Effects of Extraneous Odors on Canine Detection

L. Paul Waggoner[a], Meredith Jones[a], Marc Williams[a],
J. M. Johnston[a], Cindy Edge[a] & J. A. Petrousky[b]

[a] Institute for Biological Detection Systems, Auburn University, AL 36849
[b] Office of Special Technology, Fort Washington, MD 20744

ABSTRACT

Dogs are often required to detect target substances under challenging conditions. One of these challenges is to detect contraband in the presence of extraneous odors, whether they are part of the ambient environment or placed there for the purpose of evading detection. This paper presents the results of two studies evaluating the ability of dogs to detect target substances in the presence of varying concentrations of extraneous odors. The studies were conducted under behavioral laboratory conditions, providing good control over vapor sources and a clear basis for evaluation of detection responses. Dogs were trained to sample an air stream consisting of the extraneous odor only or the extraneous odor plus the target odor and then press the appropriate lever to earn food. The results are described in terms of the ability of dogs to detect target odors in the presence of a wide range of concentrations of the extraneous odors.

Key words: dogs, olfaction, discrimination, chemical detection, extraneous odors

1. INTRODUCTION

The trained dog and handler are by far the most widely used technology employed by law enforcement for the remote detection of contraband[1]. Not surprisingly, purveyors of illicit materials sometimes incorporate odoriferous substances with their shipments in attempts to thwart canine detection efforts. In addition, dogs must sometimes work around pervasive extraneous odors such as automotive exhaust. Anecdotal evidence suggests that the detection capability of a properly trained canine/handler team is not completely incapacitated by the presence of extraneous odors. However, there is no quantitative information regarding the extent to which the presence of an extraneous odor may affect detection of target odors.

There are several mechanisms by which an extraneous odor may interfere with detection of other odors. An extraneous odor may temporarily incapacitate olfactory sensory reception. Exposure to high concentrations of substances such as ammonia or bleach may be speculated to reduce olfactory capability by destroying olfactory receptors. However, Youngentob & Schwob have shown that the ability of rats to discriminate between odors is only partially impeded and their olfactory sensitivity is affected very little by chemical ablation of over 90% of the olfactory epithelium (i.e., the chemically sensitive portion of the nose)[2]. An extraneous odor could also chemically interact with a target odor causing the target to smell differently[3]. The most likely means by which an extraneous odor would interfere with detection of a target odor is by competing for olfactory receptor sites or by neural inhibition in the olfactory bulb or other central structure[4, 5].

Regardless of the mechanism, human studies have indicated that the most common result of mixing two odors is decreased perception of one or both odors[6, 7]. The present study was specifically concerned with the extent to which extraneous odors impede the detection of odors dogs have been trained to detect (target odors). Furthermore, the target odors that were used in this study are ones relevant to law enforcement canine detection tasks. As well, the extraneous odors used were ones known to sometimes be incorporated with shipments of these targets, presumably for the purpose of hindering detection efforts. The question this study addresses is whether and to what extent these extraneous odors may be expected to interfere with detection of target odors.

Because the target and extraneous odors used in these studies are relevant to practical detection tasks, the substances from which they originate will not be disclosed in this report. Rather, they will be referred to as target odor (substance) A & B, and extraneous odor (substance) A & B.

2. METHODS

2. 1 Dogs

Six random source medium to large size mixed breed male and female dogs of normal health were used in this study. Auburn University's department of Lab Animal Health supervised the housing and care of the dogs. The dogs were maintained between 85 and 100% of their normal feeding weight in order to arrange a context in which they would reliably engage in the detection task required by the experiment.

2.2 Apparatus

Training and testing was conducted in a ventilated and sound attenuated experimental chamber[8]. An interface panel was located at one end of the chamber with two levers located 50 cm above the floor. A 9 cm diameter aperture allowing insertion of the muzzle into a 1 liter glass scent chamber was located on the interface panel. Evacuation of odors from the scent chamber was accomplished by four vacuum ports surrounding the chamber. A photo beam was used to insure that the muzzle was inserted beyond the vacuum ports of the scent chamber and to control how long the dogs sampled from the scent chamber. Directly below the interface panel was a food dish used to deliver food reinforcers (Hill's Canine Growth Formula).

