Reinforcement for Operational Mine Detection Rats

When using animals for the detection of landmines, handlers face challenges of when to reinforce indication responses, as the actual location of landmines in the field is unknown. *Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling* (Anti-Personnel Landmine Detection Product Development or APOPO) evaluated an inexpensive method to reinforce rat-indication responses in field settings using TNT to contaminate ground area. Rat detection accuracy was high over the TNT contamination after an overnight soak period of 16 hours and detection accuracy decreased as a function of days passed since soaking.

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The fishing rod apparatus used to place a TNT-filled bag inside the search area.
All graphics courtesy of the authors.

Over the past decade, the *Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling* (Anti-Personnel Landmine Detection Product Development or APOPO) has explored the use of giant African Pouched Rats (*Cricetomys gambianus*) for the detection of landmines and other explosive remnants of war (ERW). In an evaluation conducted in 2005, seven rats searched 20,234.28 sq m of land in Mozambique, and their overall detection accuracy exceeded 95%.[1] Similarly in 2010, teams of two rats searched 93,400 sq m of land in Mozambique, revealing 41 mines with a detection accuracy of 100%.[2] In both studies, human deminers verified the rats' indication responses by searching the area with metal detectors. Between 2007 and 2012, the rats were an integral part of APOPO`s efforts to survey, clear and subsequently release to the public the Mozambique province of Gaza one year ahead of schedule. These results suggest that pouched rats are a valuable, adjunctive technology for locating landmines.

Other publications provide details on how the rats are trained and used.[3,4,5] In brief, food immediately reinforces (rewards) correct indication responses (i.e., those that occur within 1 m of a mine).[5] Incorrect indication responses are not reinforced; this is known as operant conditioning.

Occasional or intermittent reinforcement of correct responses is sufficient to maintain search behavior; however, by consistently failing to reinforce responses, a process technically termed **extinction**, performance decreases substantially.[6,7,8] A previous study conducted at APOPO's training center demonstrated the adverse effects of extinction on mine detection rats.[9] This is a general problem for all animals used in detection including mine detection dogs.

Such results suggest that the rats should not work in an operational setting for extended periods of time unless the incorporation of regular reinforcement opportunities is possible. Contaminating a ground area with 2,4,6 trinitrotoluene (TNT), the primary explosive in most mines, and reinforcing indication responses within 1 m of that area may provide an opportunity for reinforcement. To implement such a system, however, a controlled method for TNT contamination must be developed, and the performance of rats exposed to that system must be systematically evaluated. The purpose of the present study was to evaluate a procedure for arranging TNT contamination and to assess rats' performance in detecting a TNT-contaminated spot as a function of a) the duration of the contamination (soak) time and b) the time elapsed from contamination to testing.

Setting and Subjects

Trials took place in Morogoro, Tanzania, on the APOPO training field, which contains approximately 1,553 landmines buried in a fenced 283,279.95 sq m site. The mines are buried within permanent boxes ranging in size from 100 to 400 sq m, and their locations are recorded in a database. The number of mines in a given box varies from zero to four.

Each condition comprised three test days during which six rats were tested once per test day in 18 different 100 sq m boxes containing no mines. Boxes were reused, but no box was repeated within a two-week span and, when repeated, the TNT contamination was put in a different part of the box. In total, 72 boxes were used.

Six fully trained adult rats participated in the test: Bila, Brandy, Evans, Malindi, Ndimalo and Stanley. The rats were distributed between two trainer teams; each team comprised two accredited rat trainers and one data recorder. The data recorders were minefield supervisors.

Materials

Materials included data sheets, leak-proof Ziploc® bags containing 5 mg of military-grade TNT and six T-shaped, metal stands each holding a telescoping, fiberglass fishing rod parallel to and approximately 1 m above the ground. When fully extended, the rod had a 3 m length. One

An illustration of the rats' search configuration.

end of a 1 m cotton string was attached to the end of the fishing rod, and the other end was tied to the bag containing TNT. Contamination spots could be placed at desired locations by positioning the metal arm of the apparatus at various locations around the perimeter of a box and adjusting the length of the fishing rod, then tipping the device so that the bag of TNT (and nothing else) touched the ground in the box.

