CANINE DETECTION CAPABILITIES:

OPERATIONAL IMPLICATIONS OF RECENT R & D FINDINGS

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Background

Dogs have been successfully used for many years by military and law enforcement agencies to detect varied substances. However, the science underlying their olfactory detection capabilities has been slow to accumulate and even slower to impact operational training and deployment protocols. Since 1989, the Institute for Biological Detection systems (IBDS) at Auburn University has worked to ameliorate this problem. A number of recent laboratory and field studies have begun to reveal the dog's olfactory sensitivity, how it recognizes substances, and how it performs in the field. This paper summarizes selected findings and their possible operational consequences.

Olfactory Sensitivity

A series of studies was conducted under behavioral laboratory conditions to determine canine sensitivity to various substances (Johnston, 1997), and additional sensitivity studies are in progress. Such studies require precise control of vapor generation and delivery, aided by analytical analysis of vapor characteristics. The testing protocol is designed to optimize the dog's olfactory detection performance.

The dog's limit of detection (absolute threshold) has been determined for four compounds to date. These sensitivities are in the tens of parts per billion (ppb) for methyl benzoate, cyclohexanone, and nitroglycerin. The sensitivity to DMNB, a detection taggant, is much greater at 500 parts per trillion (ppt). There is no reason to believe that these thresholds are not representative of thresholds for other compounds.

Because of the nature of the laboratory preparation, these detection limits should be taken as the best that dogs are capable of for these substances. It is not possible to make comparable measurements under operational conditions because of the difficulties in controlling and measuring vapor samples. Nevertheless, it is clear that dogs are as sensitive, or more sensitive, to at least some substances as are instrumental systems. Of course, for dogs, vapor collection, signal processing, and detection cycle times are essentially instantaneous.

This level of olfactory sensitivity plays a key role in the dog's ability to use concentration gradient information to locate an odor source. It is reasonable to presume that a dog coming into contact with the periphery of a vapor plume will initially encounter only relatively low concentrations of target compounds. Although the means by which spatially dispersed variations in concentration guide rapid movement toward the odor source has not been studied, it is clear that they are extremely efficient in using this information. That is, minimal sampling effectively guides rapid locomotion to the odor source.

All detection tasks require that dogs respond to the lowest detectable concentrations of the target odor because it is such initial samples that can then prompt them to move in directions that lead to higher concentrations. Although trainers and handlers tend to focus on the quantity of training aids used as defined by weight, dogs respond to training aids in terms of the vapor concentration of signature compounds, not weight. It is therefore important that all dogs are trained to pay attention to a range of concentrations, including even the faintest whiff of target odors, regardless of differences in search scenarios. The findings from these sensitivity studies suggest that this approach will make the best use of dogs' impressive olfactory sensitivity.

Odor Discrimination Capabilities

It is important to note that limits of detection are only one of the critical components of canine detection performance in the field. It may be that dogs' ability to discriminate among target and non-target odors is even more impressive than their sensitivity.

Two studies were conducted that highlight this discriminative capability (Johnston, 1999). These studies, conducted under behavioral laboratory conditions and using different types of operational substances, measured the ability of dogs to detect a target odor when presented mixed with a non-target odor. The concentration of the target odor was held constant across many trials and sessions, and the concentration of the non-target odor was systematically varied from low to very high levels.

The findings showed that dogs were able to discriminate the target odor under these conditions quite well. Although their ability to detect the target odor when it was mixed with the non-target odor was degraded by extremely high concentrations of the non-target odor, they were able to discriminate the target odor even when the non-target odor was orders of magnitude higher in concentration (and overwhelming to humans).

Odor discrimination training under field conditions naturally augments this capability because vapor compounds from target odors are unavoidably mixed with other compounds present in the ambient air. However, one of the keys to effective detection performance is not merely training dogs to alert to target substances but training them to detect their vapor signatures when intermingled with other odors, particularly those that might be present under deployment conditions.