Target and extraneous odors were generated via a vapor generation and delivery instrument (olfactometer) that was supplied with clean air from purge gas generators (Peak Scientific). The olfactometer delivered diluted vapor from either the extraneous substance or the extraneous substance and target substance on each trial. Varying the flow of air passing through the vessel in which the substances were contained controlled the concentration of the extraneous vapor. The flow of air passing through the vessel containing the target substance was held constant, as was the flow of the air that diluted both the target and extraneous vapor. The vapor concentrations of target and extraneous substances and general performance of the olfactometer was assessed by thermal desorption GC/MS[9]. General details of the design of the olfactometers and methods used for their assessment can be found elsewhere[9].

All experimental events were controlled through an interface panel (Coulburn) by a PDP 11-73 micro computer (Digital) running SKED experimental control software (State Systems). A PC running AXUM software (Mathsoft) was used for data handling and analysis, as well as the preparation of figures.

2.3 Odor Source Materials

Both target substances produced a vapor containing many constituents. For the purpose of these studies, one constituent of each substance was quantified and used as a measure of the strength of the odor. The constituent of target A was highly abundant and consistently present, but was not predominant in its vapor. The predominant constituent of target B was used as a measure of the abundance of the substance.

Extraneous odor A was generated from a pure compound, therefore its vapor contained a single compound. The vapor from the substance used to generate extraneous odor B contained many constituents. The predominant constituent observed in the vapor of extraneous substance B was quantified and used as a measure of the strength of the odor. However, this vapor was difficult to assess because its numerous constituents and their quantities varied greatly between collections of vapor samples. Furthermore, the concentration of the constituent chosen for tracing purposes varied considerably across time presumably due to the effects of it plating out on the surfaces of the olfactometer between daily cleaning.

2.4 Procedure

Prior to this study, all dogs had been trained to sample from the scent chamber, press one lever when diluted odor was presented and the other lever when only the diluent was presented. This performance, as well as the performance in this study, was produced and maintained by the intermittent presentation of food for correct responses and a signalled time out period for incorrect responses. Further details of this training and repertoire of the final discrete trials procedure acquired by the dogs are described elsewhere[8].

Additional training for this study involved training the dogs to press one lever (extraneous lever) after sampling vapor from an extraneous substance and the other lever (target lever) after sampling vapor from a target substance. Subsequently, the concentration of the extraneous vapor was lowered and trials consisted of either the presentation of the extraneous vapor or presentation of the extraneous plus the target vapor. Once the accuracies of the dogs in discriminating between extraneous vapor and extraneous + target vapor reached their individual asymptotes, testing began.

Testing involved two types of trials. In one, the odor presented was the extraneous odor alone; in the other, the odor was a mixture of the extraneous and target vapors. On both types of trials, the concentration of the extraneous vapor varied across sessions. Throughout these variations, however, the concentration of the extraneous odor was the same on both types of trials to prevent discrimination on this basis alone. The concentration of the target vapor was always held constant. In other words, the dog was required to detect the target odor regardless of the strength of the extraneous odor.

One or two testing sessions were run per dog per day. All of the sessions in which the detection of target A was investigated lasted approximately 55 minutes. Most of the sessions in which the detection of target B was investigated lasted approximately 35 minutes, with the remaining sessions being 55 minutes long.

3. RESULTS

Data were obtained that describe the ability of the dogs to detect the target odors in the presence of varying concentrations of the extraneous odors. Data from sessions in which a dog responded to less than 50% of the presented trials were not examined. It is reasonable to assume that if a dog responds to less than half of the presented trials in a session that it may not have been under appropriate control of the context created by the response – food contingency.

Two measures are used to describe detection performance in this study. One is the proportion of hits and false alarms at different concentrations of the extraneous vapor. In the present case, hits are defined as target lever responses on trials on which extraneous + target vapor was presented and false alarms are defined as target lever responses on trials on which only extraneous vapor was presented. Aggregate hit and false alarm proportions for each dog across concentrations are presented graphically with a line fitted to the data using the LOWESS line smoothing algorithm[10]. A high proportion of hits and a low proportion of false alarms indicate accurate detection performance. Decreased proportion of hits, increased proportion of false alarms, or both indicates decreased accuracy.

