The Effect of Reinforcement Rate Variations on Hits and False Alarms in Remote Explosive Scent Tracing with Dogs

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Detection animals offer untapped potential in terms of locating landmines and explosive ordinance in the field and in the laboratory. In this study, the Geneva International Centre for Humanitarian Demining evaluated the effect of low, medium, and high levels of reward on the performance of six dogs searching filters for explosive odor.

by Rebecca J. Sargisson | University of Waikato | and Ian G. McLean | Consultant |

Remote Explosive Scent Tracing—or Odor Capture—is a detection process in which odor is captured on an absorbent filter and analyzed by a detector, such as a dog or rat. The detector works in a safe and controlled environment and is capable of searching large areas of ground in a short period. Odor capture has a wide range of potential applications (for example, the detection of oil-pipeline leaks and the detection of cancer or tuberculosis), but with respect to explosive detection, REST's main value is eliminating road sections that do not contain explosive ordinance, allowing clearance to proceed more rapidly than is possible using most standard detection technologies.

Signal-detection theory assumes that each animal responds according to a response criterion (the vertical line in Figure 3 on page 66). An animal's responses can become biased toward one response type if more reinforcement is made available for one response type over another or if unequal numbers of positive and negative filters are presented.* Signal-detection theory makes the following predictions:

- If the sensitivity of the detector (d') varies and the response criterion (C) remains constant, hit rate and false-alarm rate should be negatively correlated, i.e., as the functions move apart, hit rate will increase, and false-alarm rate will decrease.
- If the response criterion (C) varies, hit rate should be positively correlated with false alarm rate. For example, if a detector is biased toward indicating, it will hit more positive filters, but will also indicate more negative filters, creating a high false alarm rate.
- A strong correlation between hit and false-alarm rate would be a useful finding for REST. If hit and false-alarm rates were positively correlated, the relationship between them could be optimized by manipulating reinforcement bias, filter ratios, or the experimental method.
- If hit and false-alarm rates were negatively correlated, the training approach could focus on increasing hit rate, with the desired low false alarm rate achieved without explicit training.

The present experiment used data from the regular training of six REST dogs in Angola to explore the relationship between hit and false-alarm rates. The overall reinforcement rate for positive-filter hits was maintained constant as signal availability for hits could have produced a bias toward indicating, producing a positive correlation between hit and false-alarm rate. If, however, the reinforcement rate manipulation for hits altered the dog's sensitivity to the signal, we would expect a negative correlation between hit and false-alarm rate. In other words, increasing reinforcement for hits would either have been expected to cause a bias toward indicating or to improve the dog's ability to discriminate between positive and negative filters.

Method

Subjects. Six male non-nourtured dogs, aged between 6% and 7% years, with several years of previous REST training participated. Five were Labrador Retriever (Retzina, Steros, Tan, and Zulu) and one was a Springer Spaniel (Rusty). Each dog was assigned an experienced Angolan dog handler. The dogs were exercised six days a week by walking and swimming, housed in individual kennels, given free access to water, fed a high-quality dry dog food in sufficient quantities to maintain a healthy weight, and were not food deprived.

Apparatus. Filters were placed on a carousel apparatus (Figure 1). The carousel was a large stainless-steel wheel, mounted horizontally to the floor, which could be rotated. Filters were mounted horizontally at the ends of 12 arms that were removable for cleaning. The rooms’ walls were concrete block, and tiled floors minimized odor contamination. A stainless-steel screen inside the rooms shielded a supervisor from the searching dog. All other personnel (the dog handler and documenter) watched activities from adjacent rooms through internal one-way glass windows.

The filters were a PVC core wrapped in mosquito netting and housed inside a PVC tube (known as the “Mesh” filter, named for the manufactured process).

Procedure Sampling. Unused filters were contaminated with air to produce positive filters (filters believed to contain the odor from one or more landmines) and negative filters (filters believed to be free of explo-
ters because the reinforcer for blank runs was not contingent upon a dis- crete response, such as sitting. Zero to three positive filters were present on the carousel among the remaining negative filters.

After the summer break, training recommenced for all six dogs in Week 2 of 2005 and continued for four weeks before experimental manipulations. At this point, reinforcement frequency for correct indications on positive filters was manipulated by providing a reinforcer, such as a click from the clicker and food or access to a ball, on only some correct indications (intermittent reinforcement). This can be contrasted with earlier training stages where reinforcing every correct indication is common in order to aid learning (continuous reinforcement). All other variables were held constant, including the number of negative filters available on the carousel, and reinforcement for correct rejections of negative filters.

Table 2 shows the experimental conditions. From Weeks 6 to 10, hit rates were reinforced if a dog was at a “low” level (20 to 30 percent of hits were reinforced), from Weeks 11 to 27 at a “medium” level (55 to 70 per- cent) and from Weeks 28 to 33, at a “high” level (60 to 75 percent of hits were reinforced).

Results

A decision for each filter from each dog was obtained. Signal-detection theory terminology was used to define the four analysis results pos- sible for a filter: hit (indication on a positive filter), miss (no indication on a positive filter), false alarm (FA, indication on a negative filter) and correct rejection (CR, no indication on a negative filter). Hits, misses, false alarms, and correct rejections were summed for each week for each dog and used to calculate hit rates [(Hits / (Hits + Misses)]*100] and false- alarm rates [(FAs / (FAs + CRs))]*100).