Generalization From Training to Non-Training Substances

The success of detector dogs lies not just in discriminating target from non-target substances but in the complementary process of generalizing from an odor on which they have been trained to other odors that are similar, although not exactly the same. The behavioral process of generalization is well understood (Ruling, 1977), and a study assessing its operation in the case of canine olfactory detection confirmed established general principles (Boussom, 1999). This study, which was conducted under controlled field conditions, focused on a number of smokeless powders. Dogs were trained to detect a single powder and then tested on at least four others with which they had no experience. One of these untrained powders was then added to the training list, and dogs were tested on the remaining untrained powders. This pattern continued until dogs were trained on four of the powders and tested on the fifth.

The findings showed that the degree of generalization from training to non-training smokeless powders depended on 1) the chemical similarity of vapor constituents among powders and 2) the breadth of training across different powders. That is, the more untrained powders shared some of the same vapor compounds as trained powders, the more likely dogs were to alert to the untrained powders. Similarly, the more different powders dogs were trained on, the more likely they were to alert to untrained powders. Although generalized responding to untrained powders increased systematically as dogs received training on more powders, detection of untrained powders did not consistently reach operational level, however. Furthermore, even after dogs were trained on four powders, they failed to alert to the remaining powder, which was the most chemically dissimilar from the others.

Although this study needs to be replicated with other target substances, it is clearly inappropriate to assume that training dogs on one or two variants of a target substance is sufficient to assure operational levels of detection of all other variants. These studies should be expected to reveal valuable efficiencies by identifying which variants of each target substance will yield the broadest degree of generalization when used as training aids, thus minimizing the number of variants that must be used in training.

Canine Detection Odor Signatures

Most target odors are composed of many different vapor compounds. A series of studies has shown that although dogs can probably detect many compounds in such mixtures, they learn to respond to only a few (e.g., Johnston, 1 997b; Williams, **Ct** al., 1999). These studies first involved training dogs to respond differentially to samples of clean air, varied non-target odors, and a target odor. Constituents of the target odor identified through analytical testing were then presented to determine if they smelled exactly like the target odor or like something else.

The result of this testing procedure for four explosives (a selected smokeless powder, C-4, dynamite, and military grade TNT) has revealed very similar outcomes. Dogs learn to recognize a substance in terms of its most abundant vapor constituents (typically one or two). In the case of explosives, the most abundant compounds are usually solvents. Although dogs may differ from one another in the vapor compounds that come to define the substance, these differences are within the same set of compounds. The constituent compounds by which a dog learns to recognize a substance define its detection odor signature for that substance.

These findings contradict traditional beliefs that dogs are responding to compounds of interest to trainers and handlers (e.g., the energetic compounds in explosives). The nature of detection odor signatures has pervasive operational implications. For instance, specific information about odor signatures should provide a superior basis for selecting training aids that avoid safety and security problems of actual target substances. The characteristics of odor signatures further suggest that it may be risky to force dogs to learn to alert to a substance using arbitrary training substances selected by trainers or handlers. Such aids may make it more difficult for dogs to detect the substance than would be the case if it learned a signature naturally. It may even be the case that dogs trained on an arbitrarily selected signature may gradually learn a natural signature instead as they gain experience in the field. A solid understanding of odor signatures may also enhance our understanding of the basis for false positive responses and how contamination affects detection accuracy.

Learning Multiple Odor Discriminations

Established practice has shown that dogs are capable of learning a number of odor discriminations that can be demonstrated interchangeably. Although the maximum number of odors dogs are generally capable of detecting at any time has not been determined, there is probably little value in such an exercise even if it could be accomplished. It may be more relevant to evaluate the effects of training an increasing number of odor discriminations on detection accuracy, new odor training, and refresher training.

Such a study was conducted under controlled field conditions using ten single compound substances (Johnston, 1999). Dogs were first trained to alert to a single target and to ignore ten different non-target compounds. Ten days later, they were tested on their ability to detect the target substance and there after received refresher training, if needed, before being trained on an additional target odor. Every ten days later, this cycle of testing on all odors learned to date, receiving refresher training, and learning a new odor was repeated until they had learned and been tested on ten target odors.

The findings did not reveal any systematic decrement in detection performance as more target odors were learned. Although the number of trials required to learn new odors increased somewhat over the first four odors, this increase did not continue as more odors were trained. Furthermore, the number of refresher trials dogs needed per odor after each test to reestablish performance standards decreased as more odors were learned.