The other measure employed is an index derived from the hit and false alarm rates that describes the sensitivity of the dogs discrimination between the extraneous + target odor and extraneous odor only stimuli. This measure, called the sensitivity index or SI, is a non-parametric index based on signal detection theory regarding receiver-operating characteristics[11]. According to this index, 1.0 represents perfect discrimination and 0.0 represents a complete inability to discriminate between stimuli. The SI for each dog across concentrations is presented graphically with a line fitted through individual values using the LOWESS line-smoothing algorithm[10].

3.1 Target and extraneous odor A

Graphs in Figure 1 depict hit and false alarm rates for each dog's detection of target A vapor across concentrations of extraneous vapor A. The abundance of the tracer constituent of target vapor A was calculated to have ranged between 1.7 and .39 ppb.

The most remarkable feature of these data is that the detection performance of most dogs showed little decrease except at the highest concentration of extraneous vapor A. The ability of dog 6251 to detect target A was effected least by the presence of extraneous odor A, whereas the ability of dog 6541 was affected the most. With the exception of 6251, the target A detection performance of all dogs is not highly accurate at even the lowest level of extraneous odor A. (The concentration of target A vapor used was the highest capable of being produced by the olfactometer in its present configuration.) Nonetheless, it can be seen that detection performance changed little in the presence of all but the very highest extraneous odor concentrations.

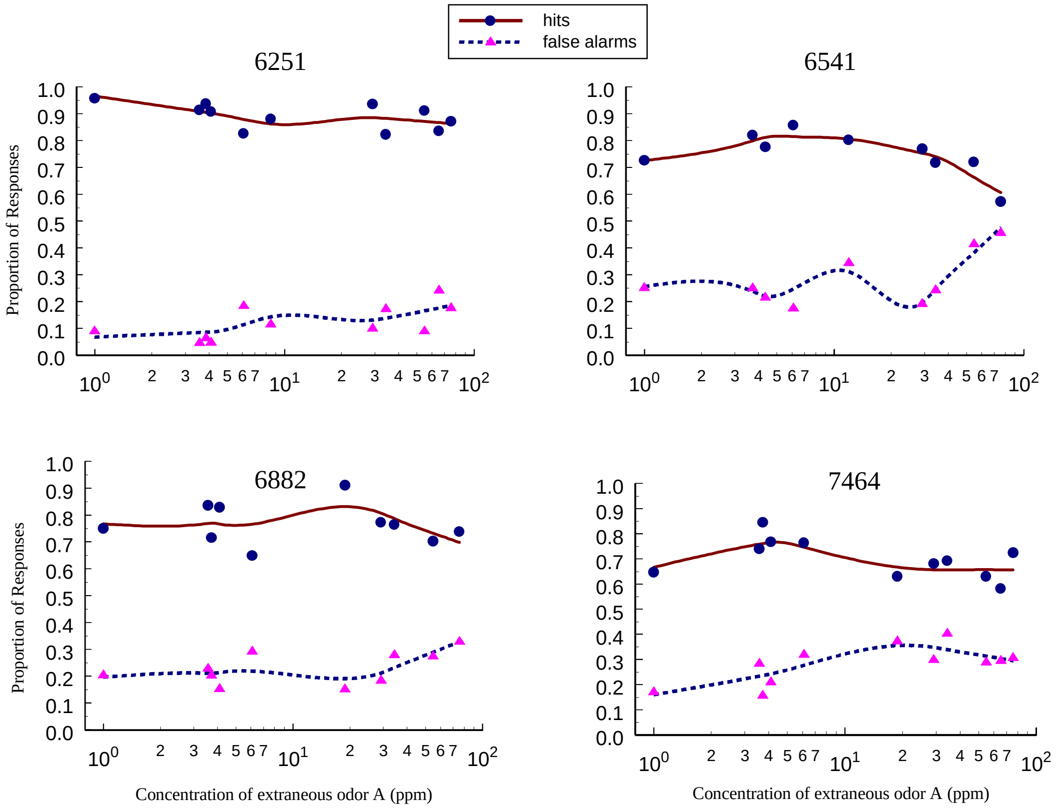

Figure 1. Average proportion of hits (circles) and false alarms (triangle) for detecting target odor A across extraneous odor concentrations.

