Canine Detection

1. INTRODUCTION

1.1. History of Working Dogs

For nearly 15,000 years[1] dogs have lived with and served humankind as companions, hunters, shepherds and most recently detectives.[2] Much of the relationship has been forged in warfare with dogs serving as sentries, guards, mascots, messengers, draft animals and scouts for the Egyptians, Greeks, Assyrians, and the Persians armies. In fact, the Roman legions trained entire formations of armoured attack dogs which were deployed against enemy armies.

Our appreciation of the canine scenting ability was slow to develop. As early as 1888, bloodhounds were employed by Scotland Yard for scent detection work in the "Jack the Ripper" case. Tracking dogs were also employed by the Nazi army to silently follow tracks of the British Special Air Services (SAS) officers who parachuted into Germany to collect intelligence prior to WWII. The British Army adopted this idea and incorporated this training into their war dog program which, in 1943, established "Recce Patrols," using human scouts and tracker dogs to locate the Japanese who were hiding on islands in the Pacific theatre.

It was from the pioneering work of the British police and military and their use of trained scent dogs, which they used in a limited capacity to detect land mines during World War I (WWI) and munitions caches in World War II (WWII), that the modern day detector dog developed.

Today, detector dogs have many functions—they assist law enforcement agencies in locating evidence, intercepting contraband and smuggled items, help police officers find criminals, lost children and the bodies of victims, are members of search-and-rescue teams, seek out land mines, and search for live victims of earthquakes and other disasters

1.2. History of Substance Detection Dogs

Although the Metropolitan Police Department's Scotland Yard had trained dogs as substance scent detectors as early as the mid-1950's, the use of dogs for the detection of illegal substances, such as narcotics and explosives, began in earnest the 1960's. The U.S. Department of Defense established a Military Working Dog Program in 1968 and, three years later, began training detector dogs for drug interception duties on ships and aircraft returning from South Vietnam.

U.S. Customs trialed an experimental narcotic detector dog training programme in 1970 which concentrated on training dogs to detect and respond to marijuana and hashish and, later that year, they expanded the targeted drugs to include cocaine and heroin. At the time, the success of training a drug detection dog on four odours was considered unlikely, and the Customs dogs gave the first example of the versatility of dogs in learning to discriminate several target odours.

Odour detection has become a focused area of research in recent years because of its importance to the forensic law enforcement and legal communities. It has been explored with both biological and instrumental detectors. Even with the advancements in the sensitivity of the "Electronic nose" however, detection or sniffer dogs are being used with increasing frequency to detect a variety of illicit and dangerous substances, such as accelerants, explosives, illegal drugs, [3,4,5] environmental hazards[6] and other contraband.[7] The acute sensitivity of the canine olfactory system has further enabled dogs to identify very specific scents and dogs have been trained to detect guns, cellphones, pipeline leaks, gold ore, contraband food, mold, and individual human scent.[8,9,10,11,12,13,14]

By the mid-1970's government agencies throughout the world were using detector dogs for specialized tasks. In New Zealand drug detector dogs are used by Customs at all entry points to the country and aviation security employ explosive detection dogs at airports. The protection of our borders from pest and pathogen incursion has seen a comprehensive biosecurity programme developed by MAF. As part of this programme, MAF use dogs to detect food and other organic material being brought into the country illegally. Detection dogs are also used in the conservation estates, where dogs have been trained to locate kiwi and other endangered wildlife and to track down predators such as rats, stoats and weasels.

2. CANINE DETECTION

2.1. Odour

An odour is a volatilized chemical compound which humans and other animals perceive through the sense of olfaction.[15] The perception of an odour is considered a two-step process: the physiological step and the psychological step. The physiological step is the stimulation of the receptors in the nose by the stimuli (odourants). The psychological step is where the receptor-impulses are processed by the region of the brain responsible for smell.

2.1.1. *Physiological Step in Odour Detection*

With respect to olfaction, dogs are considered macrosmatic because they rely almost completely on their sense of smell over their other senses.[16,17] Humans are considered microsmatic because the human sense of smell is much less developed and, as a species, humans rely heavily on other senses such as vision.

