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Narcotic detection dogs: an overview of high-performance animals

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ABSTRACT: *Considered one of the best odor detectors, dogs go through a rigorous selection and training process. Based on learning theories, modern techniques are used for dog training, respecting individual characteristics, efficiency, and well-being. Since narcotics detection work is perceived as a "play" for the dog, in practice, this promotes a high use rate in the service. The performance of handlers influences the work of the dogs, and well-trained and well-run dogs must work comfortably and accurately. This paper aimed to review the aspects related to the selection, training, and performance of narcotics detection dogs.*
Key words: *animal behavior, drug detection, ethology, narcotics, working dog.*

Cães de detecção de narcóticos: uma visão geral dos animais de alto desempenho

RESUMO: *Considerado um dos melhores detectores de odores, os cães passam por um rigoroso processo de seleção e treinamento. Baseado nas teorias da aprendizagem, utilizam-se técnicas modernas para a formação do cão respeitando suas características individuais, eficiência e o bem-estar. Uma vez que o trabalho de detecção de narcóticos seja entendido como uma grande brincadeira para o cão, isso na prática promove um alto índice de aproveitamento no serviço. O desempenho dos condutores influencia o trabalho dos cães, que bem treinados e bem conduzidos, devem trabalhar de forma confortável e precisa. Este trabalho objetiva revisar aspectos relacionados à seleção, formação e desempenho dos cães de detecção (K9) de narcóticos.*
Palavras-chave: *Cão de trabalho, comportamento animal, detecção de drogas, etologia, narcótico*.

INTRODUCTION

Man has been interacting with dogs longer than with any other domestic animal. There are 500,000-year-old *Canis lupus* hominid sites in Kent, England. At the beginning of this domestication, there was a mutually advantageous relationship between wolves and humans in sharing the hunt (GRAJDJEAN, 2001). Since then, the evolution of dogs has been occurring rapidly and continuously, and reports of fighting dogs, sheepdogs, and guard dogs could already be found in the Roman Empire, such as *cave canem* warning signs, which were the first signs of "beware of the dog" (BEAVER, 2001).

Detection dogs (K9) are widely used by the police, armed forces, and customs in most countries. Such use encompasses searches for people, narcotics, weapons, ammunition, and explosives. The US Pentagon, for example, has a budget of millions of dollars for the detection of bombs by dogs. The US military initially located about 50 percent of improvised explosives planted in Afghanistan and Iraq; this number increased to 80% when US and Afghan patrols began using detector dogs (ACKERMAN, 2010).

One of the characteristics that make this tool so widespread is the enormous olfactory ability of dogs. With respect to humans, dogs have a sharper olfactory mucosa, with a larger amount of olfactory receptors, which project to a large olfactory bulb from which information reaches other areas of the central nervous system; in all these regions, the

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number of cells for processing olfactory information is considerably higher than the number reported in humans. The internal folding of the nasal cavity, the elongated nostrils, and sniffing contribute to the dogs´ superior olfactory sensitivity (LOURENÇO & FURLAN, 2007).

Another important reason for using sniffer dogs is the financial cost. For example, a tool used in non-invasive surveillance, but without the accuracy of a detection dog, is the scanner, and on the Brazilian market, there are several types of scanners ranging from US$ 70,000.00 to US$ 357,000.00 (www.smithsdetection.com), while a good detection dog can be purchased for about US$ 6,000.00. Also, unlike a scanner, a dog can move and work in the most diverse surveillance environments.

Overall, detector dogs still represent the fastest, most versatile, and reliable real-time explosive detection device available. Instrumental methods, while continuing to improve, often suffer from a lack of efficient sampling systems, selectivity problems in the presence of other interfering chemicals, and limited mobility/tracking ability (FURTON et al., 1997; LORENZO et al., 2003). Considering the importance of international narcotics trafficking, this paper aimed to review aspects related to the selection, training, and performance of narcotics detection dogs.

Behavioral characteristics

A working dog performs tasks to help their human companions. There are dog lines that have been developed to be working dogs, as well as breed groups that can be trained and are appropriate for specific tasks. Working dogs must demonstrate a strong drive (impetus), which is essential for all detection work and is already observed in puppies that have a motivation to chase toys and to follow moving objects (United States Police Canine Association, 2018).

The concept of "drive" is a dog's propensity to exhibit a behavioral pattern when confronted with particular stimuli, clearly defined as willingness, vigor, or enthusiasm to develop a certain behavior (SWGDOG, 2011). However, this is a term still widely discussed by experts. The basis of the detection work is the so-called "prey drive", and some authors have differentiated it from the "hunting drive", which is the functional behavior in food acquisition. The actions of sniffing, fetching, fighting with the prey, and chasing are characteristic of this desire for hunting, which can be observed when a dog plays with a rubber toy or a ball. To get a good example of the perception of what triggers the behavior, one can just watch a wolf on a hunt; the behavior is triggered by the prey, which moves to escape the hunter (RAISER, 1996).

