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Evaluating Landmine-detection Rats in Operational Conditions

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Evaluating Landmine-detection Rats in Operational Conditions

Researchers evaluate the accuracy of pouched rats' ability to detect landmines under operational search conditions. Results indicate the ineffectiveness of one training method for maintaining quality operational performance and suggest further examination.

by Amanda Mahoney, Timothy L. Edwards, Kate Lalonde, Christophe Cox, Bart Weetjens, Tekimiti Gilbert, Tess Tewelde and Alan Poling [APOPO and Western Michigan University]

The uncertainty of specific landmine locations presents a unique challenge to using animals for landmine detection, preventing rewards from being arranged under operational search conditions. A common strategy is to create a training field near the operational site, so animals receive regular refresher training. However, the animals may discriminate between the operational condition and the training condition based upon contextual discrepancies.

Overview

Phase 1 of the present experiment evaluated the accuracy of five rats' abilities to detect landmines in a **no-reward** condition followed by a **reward** condition on a training field (i.e., non-hoed ground). Phase 2 evaluated the same conditions when the no-reward condition was conducted in an area made to simulate an operational minefield (i.e., hoed ground). When the sites were identical, the rats' accuracy was similar across conditions. When the no-reward session ground was hoed in Phase 2, the rats' accuracy fell relative to their performance in the baseline condition and reward session.[1] These results indicate that conducting training with reinforcement in areas that differ substantially from operational search areas is an ineffective method for maintaining good operational performance. Alternative reinforcement methods, such as creating reinforcement opportunities within a minefield using TNT contamination, should be examined.

Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling (APOPO) uses pouched rats trained with operant conditioning; the organization's operational experience and published data suggest these rats can detect landmines and other explosive remnants of war (ERW) successfully.[1,2,3,4] The rats work in extinction when they search for mines, because landmine locations are unknown. Therefore, whether an indication response is correct (i.e., near a mine or other ERW) or incorrect is unclear, and such responses are never reinforced (i.e., rewarded with food) in the field.[5] Studies have shown that operant behavior weakens and becomes more variable when extinction is arranged, and Mahoney et al. recently examined whether similar results would be obtained with pouched rats exposed to extinction on our training minefield.[6] Every day during the baseline condition, five rats separately searched one 100-sq-m box that contained a single mine under conditions where an indication response within 1 m of a mine was reinforced with food, while all other responses had no programmed consequences. Rats detected, on average, 97.8% of the mines and made very few errors. An extinction condition was then implemented in which food was not presented. Each rat emitted fewer identification responses thereafter. While the rats' accuracy fell substantially, false alarms did not significantly increase. On average, the decline in accuracy was evident within three days of the onset of extinction. Furthermore, when the reinforcement condition was reinstated, rats took an average of four days to recover accuracy to baseline levels. These results show that mine-detection rats' performance deteriorates quickly when extinction is arranged.

Consistent with the International Mine Action Standards (IMAS) 94.01 (2008), APOPO's mine-detection rats are given opportunities for reinforcement at a training site located close to the actual minefield.[6] The training site contains inactive landmines planted at known locations and resembles the operational site as closely as possible. At the training site, rats receive differential reinforcement for correct indication responses, and groups of rats rotate between the operational and training sites so that there are no disruptions in landmine clearance. This arrangement provides differential, albeit intermittent, reinforcement for correct indication responses and should be sufficient for maintaining accurate detection so long as

- Training and operational sites closely resemble one another, preventing the rats from discriminating settings where reinforcement is and is not available
- Exposure to the former setting is limited in time so that the deleterious effects of extinction are not manifested.[8,9] Previous findings suggest the reinforcement for correct indication responses does sufficiently maintain accurate in the operational settings under which the rats' performance has been evaluated.[3,4]

However, if the training field does not sufficiently resemble the operational site, accurate operational performance will likely be unsustainable. Basic research shows that animals exposed to arrangements in which periods of extinction alternate with periods of reinforcer availability, each correlated with a salient exteroceptive stimulus, respond rarely during the **signaled** extinction period.[10,11] Since creating a training site that closely resembles a particular demining site is sometimes impossible, ascertaining whether a similar relation occurs under field conditions is important. The present study was intended to determine whether the reinforcement of correct identification responses in settings that did not closely resemble settings in which extinction was in effect was sufficient to maintain accurate landmine detection. For comparison, we also determined detection accuracy when the extinction

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The rat's location is easily calculated in x and y coordinates.
All photos courtesy of APOPO.

setting and reinforcement setting were the same. In some applications, APOPO's rats searched for landmines (and other explosives) in areas that had first been cleared of vegetation by a brush-cutting machine or rototilled by large armored machines that sometimes fail to detonate every piece of unexploded ordnance. Because training fields cannot be rototilled in ways that mimic minefields, grass-covered, pre-prepared boxes were hoed by hand to uncover raw soil and used as the two settings of interest.