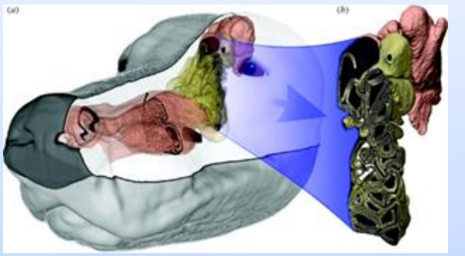

Figure 1. The canine nasal airway. (a) Three-dimensional model of the left canine nasal airway, reconstructed from high-resolution MRI scans. (b) The olfactory recess is located in the rear of the nasal cavity and contains scroll-like ethmoturbinates, which are lined with olfactory epithelium. The olfactory (yellowish-brown) and respiratory (pink) regions shown here correspond to the approximate locations of sensory (olfactory) and non-sensory (squamous, transitional and respiratory) epithelium, respectively.

The canine's olfactory sensitivity is far superior to that of a human's. Physiologically this is manifested in the larger olfactory system of the later where more than 40% of the canine internal nose is committed to olfaction.[18] Estimates for the size of the nasal chambers (shown in Figure 1[19]) and the sinuses, which serve as receptor areas for scent and the olfactory nerves, are between 18 and 150 cm^2 which is at least 6 times larger than the equivalent area in a human. The number of receptor cells resident in this area varies according to the size of the dog (Table 1), but for a typical working dog such as the German Shepherd, the number of olfactory sensory cells is estimated to be 220 million, this is 44 times the number found in humans.

Table 1. Comparison of the Canine and Human Olfactory Systems

Olfactory Attribute	Canine	Human
Nasal Epithelial Area (cm^2)	18-150	3-5
Olfactory Sensory Cells (million)	Bloodhounds: 300 German shepherds: 220 Fox terriers;147 Dachshunds; 125	5
Percentage of brain devoted to analyzing smells	40	1
Sensitivity	>10,000	1

The canine detection process of inhaling odourants followed by interpretation of the receptor-impulse is considered to be a dynamic system that occurs in less than one second. Due to the orientation of its nose (*i.e.* air is inhaled from the front and exhaled through side slits) a canine's sniffing frequency is around 5Hz, which is approximately 300 breaths per minute.[20] This volume of air inhaled through the canine nose is around 60mL/s.[21] At a frequency of 5Hz, this totals 300mL of air sampled each second. This efficient odour "collection" system combined with the large area and proliferation of receptor cells most certainly enhances the discriminatory ability of the canine.

2.1.2. *Psychological Step in Odour Detection*

The increased significance for the sense of smell over the other senses can also be attributed to the size of the olfactory bulbs in the canine brain and nearly 1/8th of the canine brain is committed to olfaction.[18] The olfactory bulbs of dogs are much larger in size than humans and comprise a larger percentage of the total brain mass, this results in the dog olfactory receptor repertoire being around 30% larger than in humans.[22]

The dynamics of the breathing combined with the large olfactory system, give the canine its ability to search and identify odors quickly and efficiently. Because of these factors, a canine's olfactory sensitivity can be as high as ten thousand times that over a human's olfactory sensitivity.

2.1.3. Odour Detection

The most remarkable aspect of the canine sense of smell is their ability to discriminate between complex mixtures of odours. Although dogs can detect odourants in quantities far lower than humans can, it is the accuracy with which they can discriminate among odours that is the primary quality making them invaluable for odour detection. This is referred to as "odour layering" and is the reason odours cannot be effectively masked from detection by the canine nose simply by attempting to disguise them with stronger odours. Because dogs can detect minute quantities of odourants, and because they are considerably more capable of discriminating between the individual molecular combinations that identify odourants, attempts to "fool" detector dogs by packaging contraband with other strong-smelling items are usually unsuccessful.

Another feature of the canine results in their ability to take their handlers directly to an odour source. As they move they pick up the "thread" of an odour and by casting back and forth with their heads, all the while constantly sampling the air, the dog compares the strength of scent received in each of its mobile nostrils and "calculates" the direction of increasing concentration. By following the molecular concentration gradient to its strongest point or source, the canine achieves a stereoscopic pinpointing of odour.