Training box materials consisted of measuring tapes, a rope, a hand-held device that made a loud click when pressed and bananas for food rewards (on non-test days only). The rats, attached to the rope via a harness, searched the box (see photo above). Between two trainers, the ends of two measuring tapes were attached to a rat's harness at zero. This procedure allowed the location of indicator responses to be recorded in x and y coordinates. In all tests, rats were allowed to traverse the rope only once before they were moved to the next search lane.

Data were recorded on graph paper that depicted the box in x and y coordinates. When a trainer observed an indication response, which was scratching the ground for any length of time, the trainer informed the data recorder who recorded the location of the response. No food reinforcement was delivered during tests, however, four training days were scheduled between tests.

Procedures

This study was completed in three phases. All phases involved a series of tests in which six rats searched 100 sq m boxes. Six boxes were prepared for each test, and each rat searched one box. Two trainers who were otherwise uninvolved in the experiment set up the boxes. All tests were conducted under blind conditions, meaning that trainers and data recorders were unaware of the contamination location. All indications, defined as scratching for any length of time, were recorded, and indications occurring within 0.5 m of the TNT-contaminated spot were considered correct. Each test took 10–18 minutes to complete, and test sessions were conducted between 0700 and 0900 hours.

The trainers withheld food reinforcement during the tests. To ensure that the rats continued to search on test days, four reinforcement days were scheduled between test days. On these reinforcement days, which were conducted in different boxes than those used during test days, the trainer received a data sheet indicating the location of the TNT-contamination area. When a correct response occurred, the trainer clicked and rewarded the

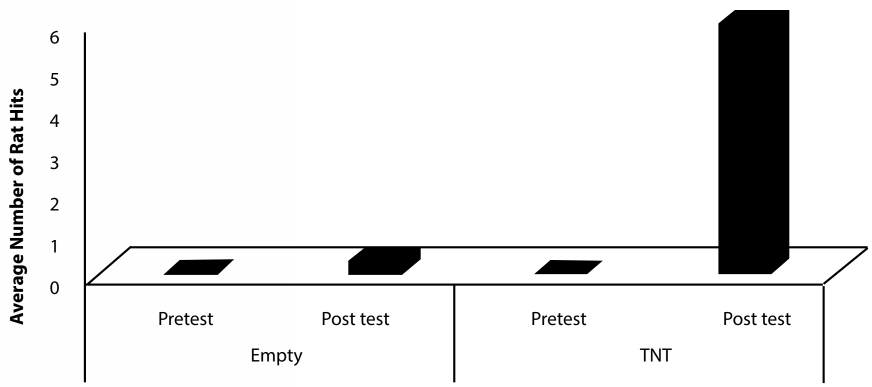

Figure 1. TNT vehicle assessment: empty bag versus bag with TNT.

rat with a small amount of banana. The results on reinforcement days were not included in the test results.

Phase I: TNT Contamination Vehicle

The first test phase identified a vehicle for transferring TNT-volatile compounds to the ground. An APOPO supervisor placed 5 mg of military-grade TNT (crystal form) in six small, plastic, Ziploc bags. These allowed the amount of TNT crystals used and the size of the contamination area to be controlled. The TNT was placed in the bag at least 24 hours before the experimenter placed the bag in the field. While not in use, the bags were stored in a sealed aluminum container.

This phase included a pretest and a post-test, and both were repeated three times with all six rats. For each rat, the pre- and post-test were conducted on the same box, thus this phase used 18 boxes (six rats, three task repetitions of the pre- and post-test). Prior to each pretest, the experimenter determined locations where bags containing TNT and empty bags were to be placed later, and during the test the experimenter recorded rat indications within 0.5 m of these locations. The pretest was conducted to ensure that any indication occurring over sites with TNT contamination was not the result of random responses by the rats. The same box was used in the pretest and post-test for each rat to demonstrate that before the empty bag and TNT-filled bag were placed in the box, there was nothing in the box to account for any rat indications.

Subsequently, the boxes used during the pretest were prepared with two targets each: a TNT bag and a bag without TNT for the control. The bags were placed at least 6 m apart and were left on the ground for 16 hours. The bag and presentation apparatus were then removed, and the hole created by the apparatus stand (holding the fishing rod of TNT) was concealed; afterward, the post-test commenced within 1 hour.

All rat indications, defined as scratching for any length of time, were recorded but not reinforced. Indications occurring within 0.5 m of a location where a bag with TNT or an empty bag was placed were considered hits on the target. These test results showed that the rats reliably indicated TNT locations but did not indicate the location of empty bags (see results section), and so this system was used for the remaining tests.