The sensitivity index (SI) for target odor A discrimination across concentrations of extraneous vapor A for each dog is displayed in Figure 2. Commensurate with earlier comments, only dog 6251 displayed high sensitivity in detecting target odor A. The remaining dogs displayed rather modest sensitivity at even the lowest level of the extraneous odor. However, one dog (6541) showed markedly lower detection sensitivity at the highest level of the extraneous odor.

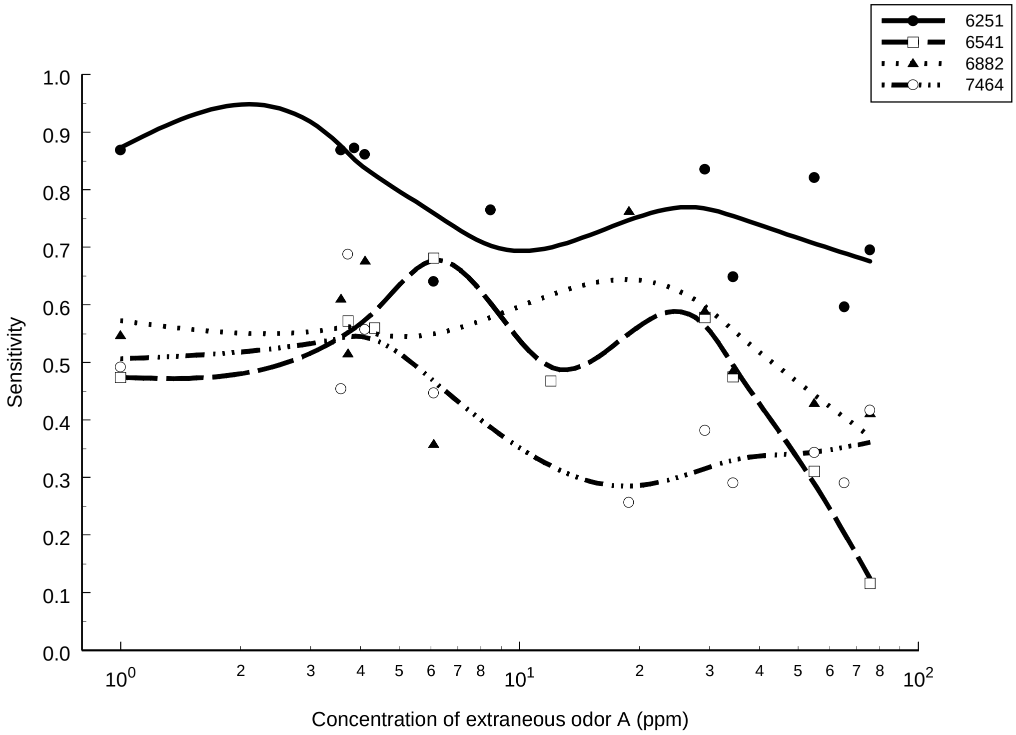

Figure 2. Sensitivity Index for target odor A discrimination across concentrations of extraneous odor A for each dog.

3.2 Target and extraneous odor B

Graphs in Figure 3 depict hit and false alarm rates for each dog's detection of target vapor B across concentrations of extraneous vapor B. The abundance of the tracer constituent in target vapor B was estimated to have ranged between 0.267 and 0.424 ppb. The typical strategy employed by this laboratory to characterize the quantity of a vapor constituent is to obtain multiple samples for GC/MS analysis across a sub-selection of odor dilutions used and extrapolate between these obtained values to predict non-sampled dilutions. In the case of extraneous vapor B, this strategy was inadequate for quantifying the tracer constituent used. As previously noted, extraneous substance B produced a complicated and varying chemical vapor signature. For this examination, estimated quantities of the tracer constituent of extraneous vapor B were estimated by linear regression from obtained samples of vapor across a range of dilutions that approximates those presented during testing. However, this analysis is inadequate to make an accurate assessment of the quantitative relation between the presence of extraneous vapor B and the detection of target vapor B.