In wolves, as in dogs, the drive is born with the puppy and is intensified in its maturity. Therefore, it can be changed through learning and training processes (RAISER, 1996). Ideal dogs of any age will persistently chase and search for objects in a new and adverse environment (such as a slippery floor or rising on an unstable base). The best candidates for the detection job should always be selected (United States Police Canine Association, 2018).

There is a large behavioral variation among individuals across the entire dog population. Most working dog programs have recognized this fact and attempt to quantify behavior by using standardized tests (WILSSON & SINN, 2012). When selecting a dog that will be used in the various fields of detection to comply with training protocols and to be efficient at work, the focus is on a dog with true "fascination" with the toy, having a stable character, being a born hunter, with the will to overcome difficult obstacles (SWGDOG, 2011).

A questionnaire of 180 dog trainers in the UK based a ranking on the desirable characteristics of detection dogs and identified 30 characteristics considered important in the selection of specialists. The most important ones were acuity of sense of smell, willingness to look for an object outside the field of view, health, tendency to hunt alone, and endurance. There were also several characteristics (7/30) that were undesirable, such as body sensitivity, noise reactivity, fears, motivation to obtain food, ease distraction, and aggression to humans and other dogs (ROONEY et al., 2009).

A suitable detection dog is a medium-sized individual with a high degree of agility, a strong motivation to play, a high level of intelligence and obedience, and independence when working without a guide. Although, certain races generally have traits proposed as ideal, this does not mean that each individual will be suitable for this work, nor does it mean that in any other race, there will be suitable individuals. Therefore, the mass breeding of the most appropriate specific breeds will have no future, but rather the breeding of specific individuals with traits necessary for successful detection dogs (JAMIELSON et al., 2018).

This variation in the detection of dog performance often does not correlate with the breed and has not been rigorously tested. Few pieces of research have compared dog breeds for their suitability as detection dogs, and even fewer studies have concluded which characteristics should be

selected. This is important considering the number of dogs produced for the detection work (JAMIELSON et al., 2017). Furthermore, the findings of MACLEAN & HARE (2018) suggested that individual differences in cognition contribute to variation in working dog success, and that objective canine cognition measures can be used to improve the processes by which working dogs are evaluated and selected.

Behavioral modeling depends on learning, but learning is only possible to the extent that an animal is biologically equipped and prepared to learn (LINDSAY, 2000). According to PAVLOV (1927), sensory inputs stimulate the nervous system in two opposite directions: arousal or inhibition. PAVLOV (1927) also studied the physiological meaning of reflexive behavior in terms of psychic balance, stating that "Reflexes are the elementary units in the mechanism of perpetual equilibrium." Classical or responding conditioning or Pavlovian conditioning is the most basic form in which the animal learns about changing contingencies of stimulus in the surrounding environment, adjusting to it through the anticipated action of various preservative and protective mechanisms.

Through classical conditioning, innate reflexes are brought under the prediction of a causally independent (neutral) control, related to the unconditioned stimulus-response event of the temporal form, contiguity, and spatial orientation. Such learning is usually beyond voluntary control and is largely (but not entirely) independent of the consequences generated by responses (e.g., rewards and punishments) (MEYER & LADEWIG, 2008).

In classical conditioning, the unconditioned stimulus (UNS) results in an unconditioned response (UNR), being associated with glandular or smooth muscle action. Food is an example of a UNS when presented to the dog. It responds by salivating, with salivation being a UNR. This conditioning requires no training and is a predictable outcome: UNS → UNR. It is called a neutral stimulus (NS) when it alone has no influence on the dog's behavior. However, if it is associated before or at the same time as UNR, the animal will make an association between NS + UNS = UNR. If this action is repeated a few times, the neutral stimulus becomes a conditioned stimulus CS, which now alone can elicit the same UNS response. The response is called the conditioned response (CR) when it results from the apprehended stimulus (BEAVER, 2001).

Among the learning processes, the most used one is the operant conditioning, through which the probability of occurrence of a certain behavior is increased or decreased, organizing its consequences (SKINNER, 2015).