2.2. The Canine Detector

In general, a dog trains and operates as a partner with a person who is referred to as a handler or canine enforcement officer. Detector dogs are trained to alert the handler of a "find" in one of two ways. The Passive alert is used when dogs locate drug odour on people or in their possessions, commonly these dogs are employed in airports, prisons, workplaces and schools. In these cases, the canine will sit, point, or lie down to indicate the target odor has been detected. All explosives dogs are trained to give a Passive alert. A canine trained to alert Actively will scratch or bark to indicate the target odor has been located, these dogs are commonly used when searching buildings and outdoor areas. Search and rescue are typically trained to give an active alert when a human subject is located. Because the choice of alert is dependent on the search scenario, this may also affect the type of dog that is required.

Several types of dogs have been used for drug detection, of which the Labrador Retriever is perhaps the most common. Other types used have included Golden Retrievers, German Shepherds, Brittany Spaniels, German Short-Hair Pointers, and mixed breeds. Dogs have traditionally been obtained from animal shelters, however these dogs have very low success rates associated with training as search dogs. Approximately one shelter dog out of 1000 passes the basic tests that serve to admit a dog to a formal training program; of those that do pass, only a small fraction (perhaps 1 in 40–50) eventually pass a full training program and become certified search dogs.

Selection of the candidate detector dog is critical for both dog and handler success. While no selection method will be 100% accurate at selecting dogs that will be successful, the chances of developing a successful team are greatly increased by appropriate screening. The primary concerns during candidate screening are the presence of appropriate drives (particularly prey and play drives), tractability, temperament, and tenacity ("work ethic"). In a survey of Specialist Search Dog Handlers,[23] the ten most important characteristics of passive drug detection dogs were identified as the following (in order of importance);

1. Acuity of sense of smell,
2. Tendency to hunt by smell alone,
3. Health,
4. Ability to learn from being rewarded,
5. Friendliness to people,
6. Consistency of behaviour from day to day,
7. Level of aggression towards humans,
8. Tendency not to be distracted when searching,
9. Incentive to find an object which is out of sight, and
10. Stamina.

The relative importance of these characteristics and their ideal levels varied dependent upon whether dogs were used for explosives, active or passive drugs work.

2.3. Substances Detected

As stated above, dogs can, in principle, be trained to detect any type of drug or any type of volatile chemical substance. However, a single dog cannot be trained to detect all drugs. There is always a trade-off between the number of drugs or other substances the dog can detect and the proficiency with which the dog detects one particular substance. Typically, detection dogs are trained to detect up to nine different substances. Dogs have proven to be very effective at locating some of the most widely abused and economically important illicit drugs, including (but not limited to) marijuana, cocaine, heroin, and amphetamines.

It should be pointed out that the detection of a drug by a dog does not necessarily mean that the dog detects the active agent characterizing the detected substance. In many cases, the scent of an illicit drug is comprised of a variety of volatile organic compounds (VOCs) that are present in the sample in addition to the actual parent compound.[3,25,24] Table 2 lists some illicit drugs and their dominant odours components. In fact, studies have shown the contaminant, methyl benzoate, is the dominant odour signature in the headspace analysis of cocaine and the compound to which the canine detector alert.[3,25,26]

Although, dogs may not detect a substance if it was manufactured in ultrapure form, this, however, can also be an advantage of canine detection. Unlike a technology-based trace detector, a dog will not alert on a minute amount of residue that has been present for a long time because the volatile impurities would have dissipated.

Table 2 - Primary and secondary odour compounds for drugs.[8,24,27,28,29,30,31,32,33,34]

Forensic Specimen	Headspace Components	Primary Odour	Secondary Odour
Cocaine	Methyl Benzoate Benzoic Acid	Methyl Benzoate	Benzoic Acid
Heroin	Acetic Acid	NA	NA
Methamphetamine	Benzaldehyde Methamphetamine Phenyl-2-propanone	Benzaldehyde	1-Phenyl-1,2-propanedione 3-Phenyl-3-buten-2-one
3,4-Methylene Dioxymethamphetamine	Piperonal 3,4-(Methylenedioxy)-phenyl-2-propanone	Piperonal	Benzoic Acid
Marijuana	Polycyclic Aromatic Hydrocarbons	β –Pinene Caryophyllene	Limoene Myrcene

2.4. Strengths and Limitations

As with all detection techniques, canine detection has certain strengths and limitations. The greatest strength of canine detection are high mobility and the ability to track a scent to its source. The ability of a dog to rapidly screen a large area and to follow a scent gradient until it locates the object from which the scent is emanating greatly exceeds those of technology-based “sniffer” systems such as Ion mobility spectrometer (see Appendix 2). For this reason, dogs are ideally suited for drug detection applications that have a significant search component. These include searches of buildings, property and people; large and small vehicles including cars, trucks, ships, and aircraft; and large containers such as shipping crates. A dog can usually screen a large vehicle in about 5 min and a small vehicle in as little as 1 min. These times compare favourably with the screening times needed for other methods such as physical search by security guards or x-ray based vehicle portals. Dogs can also screen large amounts of luggage and mail, with reported screening rates of up to 2300 kg of mail in 30 min.

