an invaluable tool for law enforcement personnel.

When assisting a law enforcement agency in locating a critical missing person or a suspect who has fled, the accuracy of the bloodhound is extremely important. The overall trailing abilities between the novice and veteran bloodhounds were statistically different. The differences in performance between the two groups may be enough to affect the outcome of a criminal case. In the veteran dog group there was only one bloodhound that did not complete her trail without interruption, whereas dogs in the novice group were not able to make their finds 8 out of 15 times. The one veteran bloodhound that did not make the find was distracted by a foul smelling dumpsite that was located about 300 yd off the trail. The handler was not able to keep the dog's attention on the trail and decided to stop his dog. Once the dog was walked a substantial distance from the dumpsite, she continued the trail and made the find.

One suggestion for the lower success rate of finds for the novice dogs compared with veteran dogs may be the potential differences in the maturation of their neurological system. Previous studies in puppies have shown that their ability to understand invisible displacement does not fully develop until approximately one year of age (11). Invisible displacement or object permanence allows an animal to locate an object that is no longer available to its immediate perception (12). In the case of an adult dog, it has been demonstrated that if it cannot visibly find the subject/object, it will then rely on a second sense, such as olfaction, to locate the subject/object (13). Dogs first start showing signs of invisible displacement at approximately 11 to 12 months of age, which seems to indicate a delay in the full development of their neurological system. Our two youngest dogs were 10 and 11 months old during the first two sets of trails. It was during these two sets that both dogs were not able

to find their trail layers and one dog made a false identification of the trail layer's partner. However, over the next three months, these two dogs improved to such a degree that they made their finds 100% of the time. Development of the neurological system over time may influence the sensitivity and discriminatory powers of the bloodhound.

Another possibility for the decreased find rate of the novice dogs may be handler error or inexperience. For the majority of handlers in the present study, the amount of their training correlated directly with the amount of training the dog had received. Nevertheless, there were some more experienced handlers in the study who were working younger dogs. The youngest dog used in the study named Shelby, had an overall success rate of only 40%. Shelby's handler was also the handler for a two-year old veteran dog, Dana. Dana had a 100% rate of finds. Although previous studies have indicated that handler error may contribute to the accuracy of the dog's find, the results of the present study seem to indicate that handler error and inexperience may not have played a significant part in the outcome of the study (7,14).

Handlers are frequently asked by police agencies to run trails that can be from minutes to months old. During the present study, aging of the trail did not appear to play a significant factor in the success rate of the veteran bloodhounds in finding the correct trail layer. When veteran dogs were tested on 48-h old trails, their overall success rate was 96%. The degradation of scent on a 48-h old trail does not appear to be noticeable to a well-trained bloodhound. Many factors may be involved in scent degradation along the path of travel. These may include half-life of scent material, pollutants, as well as additional cross trails made by people, cars, and animals. As the trail is laid down, there will be an initial concentration of scent deposited on the ground or other surfaces. The structural/molecular integrity of the scent material itself may be degraded with time. Previous studies using German shepherds have demonstrated that these dogs can determine the direction of a person's footprints up to 30 min old (15). However, shepherds were unable to follow the direction of prints that were 3 h old. Both studies concluded that the odor strength of the prints were not strong enough for the shepherds to perceive. It would appear that the olfactory capabilities of the bloodhound, pertaining to scent degradation, greatly exceed that of the German shepherd.

Another consideration in successful mantrailing is the climactic conditions. Wind speed, air temperature, and humidity may all come to bear on the success of a find. Prior to the dogs running the first two sets of trails the weather changed dramatically. Wind speeds were measured up to 60 mph prior to the second set of trails and 1.5 in. of rain fell prior to running the first set of trails. As wind blows and/or rain falls, scent will most likely be dispersed and the concentration along the path of travel reduced. Even with these potential weather problems, the veteran bloodhounds did not have any difficulties finding their trail layers. Scent line-up studies were previously performed indoors in a controlled environment (4,5,7,16,17). Unfortunately, the majority of mantrailing as well as cadaver recovery takes place outdoors. A preliminary study on cadaver recovery in cold weather has reported that air scent detection dogs have little to no problem finding scattered human remains after being trained in similar conditions (14). The veteran bloodhounds in the present study had been trained during various weather conditions in order to assist law enforcement agencies whenever the need arose.

In collecting human scent, the assumption is made that the scent is unique to every individual (17–20). Nevertheless, it has been suggested that human scent may be different depending on which area of the body the scent is collected (18). This same study utilized three different dogs to discriminate between their handler's scent and that of a stranger. One of the dogs in the study was a bloodhound. The bloodhound demonstrated less confusion or indecision when choosing the correct scent in comparison with the other two dogs. The authors suggest that appropriately trained canines may be able to detect individual scent regardless of where on the body scent is collected. Studies have since demonstrated the ability of well-trained dogs to match scent taken from various parts of the body to objects containing the same individual's hand scent (4). The dogs used in the present study were trained to scent off of multiple parts of the human body, as well as single locations. If a person's scent is present on the scent pad, but does not match scent found in close proximity to where it is presented to the dog, the dog should not trail. When the dog does not match a scent on the pad with a scent in the environment this is referred to by bloodhound handlers as a negative trail. In the present study the bloodhounds were each presented with a blank scent pad. Once presented with the blank, they all demonstrated a strong negative trail. When the dogs were presented with a scent pad containing human scent, every dog in the study picked up the trail immediately and followed the trail layer in the correct direction of travel. Unfortunately, on some trails the novice dogs were not able to follow their trails to the correct outcome and tag their trail-layer. Nevertheless the success of the veteran bloodhounds was remarkable.

Conclusion

This study documents the ability of well-trained trailing bloodhounds to scent discriminate between two individuals. The bloodhounds were used to follow human scent trails over commonly encountered terrains. The trails were cross-contaminated with additional incidental human scent trails. The weather conditions and cross-trail contamination varied greatly. The bloodhounds were able to effectively follow a quarry through and across numerous environments to an effective conclusion for investigative purposes.

A previous study on scent discrimination suggested that scent was area specific on the human body. In the present study a new device for scent collection was introduced. The scent transfer unit was found to be effective in the collection of scent without disturbing any other forensic evidence such as hair, fibers, or fingerprints. Scent was taken from various locations on the human body, not one specific area. These scent samples allowed the bloodhound to follow and find the matching trail layer.

The use of bloodhounds in law enforcement is well documented by the courts. Any evidence garnered by the bloodhound's trail could be used in a court of law to incriminate a suspect. However, until now only anecdotal evidence for their use existed. The present study creates a body of knowledge that can be used for investigative applications and courtroom testimony.

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