With the exception of #6882, all of the dogs exhibited accurate detection of target odor B at lower levels of extraneous odor B, as witnessed by high hit and low false alarm proportions in Figure 3. The presence of higher levels of extraneous odor B clearly reduced the accuracy of target B detection by all dogs. Target detection by dog #7307 was affected most by odor B, as seen by a sharp increase in proportion of false alarms with increasing quantities of the extraneous odor. The most pronounced effect on detection performance across the dogs was increasing proportions of false alarms in relation to increased levels of the extraneous odor.

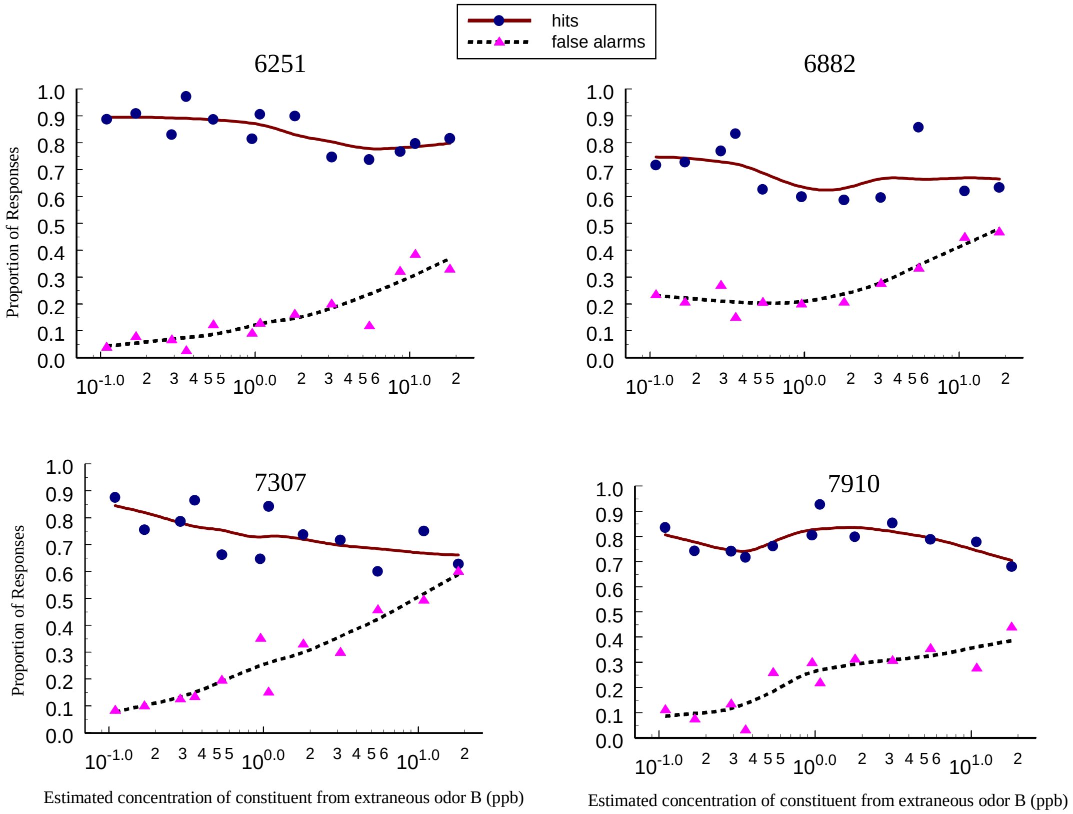

Figure 3. Average proportion of hits (circles) and false alarms (triangle) for detecting target odor B across *estimated concentrations of constituent from extraneous vapor B. (*see text for provisions related to this measurement)

The sensitivity index (SI) for target odor B discrimination across concentrations of extraneous vapor B for each dog is displayed in Figure 4. As was the case in discrimination of target odor A, dog #6251 exhibited the greatest sensitivity to the target odor. Unlike the discrimination of target A, all dogs except # 6882 were very sensitive detectors of target B at lower levels of the extraneous odor. Figure 4 also shows that there was an orderly decrease in detection sensitivity of all dogs in relation to increasing levels of extraneous odor B. This effect is most evident in the detection performance of dog #7307. The SI for target detection of this dog goes from 0.8 at the lowest level and sharply decreases to nearly 0.0 at the highest level of the extraneous odor. A SI of 0.0 is indicative of the complete inability to detect the presence of the target odor.