As miniaturization progresses technology-based “sniffer” systems are becoming easier to move around, however these systems are still a long way from competing with canines in being able to follow a scent to its source. Furthermore, a “sniffer” response is usually a single discreet reading at a given point, and this reading does not vary instantaneously as the system is moved closer to or farther from the source. These facts make it extremely unlikely that canines will be rendered obsolete at any time in the near future.

The effectiveness of canine detection in real-world settings is exemplified by some statistics on seizures made as the result of detections by New Zealand Customs canines. In 2004, the Customs Service Drug Detector dogs were trained to detect pseudoephedrine. In the four year period to 2008, over 100kg of pseudoephedrine was detected by the dogs and seized; this amount of precursor would have been used to make approximately $25 million worth of crystal methamphetamine.

Drug-detecting canines do have limitations however; the most significant of these is the short “duty cycle.” A dog can typically work for only about 1 h before requiring a break. This is in contrast to many technology-based systems that, in principle, can operate 24 h a day. For this reason, dogs are usually not the detection method of choice for applications that involve extended periods of repetitive screening. However, provided that the dogs have an opportunity to rest periodically, canine detection is still useful in random screening situations, or for alarm resolution. Technology based sniffer systems do offer the added advantage of drug identification, a feature that the canine cannot communicate to the handler.

Another issue faced in canine detection stems from the unconscious influence of the dog handlers on their canine partners. Dogs, being excellent readers of body language, can pick up on the preconceptions and expectations of the human which may, unintentionally, lead to a false positive alert. This can occur when both the human and the dog are highly trained professionals.[35]

Finally, being a living biological organism, the dog's performance may vary somewhat due to health and weather conditions.

Table 3 – Comparison of Technology-based "sniffers" and canine detectors

Aspect		Instrument	Canine
Effectiveness	State of scientific knowledge	Relatively mature and developing	Late emerging
	Molecule Detected	Drug of interest or adduct or fragment	Uncertain in most cases, can be contaminants
	I.D. of target	Presumptive I.D. possible	No
	Selectivity	Sometimes problematic	Very good
	LOD	Compound dependent (nanogram levels)	Compound dependent (nanogram levels)
Operations	Operation Time	24 h/day, in principle	1–2 h before rest
	Scent to source (Mobility)	No - Difficult with present technology	Yes - Natural and quick
	Overall speed of detection	Area dependent	Generally fast
	Environmental Conditions	Not affected	May adversely affect
	Operator/handler influence	Less of a factor	A potential factor
	Calibration standards	Can be run simultaneously	Run individually (i.e. dog trained on individual scents)
	Re-calibrations	Daily	Weekly (training)
	Performance issues	Electronics and mechanical	Same as any living organism
Costs	Purchase Cost	Moderate to high - \$20K - \$100K	Low - S1K - \$10K (depending on level of training)
	Annual costs	Low to moderate - ca. \$4000 (service contract)	High (including training and handler)
General	Courtroom acceptance	Generally unchallenged	Sometimes challenged
	Intrusiveness Variable	(apprehensiveness not uncommon)	Often innocuous
	Best Application	Checkpoint screening	All Search

Table 3 compares some of the strengths and weaknesses of using canines and technology-based "sniffer" equipment. These two screening methods tend to have complementary strengths, so it is often advantageous to have both capabilities on hand and to use either or both depending upon the circumstances.

Overall, canines are still the most versatile and reliable detectors available, however improvements can be made in the way the dog team interacts and efforts are underway to further advance the effectiveness of the canine detector unit, these include:

- Development of a robust scientific literature in the area of canine detection will improve performance as well as courtroom admissibility.
- Development of an International Best Practice Standard that will improve the reliability of detector dog teams *e.g.* the Scientific Working Group on Dog and Orthogonal detector Guidelines.
- Canines serving as models for improved instrumental detectors used in combination with dogs to maximize location of forensic evidence.
- Availability of field calibrants, including controlled odour mimic permeation systems (COMPS) that will allow for improved canine performance and field instruments with the ability to critically compare available detectors.

