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

Detection animals offer un tapped potential in terms of locating landmines and explosive ordnance in the field and in the laboratory. In this study, the Geneva International Centre for Humanitarian Demining investigated 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—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.1 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 ordnance, allowing clearance to proceed reliably without the use of standard detection technologies.

REST will only be used if it can deliver consistently high detection reliability for filters containing explosive odor (hits on “positive” filters). However, if REST is for uncontaminated land release, REST is still deliver reliable detections on filters not containing explosive odor (correct rejection of “negative” filters). A filter analysis produces four possible outcomes (See Table 1), of which two are undesirable—“miss” and “false alarm.” A miss means that explosive ordnance is undetected, presenting a danger to future land users. A false alarm means unnecessary additional work for the mine-clearance program. Low reliability on either of these outcomes reduces confidence in REST as a detection technology.

The typical procedure is summarized as follows. A team uses a suction pump to vacuum the air over a road section, typically 100 or 200 meters (100 or 218 yards) long and about 1.5 meters (5 yards) wide. The air is sucked through a filter, and careful records are kept of the road section that each filter represents. The filters are transferred to a laboratory where they are presented to trained detectors (usually dogs or rats) using a standard methodology, such as on the arms of a carousel (Figure 1) or in a line of stands (Figure 2). The dogs are trained using filters made from controlled odor sources (“benchmark filters”). For training mine detection, most REST agencies plant test minefields, noting each mine’s location, type, and depth. Filters can then be made in areas that should be contaminated with explosive odor from a known source, and used as training relatability without explicit training. A filter’s signal strength can be placed somewhere in a range of response values (Figure 3 on page 66). Signal detectability is a characteristic of the detector’s ability to discriminate between positive and negative filters.

A filter’s signal strength and hit rate and false-alarm rate are not significantly correlated; i.e., as the functions move apart, hit rate will increase, and false-alarm rate will decrease.

Signal-detection theory makes the following predictions:

- 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.
- The response criterion (C) varies, hit rate should be positively correlated with false-alarm rate.
- If the response criterion is lower, each missed filter is likely to increase the false-alarm rate.

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 response can be 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.

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 photographer) 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 “Mechin” filter, named for the manufacturer).

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-
were odor but containing other neutral odors from similar locations). Air was added to the filters by placing the filters at the end of a long stainless-steel tube subject to continuous suction via a vacuum-pump machine worn as a backpack. The filter was held close to the ground and swung to the left and the right of the pump operator as he slowly walked a 100-meter distance. Filters were considered positive if the pump operator moved within 1 meter of a buried landmine or negative if no landmines were present within 100 meters of the filter during searching. The landmines were a range of anti-tank and anti-personnel mines commonly found in Angola. The mines were laid between 0 and 10 centimeters (0–4 inches) beneath the ground surface for a minimum of six months before they were used for sampling. A total of 275 mines were available for sampling. All sampled filters were stored inside small PVC containers, and positive filters were separated from negative filters until analysis to avoid odor cross-contamination.

**Analysis.** The dogs searched filters on the carousel between 8 a.m. and 1 p.m., Monday through Friday, taking rest breaks when required. After preparation of the carousel, each dog was brought to the carousel room's door in a sequential but random order. When the dog was calm, the handler instructed the dog to "search," and the dog handler stepped behind a wall out of the dog's view. The dogs walked unaccompanied, off-leash, in an area whose size was consistent with the carousel, sniffing each filter consecutively. The dog exited the room after it had correctly responded because the reinforcer for blank runs was not contingent upon a discrete 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 reinforcement were held at a "low" level (20 to 30 percent of hits were reinforced), from Weeks 11 to 27 at a "medium" level (35 to 50 percent) 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 possible 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)] and false-alarm rates [FAs / FAs + CRs] for all individual dogs.

### Figure 4: Hit and false-alarm rates (%) for all six experimental conditions for each of the six dogs and for the mean. All values are shown in Figure 5 (on page 68) 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 step-wise 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 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 were found across the three reinforcement conditions [F(2, 15) = .89, p > .05]. However, Figure 6 (on page 68) shows that false-alarm rate was lowest during the medium reinforcement-rate condition for four of the six dogs, and for the mean.

**Discussion.** Hit and false-alarm rate were overall significantly negatively correlated. Thus, as hit rate increased, false-alarm rate 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 discriminability between positive and negative filters, or by changing the dog's sensitivity to the signal. Both of these causes led to the same overall effect. The critical difference here is that the filters' discriminability 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 reinforcer rate for hits. This result suggests that the experimental method's nature, reinforcing hits and not correct rejections, does not produce changes in the dog's response bias. In other words, greater reinforcer availability for hits did not cause increases in indicating. Instead, in the present experiment, low reinforcement rates for hits produced poorer performance on negative and positive filters, while medium and high reinforcement levels produced more accurate responses on both filter types. In the present experiment, performance peaked under the medium level of hit reinforcement. Increasing the reinforcement frequency beyond this level did not result in greater accuracy on positive or negative filters. One implication 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 procedure itself. The current procedure was a "go/no-go" procedure, whereby animals indicated, 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, and because the dog's behavior could become biased toward responding by not ignoring because it is the most frequently required response. An analysis of bias, using [log b = 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-adjust any imbalance. Manipulation of reinforcement rates can eliminate response bias more easily in procedures where responses to positive and negative filters are directly reinforced. 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 ratio between positive and negative filters. REST programs should seek to determine the optimum ratio for their procedure and animals, and maintain this ratio while continuing to monitor ongoing response bias.

Other factors which affect the overall accuracy of animals’ responses concern the quality of the sample. Sampling can be optimized in terms of filter material, climatic condition, avoidance of contamination, and so on. Once collected, filters should be handled to minimize cross-contamination. By maintaining as clear a signal on the filter as possible, the animal is given the best chance to obtain high hit rates.  

Figure 6: Mean hit rate (%) and false-alarm rate. (2) see endnotes page 62