Animals endowed with an evolved central nervous system are able to learn, which is the basis of the consequences of their actions. Success acts as a reward or reinforcement, while mistakes end in punishment and may end up in extinction (LORENZ, 1995). Depending on whether the consequence of the behavior is the addition or removal of a stimulus and whether the likelihood of the same behavior is increasing or decreasing, operant conditioning is divided into four quadrants: (a) positive reinforcement (R +), where a behavior results in a stimulus (pleasant) and the likelihood of increased occurrences; (b) negative reinforcement (R −), where a behavior removes an (unpleasant) stimulus and the probability of its occurrence increases; (c) positive punishment (P +), where a behavior results in an (unpleasant) stimulus and the probability of its occurrence decreases; and (d) negative punishment (P –), in which a behavior removes a (pleasant) stimulus and the probability of its occurrence decreases (FERNANDES et al., 2017).

Generally, in operant conditioning, animals learn to perform specific behaviors because they result in the avoidance of unpleasant stimuli and/or the achievement of pleasant stimuli. However, according to LORENZ (1995), not all processes in which an animal gains information through its own activities represent operant behavior. This term should be used only when the organism learns to select, from among several available behaviors, the one that fits the immediate situation (LORENZ, 1995).

LORENZ (1995) further explained that when we say that an animal has become domesticated, it has become accustomed to the previously eliciting escape stimulus, with an association with the perception of proximity to humans. COBB et al. (2015) reported that the affective state may strongly influence the results of operant conditioning and that shyness varies with the age, breed, and sex of dogs.

Over a brief period of 3 to 16 weeks of age, most dogs will most likely learn more than in their entire lives, forming a lasting emotional and cognitive scheme of a social and physical environment. At about 4 months of age, the rate of conditioned reflex formation begins to slow down, probably not because the nervous system deteriorates, but because what the puppy has already learned begins to interfere with new learning (LINDSAY, 2000).

A study of labrador retriever dogs showed that post-learning play improved the training performance required to relearn the same task 24

hours after initial instruction (AFFENZELLER et al., 2017). Nothing is more motivational and important in dog training than the game, and the playful interaction continues only as long as players remain friendly and confident. Playing and training are not contrary things but complementary activities (LINDSAY, 2000).

Performance

Only 50% of dogs bred and selected or considered fit to work or compete can achieve operational performance. This "waste" is a financial and sustainability issue, with considerable space for improvement and subsequent economic advantages, such as genetic selection, young animal breeding, recruitment and evaluation processes, housing and management, training techniques, handler education, and management. In other words, all aspects of the production system can affect the quality of the final product: the working dog (COBB et al., 2015).

Undoubtedly, one of the biggest challenges to be overcome in the range of work of detector dogs is how to evaluate dog performance, especially in an objective manner. According to HELTON (2009), dogs are complex biological systems; they are not well-built mechanical devices; they have particular characteristics that make generalizations inherently difficult. ZIV (2017) added that their performance is affected by various environmental, physiological, and psychological factors.

In addition to individual differences between dogs, there is not enough literature to assess dog capabilities; however, HELTON (2009) suggested two objective measures: speed and accuracy. Both a very fast dog and a slow dog can affect work efficiency. A fast detection dog can be of paramount importance in congested areas and cannot be disrupted, and can also assist other mechanical detection systems. However, its accuracy of odor response may decrease. MICHELETTI et al. (2016) explained that speed could quickly tire the animal when it begins to pant. As the dog cannot gasp and sniff at the same time, the gasp decreases the smell efficiency.

A study of four screening dogs suggested that during the decision phase, the dog behaves in a way that provides constant detection variables as far as possible. These variables include the distance between the source of the odor and the nose, the volume of each inhalation, and the frequency of smelling (THESEN et al. 1993).

Sensitivity and specificity

Detection accuracy involves measuring correct indications and false alerts. Two main parameters can be calculated: sensitivity = ratio of hits to (hits and false alerts), and specificity = ratio of correct rejects to (false alerts plus correct rejects). It is important that no targets remain undetected, and no material other than the target is indicated by the dogs. It should be noted that false alerts may not always be the dog's fault, but may be the result of a series of false alerts (JEZIERSKI et al., 2014).

False alerts may be the result of handler actions, as described by LIT et al. (2011), in their research that evaluated 18 certified teams (handler and dog) from various agencies. In this study, handlers were induced to believe that there was a target odor in certain locations; the result was a high rate of false alerts, confirming that handler influence affects team performance. In another study, 1120 samples were verified by seven dogs. Overall, the seven dogs correctly identified 258 of 280 samples (92.1% sensitivity) and falsely indicated samples in 22 cases. Of 840 negative samples, 818 were correctly identified as true samples (97.4% specificity), and 22 negative samples were falsely identified as positive samples (JOHNEN et al., 2013).