Figure 4 shows hit and false alarm rates for each dog, and for the mean. For the mean across all dogs, as a function of week. When actual rein- forcement rates were found to deviate from planned reinforcement rates, these data were removed, and are therefore missing from Figure 4. Pear- son correlation coefficients were used to test the relationship of hit rate to false-alarm rate shown in Figure 4. A significant, negative correlation appeared between mean hit rate and mean false-alarm rate (r = -.72, p < .001). The correlation between hit and false-alarm rate was also negative for all individual dogs and significantly so for two of the six dogs. All values are shown in Figure 5. Figure 5 (on page 68) displays the data used to calculate the mean correlation and clearly shows a strong negative relationship between hit and false-alarm rate, in that, as hit rate increases, false- alarm rate decreases.

Weekly hit and false-alarm rates for each dog, and for the mean, were grouped according to reinforcement-rate condition (low, medium, and high). These data are shown in Figure 6 (on page 68). A one-way analysis of variance indicated that hit rates in the three groups differed significantly [F(2, 15) = 5.34, p < .05]. A Fisher’s LSD post-hoc test showed that the high and medium 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 were found across the three reinforcement conditions [F(2, 15) = 0.89, NS]. However, Figure 6 (on page 68) shows that false-alarm rate was lowest during the medium reinforce- ment-rate condition for four of the six dogs, and for the mean.

Discussion

Hit rate and false-alarm rate were overall significantly negatively correlated.

Thus, as hit rate increased, false alarms decreased. According to signal-detection theory, these negative correlations are to be expected if the distance between the noise peaks and the signal-plus-noise functions changed. In other words, the correlations between hit and false- alarm rates were caused either by changing dis- crucibility between positive and negative filters, or by changing the dog’s sensitivity to the noise. The non-significance of a response bias (decision criterion). Given that the filters’ dis- crucibility was not manipulated, the likely reason for the negative correlation between hit and false-alarm rate was the dog’s increasing sensitivity due to changes in the overall rein- forcement rate for hits.

This result suggests that the experimen- tal method’s nature, reinforcing hits and not correct rejections, does not produce chang- es in the dog’s response bias. In other words, greater reinforcer availability for hits did not cause the dog to respond indicating. Instead, in the present experiment, low reinforcement rates for hits produced poorer performance on neg- ative and positive filters, while medium and high reinforcement levels produced more ac- curate responses on both filter types. In the present experiment, performance peaked un- der the medium level of hit reinforcement. In- creasing the reinforcement frequency beyond this level did not result in greater ac- curacy on positive or negative filters. One im- plication of this finding is that procedures to improve the REST system’s accuracy should focus on increasing the animals’ hit rates, and that any hit rate increase will be accompanied by a false-alarm rate decrease.

Manipulating reinforcement rates is one way to alter an animal’s response accuracy. Another way is through the experimental pro- cedure itself. The current procedure was a “go/ no-go” procedure, whereby animals indicat- ed, by sitting, the presence of explosive odor but made no response to filters containing no explosive odor. Such a procedure producing a bias toward indicating, rather than ignoring, is possible because ignoring is not explicitly reinforced. Alternatively, due to the greater number of negative filters (194 per- cent and 99 percent of filters were negative), the dog’s behavior could become biased to- ward ignoring because it is the most frequent- ly-required response. An analysis of bias, using [log b = ½ log (FA / CR) (CR / Miss)], showed
that the behavior of four of the six dogs was biased toward indicating, and this bias strength decreased as reinforcement for hits increased for all six dogs. The behavior of two dogs was biased toward ignoring, and this bias was unaffected by reinforcement-rate manipulations. Thus, the present procedure appeared to not produce consistent effects on response bias, nor did it produce bias in one direction over another. Instead, each dog tended to maintain a fairly reliable preference for either indicating or ignoring, and biases toward indicating were counter-intuitively reduced by increasing reinforcement availability for correct indications.

REST programs should include ongoing monitoring of response bias, so they can re-
dress any imbalance. Manipulation of rein-
forcement rates can eliminate response bias
more easily in procedures where responses to positive and negative filters are directly rein-
forced. In procedures where responses to only one type of filter are reinforced, such as in the present REST system, response bias may be
eliminated by careful manipulation of the ra-
tio between positive and negative filters. REST programs should seek to determine the opti-
mum rates for their procedure and animals, and maintain this ratio while continuing to monitor ongoing response bias.

Other factors which affect the overall ac-
curacy of animals’ responses concern the quality of the samples. Sampling can be opti-
mized in terms of filter material, climatic con-
dition, avoidance of contamination, and so on. Once collected, filters should be handled to minimize cross-contamination. By maintain-
ing as close a signal on the filter as possible, the animal is given the best chance to obtain high hit rates. 

Sea Miners: Live, Modified, Gone

Implementation of the general-intelligence approach, known as the Space and Air-
borne remote sensing (SAR) method, was the system’s basis, although significant
methodology and technology were the system’s basis, only significant
use of the general-intelligence approach, known as the Space and Air-
borne Mixed Area Reduction Tool (SMART) system, made its substan-
tial operational success in mine action possible. 

Well-developed mine-action programs implement conventional technologies and standard operating procedures of General Survey (also
called Non-technical Survey) and reduction of mine-suspected areas.

Application of AI DSS in the community. Figure 11 (left): The state of the mine-suspected area (56 square kilometers) before the project. (Legend: crossed pink for undergoing clearance, striped pink for undergoing survey, yellow if used on owner’s responsibility, blue if excluded from MSA.) Figure 1.2 (right): The state of the MSA after the application of AI DSS, as carried out by CRFOMAC. Note the MSA reduction in the southern part of the MSA covers the edge of Isolated Mountain. (Legend: crossed pink for undergoing clearance, striped pink for undergoing survey, yellow if used on owner’s responsibility, blue if excluded from MSA.)

Development of AI DSS

The Croatian Mine Action Centre tries to reduce mine-suspect-
ed areas by using conventional technologies such as General Survey; however, the repeated use of these mechanisms eventually becomes in-
effective and ground-based costly means (skimming, Technical Survey)}