Phase 2: Duration of Soak Time

The amount of time that a bag containing TNT must remain on the ground for the volatile compounds to be detectable was assessed by comparing the rats' performances at soak times of 1 and 16 hours. These times were considered as potentially useful because the rats train in the morning and, therefore, the 16-hour test could be prepared the afternoon prior to the evaluation, and the 1-hour test could be prepared early in the morning and evaluated on the same day. At both soak times, a bag with TNT was placed in six 100 sq m boxes at randomly selected locations. After 1 hour or 16 hours, the bag was removed, and the rats were tested within 1 hour as described above.

Each rat evaluated one box per test. Six rats completed three tests with the 1-hour soak time and three tests with the 16-hour soak time, all on different days (18 tests per condition, 36 total in Phase 2). All rats were exposed to the same soak-time condition each test day, but the conditions were interspersed in this order: 1 hr, 16 hr, 1 hr, 1 hr, 16 hr, 16 hr.

Phase 3: Contamination Period

The third phase of testing evaluated the number of days that the TNT volatiles remained detectable by the rats. All tests were prepared after letting the TNT target soak for 16 hours. Tests were conducted one, three and six days after the TNT was removed from the box. As in previous tests, one box was prepared for each rat, and each rat repeated the test three times at each time increment in new boxes (18 tests per time increment, three time increments, 54 tests and boxes total). The targets were placed randomly inside the box, and the rats evaluated each target once. Tests at each time increment were repeated three times in different boxes and on different days.

Results

Results are displayed in Figures 1-3. Overall, they show a decreasing trend in the number of rat indications as a function of post-contamination days. During the pretests in Phase 1, none of the rats indicated within 0.5 m of where the empty bag or the TNT was put after the pretest, indicating that there were no other markers that could account for rat indications. During the post-tests in Phase 1, Ndimalo indicated within 0.5 m of the empty bag on one of his three tries, and all six rats indicated within 0.5 m of the bag with TNT on all post-test attempts.

Phase 2 compared performances after TNT soak periods of 1 and 16 hours (Figure 2). After a 1-hour soak period, 1, 1 and 2 (mean = 1.3) rats indicated within 0.5 m of the

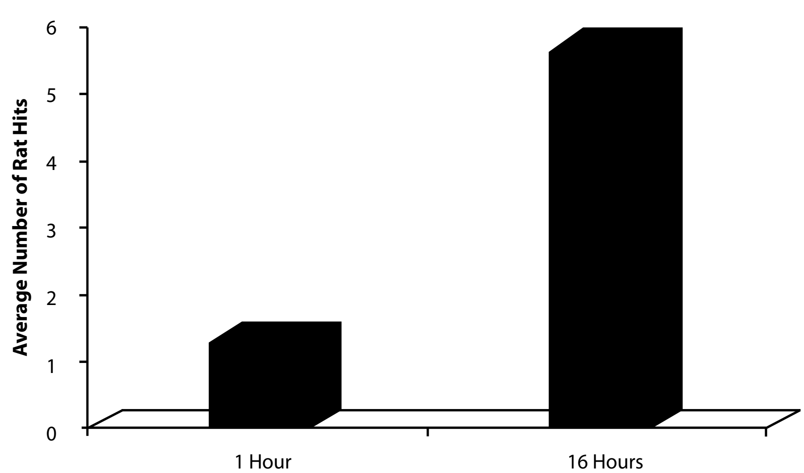

Figure 2. Effects of the duration of TNT soak period.

TNT-contaminated spot. One rat detected the TNT on the first and second 1-hour soak-time test days, and two rats detected the TNT on the third test day. After a 16-hour soak period, 5, 6 and 6 (mean = 5.7) rats indicated within 0.5 m of the TNT-contaminated spot. Five rats detected the TNT on the first 16-hour soak-time test day, and six rats detected the TNT on the second and third test days. On average, 3.67 (*SE* = .33) more rats detected the TNT after a 16-hour soak period than after a 1-hour soak period, and the standard error of the difference between the two means was found to be statistically significant ($t\,[2] = 11$, $p = .008$).