As a detection parameter for this research, the training protocol of the Dog Detection Center (CNK9) of the Brazilian Aduana is composed of 4 phases. Phase one of the protocol is the acquisition of the dogs and phases two, three, and four are of training where the objectives to be reached will be: to link the target odor to the object of the reward in the detection boxes, to initiate the searches in the odor panel and advanced training in the areas of Customs, respectively.

The acquisition of the CNK9 dogs is carried out by a government bidding process, and only registered suppliers can participate. Dogs must be between 12 and 24 months of age, present certificates, and laboratory exams showing that they are healthy (hemogram, free of infectious diseases and parasites) and radiographic exams of coxofemoral dysplasia and elbows. The dogs are submitted to socialization tests in several environments, such as airports, ports, cargo sheds, and moving vehicles. They should not demonstrate fear or any aggression type, and during all of the tests, the dogs should maintain high possessiveness towards the toy that will be hidden in several places.

After the purchase of the dog, the first phase of training for detection begins, and this is carried out within the area of CNK9 using the detection boxes. This phase is carried out in 20 training sessions. The objective of this phase is the association of the odor target with the toy of the dog; the dogs should also learn the posture of indication "passive". In this

training, the odors are separated by groups of drugs. In a box, it will be put together cocaine and marijuana and, in another box, together with the LSD and the ecstasy; all of the drugs used by CNK9 have been previously analyzed.

The second phase of training consists of teaching the dogs the principles of a search. In this phase an odor panel is used, where the target odor that is now already well consolidated in the understanding of the dog will be hidden. This training is accomplished in 15 training sessions. In this phase, the dog learns to find the odors in a separate way, each odor at once. It is also the time to differentiate between other odors, as for instance chemical products of easy access to the public.

In the third and last phase of training, the dogs are already able to search for and indicate the target odor in a precise way. In this phase, the dogs are taken to the Customs workplaces and are trained in real simulations like vehicles, luggage, containers, etc. This phase lasts for 40 training sessions. The whole process between purchase and training takes around six months.

The subject (narcotics) is highly sensitive, and the work with the detection dogs is usually associated with the intelligence personnel of each institution; also, this information involves risks for the handlers and the dogs. Some information is confidential, and if improperly disclosed, it may jeopardize all previous intelligence work.

Odor

The dog perceives the odor as a result of the odorant binding to olfactory receptors located in the olfactory mucosa in the nasal epithelium. Odorants are molecules that elicit an olfactory response. A study under controlled conditions has confirmed that dogs can easily master at least 10 odors simultaneously (WILLIAMS & JOHNSTON, 2002).

Research has shown that dogs are trained to recognize and alert the volatile odor of drug-associated chemicals rather than the original drug; targeted substances for detection usually involve multiple chemical components. FURTON et al. (1997) demonstrated, for example, that methyl benzoate, a by-product of cocaine, is the chemical that dogs alert when detecting cocaine, as well as piperonal, heliotropin (fragrance fixer) in MDMA (Ecstasy), and the main components detected in the cannabis headspace (α-pinene, β-pinene, myrcene, limonene, and β-caryophyllene). For this reason, according to MACIAS et al. (2008), the use of dogs may be justified in indicating non-illegal products. In the study, pseudo-odors were tested and none were reliably detected. This may stem from the fact that the suppliers of these products use components that do not create the same volatile odor compounds as the actual smuggled compounds.

Considering the experience of the present authors, the pseudo-odors have not been used, due to failures. The odors used for the training and formation of CNK9 dogs come from real substances, of the target narcotics themselves, and previously analyzed with a degree of proven purity.

In another study by the Polish police, with 1219 experimental searches, the results in order of difficulty were as follows: cannabis, hashish, amphetamine, cocaine, and heroin. Regarding the persistence of residual odors, hashish odor lasted longer and was indicated by dogs in 100% of searches performed 24 hours after hash removal and in 80% of searches after 48 h. The percentage of indications of hashish odor residues after 24 h was even higher than that for fresh odor emitted by samples that were present at the search site. A significantly lower detection rate was reported for residual heroin odor, which almost undetected after 48 h (JEZIERSKI et al. 2014).

Welfare of narcotics detection dogs

An individual's well-being is his state in relation to his attempts to adapt to his environment (BROOM & JOHNSON, 1993). In any welfare assessment, it is necessary to take into account individual variations when facing adversity and the effects that adversity has on animals. To have adequate welfare, an animal must be physically and psychologically fit (ROONEY & BRADSHAW, 2004), and there is a link between welfare and the work of stressed dogs, which tend to perform poorly during searches.