This study showed that dogs could learn up to at least ten odor discriminations without difficulty, even under a challenging test protocol. Although some odors will be more difficult to learn than others, it is clear that requiring dogs to detect at least ten odors need not exact a price in terms of detection performance on previously learned odors, the effort require to train new odors, or on refresher training requirements.

Durability of Odor Discriminations

The above study was then turned around to focus on the durability of odor discriminations in the absence of refresher training. A new set of dogs learned to discriminate all ten odors from a changing set often non-target odors. They were then tested after increasing periods (each approximately 50% longer than the last) during which they had no experience with target or non-target odors or the search task. Following a single test session at the end of each interval, dogs were given refresher training as needed so that they began each interval at the same high standard of detection performance.

The results for all dogs showed no systematic deterioration in detection performance for up to four months, the longest interval tested. This remarkable performance is clear evidence that dogs are quite good at retaining high levels of detection performance for considerable periods of time on a variety of odor discriminations without refresher training.

This finding suggests that the odor discrimination component of regularly scheduled refresher training may not need as much attention as is commonly thought, which has logistical implications for the availability and use of training aids. This study provides no evidence regarding the other major canine component required for effective detection performance — search skills. Both aspects of canine training must be studied further before recommendations can be offered about the frequency of different types of refresher training. The role of refresher training in maintaining handler skills must also be considered.
In sum, it is important to understand the requirements of the different components of refresher training and consider how to construct protocols that optimize both effectiveness and efficiency.

Summary

Although additional studies are underway and many more remain to be conducted, recent findings emerging from the IBDS R&D program concerning the detector dog and its training and deployment warrant consideration for possible impact on operational protocols. The following list summarizes these findings and some of their possible operational consequences.

Olfactory Sensitivity

- Documented limits of olfactory detection for the dog range from tens of ppb to 500 ppt.
- Trainers/handlers should understand that dogs detect substances in term of vapor concentration, not weight.
- Regardless of the concentration at the odor source, dogs initially encounter relatively low concentrations on the periphery of a vapor plume.

- Regardless of the deployment scenario, dogs should be trained to alert to a wide range of concentrations, particularly including low concentrations.

Odor Discrimination Capabilities
- Dogs are extremely good at discriminating a target vapor from non-target vapors that are also present, even at relatively high concentrations of non-target odors.
- Trainers/handlers should augment this capability by training dogs to detect target substances when intermingled with non-target odors that may be encountered in deployment scenarios.

Generalization From Training to Non-Training Substances
- Dogs are more likely to alert to untrained variants of training substances if the most abundant vapor compounds from these variants are the same as those from target substances.
- The more varieties of a substance dogs are trained on, the more likely they are to alert to non-trained variants.
- Training dogs on multiple, arbitrarily selected variants of a target substance will not assure that they will detect untrained variants at operationally useful levels of accuracy.
- The particular variants of a target substance on which dogs are trained that will provide the broadest generalization to untrained variants can only be determined by systematic study.

Canine Detection Odor Signatures
- When being trained to detect a substance, dogs learn to alert to one or two of its most abundant vapor compounds.
- Although the detection odor signature for a substance varies across dogs, these variations involve the same two or three vapor compounds.
- Although dogs can be trained to use an odor signature selected by trainers/handlers, this may yield poorer detection performance than allowing dogs to learn a natural signature.
- Knowing the detection odor signatures for a substance may allow informed selection of training aids and explain some types of false positive alerts.

Learning Multiple Odor Discriminations
- Dogs can easily learn as many as ten odor discriminations.
- Learning multiple odor discriminations does not necessarily worsen detection performance of odors already learned.
- As more odor discriminations are learned, the number of training trials required will not continue to increase, and the number of refresher training trials will decrease.

Durability of Odor Discriminations
- Dogs can continue to discriminate up to ten target odors from ten non-target odors after at least four months without refresher training.
- The odor discrimination training component of refresher training may require less frequent attention that is commonly thought.
- The separate refresher training requirements for canine search skills and handler skills should be identified.

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