Phase 3 evaluated the number of days that the TNT continued to be detected. Results appear in Figure 3. The 16-hour soak test provided results for Day 0 (mean hits = 5.7). On test days conducted one day after the TNT was removed, 3, 4 and 4 rats (mean = 3.7) detected the TNT or indicated within 0.5 m of the TNT-contaminated spot. On test days conducted three days after the TNT was removed, 3, 5 and 1 (mean = 3) rats detected the TNT. On tests conducted six days after the TNT was removed, 1, 3 and 0 (mean = 1.3) rats detected the TNT.

Table 1 shows the individual rat results. Rat sensitivity varied between four passed tests (Stanley) and 10 passed tests (Bila, Evans and Ndimalo), suggesting that some rats are more sensitive to TNT volatiles on the ground than other rats. Evans was the only rat that passed at least one test at each soak interval (1 hour and 16 hours) and post-soak intervals (one, three and six days).

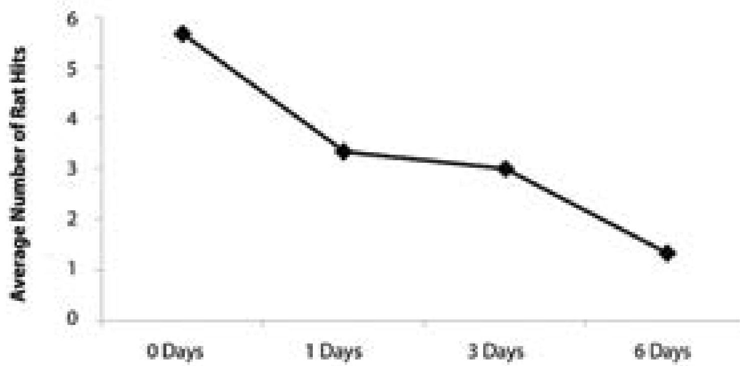

Figure 3. Effects of the number of days since TNT soak period.

Discussion

The results, obtained under dry and warm conditions with little rain, were robust. This study found that

a) TNT sealed in a small, plastic, Ziploc bag effectively transferred TNT volatiles to the search box.
b) A 16-hour soak period produced reliable TNT detection, while a 1-hour soak period did not.
c) After a 16-hour soak period, TNT volatiles were reliably detected 1 hour after the TNT was removed, and some rats could detect the TNT six days later.

Devising an effective reinforcement system for search animals in an operational demining setting is challenging. Reinforcing an indication response may strengthen either accurate or inaccurate responses, depending on whether mines are present. However, some strategy must be provided to at least occasionally reinforce hits, or the animal will stop responding. This can be accomplished in various ways: through the use of training fields that coordinate with operational fields and the use of planted defused mines in known locations on previously cleared operational fields.

Although workable, both of these strategies are difficult to arrange, and pose logistical challenges. For example, training fields should closely resemble operational fields so that animals do not learn context-specific identification responses that prevent them from differentiating the training field from the operational field. The procedure evaluated in the present study is easy to use and effectively transfers TNT volatiles to a search area without leaving other cues around the TNT target, making it well-suited for creation of reinforcement opportunities in an

Test	Bila	Ndimalo	Stanley	Brandy	Malindi	Evans	Total
1 hr	-	-	-	-	-	X	1
1 hr	-	X	-	-	-	-	1
1 hr	-	X	-	X	-	-	2
Day 0/16 hrs	X	X	-	X	X	X	5
Day 0/16 hrs	X	X	X	X	X	X	6
Day 0/16 hrs	X	X	X	X	X	X	6
Day 1	X	-	-	-	X	X	3
Day 1	X	X	-	-	X	X	4
Day 1	X	X	-	X	-	X	4
Day 3	X	X	-	-	-	X	3
Day 3	X	X	X	X	X	-	5
Day 3	-	X	-	-	-	-	1
Day 6	-	-	-	-	-	X	1
Day 6	X	-	X	-	-	X	3
Day 6	-	-	-	-	-	-	0

Table 1. Distribution of rat indications (X) by test.

operational setting. Further research is needed, however, to ensure that animals reinforced to identify TNT locations can also accurately detect landmines. Research must also verify that the animals do not eventually develop stimulus discrimination and stop responding to mines while continuing to respond to TNT contamination sites.[7]

The procedure evaluated in the present study uses inexpensive and robust materials and allows the overnight creation of reinforcement targets in an operational setting with minimal time, cost and personnel, which are favorable. For these reasons, this system appears to be practical for operational demining using rats, and APOPO is currently verifying this. A similar system may be useful with demining dogs, possibly meriting investigation.

See endnotes page 67

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