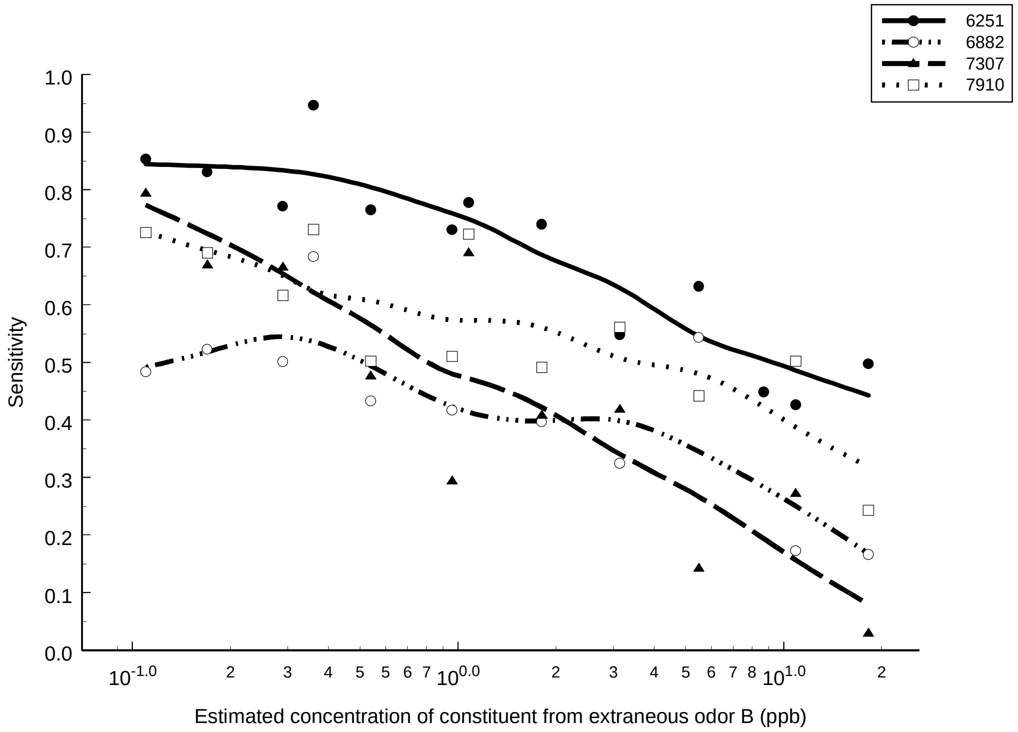

Figure 4. . Sensitivity Index for target odor B discrimination across concentrations of extraneous odor B for each dog.

4. DISCUSSION

To reiterate, it has been shown in human studies that the most likely effect of mixing two odors is the reduction in perception of either odor[6, 7]. It would hardly be surprising to find that dogs' detection of a target odor can be hampered by the presence of an extraneous odor. However, these studies have shown that, although the detection performance of dogs is susceptible to being perturbed by the presence of an extraneous odor, it takes a large or even very large amount of this odor in relation to the amount of target odor for this effect to be realized. The extent of this effect depends on the nature of the substances.

In the case of target and extraneous odors A, the quantity of the tracer constituent of target odor A averaged about 1 ppb, and it took quantities in excess of 20 ppm of the extraneous odor to affect detection performance – a ratio of approximately 3 orders of magnitude. The capability of the dogs to detect the target is even more impressive when taking into consideration that their detection performance for detecting the target at this level in the absence of the extraneous odor was never highly accurate. It would probably be the case that the dogs would have performed better if the target had been presented in quantities higher than were capable of being delivered in this study.

It is difficult to assess the quantitative relationship between the detection of target odor B and the strength of odor B because of difficulties in analyzing the varied and complicated chemical vapor signature of extraneous odor B. However, present evidence suggests a direct relationship between increasing concentration of extraneous odor B and decreasing detection of target odor B. For all of the dogs except #6882, however, this effect was minimal until the concentration of the tracer constituent of extraneous odor B was about 10 times greater than that of the target odor. Furthermore, the detection capability of dog #6251, although reduced by the presence of the extraneous odor, was very accurate until the abundance of the extraneous odor was about 100 times greater than the abundance of the target odor. The experimenters' subjective opinions of the strength of extraneous odor B were that it was overwhelming, adding to the precedent for further chemical analysis of this vapor. It is suspected that some constituent(s) of extraneous vapor B were present at much higher levels than the level of the tracer constituent used to describe the strength of this odor.