Dogs that work in military organs are bred and trained for extreme and complex behaviors. The most common reason these dogs fail in training programs involves some aspect of anxiety, which seems to interfere with their ability to learn complex tasks and to adapt to changes. They may become excessively reactive, aggressive, or nervous. Anxious dogs are eventually rejected during training programs (OVERALL & DUNHAM, 2005).

Whenever dog housing is considered, the needs associated with social and environmental enrichment deserves particular attention, and many kennel environments do not meet the animals´ needs (e.g., social contact, control over their environment, proper exercise). Therefore, dogs may have difficulty

coping with the environment and may experience negative emotions (ROONEY & BRADSHAW, 2004).

There is a belief that working dogs cannot receive the toy at any other time than during work. A study was conducted in which dogs received the "kong" toy with food inside. Handlers tend to base their evaluations on their dog's performance during regular training sessions and indicated that enrichment in an environment kennel did not affect the dog's motivation to play or retain a toy used as a reward during training. Therefore, these diverging motivations mean that providing kennel enrichment providing this kind of toy had little or no effect on a dog's motivation to play or work for a reward. Dogs do not use kong as toys, but as a feeding device. Once emptied, dogs later did not return or play with the device within the observation time (GAINES et al., 2008).

Cortisol accounts for much of the quality of the stress response. In the short term, it mobilizes energy, but its overproduction contributes to muscle wasting, hypertension, low immunity, and low fertility. Generally, during work, the detector dogs are housed in transport boxes to await the operation or even to be transported. This confinement in the box is a relevant factor for increasing cortisol levels. A study conducted at the Central Kennel of the Federal Police of Brazil showed that the 3-hour confinement was sufficient to increase cortisol concentrations. Subsequently, cortisol concentrations decreased after the completion of the detection tasks, indicating that the longer the confinement time, the higher the cortisol concentrations and that the search and detection work probably functions as a welfare and balance promoter of the dog (MACHADO et al., 2018).

The methods by which dogs are trained vary between methods that primarily involve highly controversial negative reinforcement and positive punishment (methods based on aversion) and methods primarily based on positive reinforcement and negative punishment (reward-based methods), as in FERNANDES et al. (2017). Studies have also indicated that e-collar training routines pose a risk to animal welfare. Immediate effects of training give rise to behavioral signs of distress in pet dogs, even without significant differences in corticoid levels (COOPER et al., 2014). In a study of Belgian military dogs, it was concluded that dog handler teams should train more regularly and adopt training systems that depend on the use of more positive training methods, more frequent training, and better education of trainers regarding learning theory (HAVERBEKE et al., 2008).

Some dogs are trained with reward food. But for this methodology, the dogs are deprived of food, that is, they are left without food to work. This method is based on the survival instinct, where, in theory, the animal has to work (hunt) to survive. We do not agree with this methodology, and we do not use it in our training. Other trainers at the moment of the detection training use positive reinforcement, but these same trainers use methods of negative reinforcement in training for obedience, which ends up influencing the dogs negatively in the detection work.

SARGISSON & MCLEAN (2010) investigated the effect of low, medium, and high levels of reward on the performance of six dogs searching filters for explosive odor. In this study, the medium and high reinforcement rates produced significantly higher hit rates than the low reinforcement rate condition, but that the medium and high conditions did not differ significantly from one another in terms of hit rate. No significant difference in false-alarm rates was found across the three reinforcement conditions. However, the false-alarm rate was lowest during the medium-reinforcement rate condition for four of the six dogs, and for the mean.

ZIV (2017) reviewed research, observational studies, and interventions and showed that the use of aversive training methods (e.g., positive punishment and negative reinforcement) could endanger the health of dogs. A survey of dog owners by ROONEY et al. (2009) reported that owner punishment was associated with an increased incidence of problem behavior. Similarly, HAVERBEKE et al. (2008) reported that military dogs punished by aversive training techniques had lower-performance scores.

CONCLUSION

According to the present overview, narcotic detection dogs must demonstrate a strong drive, and the most important characteristics are acuity of sense of smell, willingness to look for an object outside the field of view, health, a tendency to hunt alone, and endurance. A suitable detection dog is a medium-sized individual with a high degree of agility, a strong motivation to play, a high level of intelligence and obedience, and independence when working. The training of a narcotic detection dog is a challenge, and the affective state may influence the result of conditioning. Shyness varies with the age, breed, and sex of dogs, and false alerts may be the result of handler actions, which can influence the team performance. The welfare of dogs is

important to the training and formation of a narcotic detection dog, and it is necessary to take into account individual variations. The dog must be physically and psychologically fit. For the dog, the detected odor is the result of the volatility of drug-associated chemicals, and this can involve multiple chemical components.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors contributed equally to the manuscript.

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