2.5. Costs, Training, and Additional Information

Compared with technology-based "sniffer" systems, drug-sniffing dogs have a low purchase cost but typically high maintenance costs. Procurement costs for a single dog are typically in the range of $1K to $10K depending upon the supplier and the dog's level of training. These costs compare favourably with technology-based "sniffer" systems, which typically cost in the range of $20K to $100K. Costs for feeding the dog and veterinary costs are relatively minor: typical values are approximately $1K per year and $600 per year, respectively. The main costs associated with maintaining a canine are the training costs, especially the salary costs associated with the handler and supervising trainer.

The initial training, after a dog has been acquired, typically lasts 3 months, involves at least two people, and costs an additional $6K to $12K. Once initial training has been completed, the dog and handler continue to work and train together as a team, and a rigorous training schedule is maintained. Generally for a detection dog, training is required on a weekly basis. It is estimated that the cost of maintaining one properly trained detection officer/canine team is approximately $165K per year. Most of this cost is the salaries and overheads associated with the handlers.

3. SUMMARY

Trained canines represent one of the most widely used and time-proven methods for the detection of illicit drugs. Like the technology-based systems discussed in Appendix 2, dogs are trace detectors, but they can also apply their scenting abilities to the detection of bulk quantities of contraband. This versatility, combined with the attributes listed below, have made the canine drug detection team the method of choice for a variety of applications that have a significant search component.

Reasons why the trained Canine make such good Detectors;

- In principle, dogs can be trained to detect any type of drug that emits a vapour.
- Dogs are mobile, and can take their handlers directly to an odour source by following the molecular concentration gradient to its strongest point or source.
- Dogs are able to discriminate specific scents among complexes of many overlapping scents.
- Dogs sample air in an extremely efficient manner and process the receptor signals in a superior fashion.

All of which make the canine Dog team a wonderful odour detection and location device.

4. GLOSSARY OF TERMS

Alarm Resolution: the process by which the tester determines whether the signal is the result of a suspect item being present during analysis.

Canine detection: the detection of drugs, explosives, or other types of chemical compounds through the use of a dog that is trained to sniff out these substances.

Contraband: any item or material that is smuggled into an area or facility where it is prohibited. For example, in a prison contraband might include weapons, explosives, and narcotics.

Drive: prey drive (the tendency to chase a moving object), and hunt drive (the tendency to search or "hunt" for an object when it stops moving and disappears from sight).

Handler: the individual who works as a partner with a dog that is trained to sniff out drugs or explosives.

Interference, interferent: any chemical compound that serves to mask the presence of a drug from a given drug detection system.

Particulate: contamination in the form of residual particles attached to clothing, furniture, luggage, skin, or some other surface. Particulate contamination of drugs is often deposited in fingerprints.

Probability of detection: the probability that a certain system can detect a certain amount of a given type of drug under a particular set of conditions. If a positive detection is always made under these conditions, the probability of detection would be 100 %. If a detection is made only half the time, the probability of detection would be 50 %. In general, a large number of experimental trials must be conducted to accurately determine this parameter.

Random screening: performing drug detection on a randomly chosen selection of a large number of people or items. For example, a security checkpoint might screen every fourth person entering a secure facility. Random screening has the advantage of providing a deterrent against the illicit transport of drugs into a given area, while being less time consuming than uniform screening.

Specificity: the ability of a chemical analysis technique to distinguish similar chemicals from one another. The greater the specificity, the more certain the identification of a particular compound.

Spotter: in canine detection, a secondary trainer who works with the canine and the primary trainer (i.e., handler).

Throughput rate: the rate at which a detection system can process the people or objects being screened. It is generally expressed in units such as people per hour for a personnel portal or bags per hour for an x-ray baggage scanner.

Uniform screening: performing drug detection on all persons or items passing through a given security checkpoint and applying the same screening process to all of them. Uniform screening is contrast to random screening.

Vapour pressure: the quantity of drug vapour (usually expressed in concentration) of a particular drug compound that exists above the compound in air at equilibrium under a specified set of conditions.

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