Another consideration is that extraneous vapor A was comprised of a single substance whereas extraneous vapor B contained many constituents. Perhaps the presence of a multi-constituent vapor presents a greater challenge to detection of a target than does a single constituent vapor. Irrespective of abundance, increasing the number of vapor constituents from which a target is to be detected may have analogous detrimental effects to that of increasing the noise background in which any kind of detection instrument operates.

This study is the first investigation of the effects of extraneous odors on canine detection of target odors. More detailed behavioral and chemical analyses are required to fully describe the effects of extraneous odors on canine detection performance. For example, an experiment could be designed that directly examines the effects of the number of constituents of an extraneous odor on detection accuracy. Another question concerns the range of target and extraneous vapor concentrations in operational scenarios. Further studies may allow a comparison of the detection performance of dogs to that of other detection technologies.

Despite rapid advances in instrumental technologies, the trained dog continues to be the most efficacious and widely used tool for detection. This state of affairs is likely to continue given the versatility of the dog and its advantages in sampling efficiency, sensitivity, target noise discrimination, and gradient detection. The results of this and future studies on the effects of extraneous odors supplement the knowledge base about canine detection. This knowledge will be vital in advancing canine detection technology for law enforcement purposes.

5. ACKNOWLEDGEMENTS

This work was supported by the Technical Service Working Group through Battelle Memorial Institute task order 44 under subcontract 123090. The authors would like to thank Babara Beck for her excellent technical and managerial assistance, and Lisa Stephens for her administrative assistance.

6. REFERENCES

1. U. S. Congress Office of Technology Assessment (OTA). *Technology Against Terrorism: The Federal Effort*, (OTA-ISC-481). DC: 1991.
2. S. L. Youngentob and J. E. Schwob. “Recovery of odorant identification following methyl bromide induced lesion of the olfactory epithelium”. *Chemical Senses*, *17:726*, 1992.
3. D. G. Laing, H. Panhuber, and B. M. Slotinick. “Odor masking in the Rat”. *Physiology and Behavior*, *45*:689-694.
4. R. J. O’Connell and R. P. Akers. “Responses of insect olfactory receptor neurons to biologically relevant mixtures”. In D. G. Laing, W. S. Cain, R. L. McBride, and B. W. Ache, eds. *Perception of Complex Smells and Tastes.* Syndey: Academic Press, 1989.
5. L. D. Rhein and R. H. Cagan. “Biochemical studies of olfaction: Isolation, characterization and odorant binding activity of cilia from rainbow trout olfactory rosettes. *Proceedings of the National Academy of Science*: *USA 77:* 4412-4416, 1980.
6. W. S. Cain and M. Drexler. “Scope and evaluation of odor counteraction and masking. *Annals of the New York Academy of Science*, *237*:427-439, 1974.
7. D. G. Laing, H. Panhuber, and B. M. Slotinick. “Odor masking in the Rat”. *Physiology and Behavior*, *45*:689-694.
8. J. M. Johnston, L. P. Waggoner, M. Williams, J. Jackson, M. Jones, L. Myers, S. F. Hallowell, and J. A. Petrousky, “Canine olfactory capability for detecting NG smokeless powder”, *Proceedings of the 5th International Symposium on the Analysis and Detection of Explosives*, 1996.
9. M. G. Hartell, C. C. Edge, M. Q. Pierce, S. F. Hallowell, and J. A. Petrousky, “Overview of current olfactometer performance across different odorant systems”, In P. Pilon and S. Burmeister, eds. *Chemistry and Biology Based Technologies for Contraband Detection*, Bellingham, WA, SPIE: 29371996.
10. W. S. Cleveland and S. J. Devlin. “Locally weighted regression: An approach to regression analysis by local fitting”. *Journal of the American Statistical Association*, *83:*596-610, 1988.
11. P. W. Frey and J. A. Colliver. “Sensitivity and responsivity measures for discrimination learning”. *Learning and Motivation*, *4*: 327-342, 1973.