Setting, Subjects and Materials

APOPO conducted the experiment in Morogoro, Tanzania, on the APOPO training field. There, mines were buried within permanent boxes ranging in size from 100 to 400 sq m. Some boxes received markings to indicate the location of the landmines while some did not; however, the locations of all landmines were recorded in a database. Boxes without markings were used (i.e., note takers knew the target locations but the trainers did not) to ensure that the trainers could not inadvertently cue the rats to the presence of the landmines. APOPO conducted the present experiment in 64 100-sq-m boxes.

Five fully trained, adult rats—two females (Brenda and Malindi) and three males (Bila, Ndimalo, and Evans)—served as subjects. Brenda died during Phase 1 and was thus not included in Phase 2. The rats were distributed between two trainer teams, each comprising two accredited rat trainers and one data recorder.

Materials included clickers that sounded before providing food (bananas served as the reinforcer), timers, data sheets and mine detection training box materials. Measuring tape stretched along the side of the box, and rope stretched across the box to guide the rat as it walked inside the box. The rats, attached to the rope via a harness and leash, walked back and forth inside the box along the rope. Two measuring tapes attached to the rat's harness at the zero mark, and each trainer held one measuring tape. Thus, the exact location of the rat's indications could be specified using x and y coordinates revealed by the measuring tape in one trainer's hand and the measuring tape value at the trainer's feet. After the rat traversed the rope in one direction, trainers took a 0.5-m step forward, and the rat traversed the box in the opposite direction.

Data were recorded on graph paper that depicted the box measurements, with each test box divided on the datasheet into 0.5-m by 0.5-m cells; cells corresponding to the location of the mines were shaded gray. The indication response was scratching the ground for any length of time within 1 m of the landmine location. When an indication response occurred, the trainer informed the note taker who resolved whether or not to click and deliver the food. Following signal detection terminology, indications occurring within 1 m of the landmine were considered hits and followed by the auditory click and food, whereas indications greater than 1 m from a landmine were considered false alarms. Note takers also recorded instances of grooming, biting, and turning around in the lane.

Interobserver agreement data were collected during 20.9% of sessions, in which a second observer recorded instances of scratching on an unmarked sheet out of the primary observer's view range. Recorded instances of scratching within 0.5 m of each other were considered agreements, and instances greater than 0.5 m were considered disagreements. The overall interobserver agreement was 96.1%.

Experimental Procedures

APOPO used a multiple baseline across-subjects design.[12] Initially, the rats were randomly divided into two groups. Two rats in one group and three rats in the other group cleared two boxes daily, totaling four searched boxes per day. For example, on day 1, rats A, B and C might search boxes 1 and 2, and rats D and E search boxes 3 and 4. The order in which the rats in each group evaluated the boxes rotated daily. This rotation ensured that a particular rat's accuracy was not consistently influenced by cues left from the previous rat. The trainers remained blind to the location of the landmines but, following reinforcement for the first rat, were presumably privy to the location of the relevant landmine. Rotating the order of the rats helped to ensure that trainer cueing did not influence rat performance. Staff selected the boxes randomly each day until all boxes were used, then the process repeated.

APOPO conducted sessions five days per week and excluded weekends, holidays or days with heavy rain. Food intake was controlled throughout the study to ensure that the rats were mildly food deprived during the experiment. This was arranged by feeding the rats two hours after each experimental session had ended. All rats were given two (2 g) rodent food pellets per day during the reinforcement and extinction conditions. Weights for all rats were taken each Monday and Friday immediately prior to training and sufficient additional food (fruit and vegetables) was given on weekends to ensure that relatively constant weights were maintained.

Phase 1: Discrimination with consistent order of conditions. This phase determined the rats' hit and false alarm rates across two boxes when reinforcement for hits was not arranged in the first box searched (B1), but was arranged in the second box searched (B2); both boxes were similar. Twenty-four boxes were used in Phase 1. There were six boxes with no mines, five boxes with one mine, eight boxes with two mines, and five boxes with three mines.

Baseline. During baseline, all rats were exposed to a fixed-ratio 1 (FR 1) schedule of food reinforcement in both B1 and B2. That is, each hit was immediately followed by a click and food. Performance in the second box was always evaluated within one hour of the evaluation of the first box's performance. All instances of scratching the ground were recorded by writing **S** on the datasheet at the coordinates that matched the location of the rat in the box and circling the **S** if a click was sounded and followed by food delivery. The click was sounded only when the response occurred within 1 m of a landmine.

Extinction (B1) and FR 1 reinforcement (B2). The purpose of this condition was to examine the rats' performance under an extinction condition when followed by a reinforcement condition in an identical area. During B1 searches, hits had no programmed consequences (i.e., extinction was arranged). During B2 searches, rats were exposed to FR 1 reinforcement and sessions were conducted exactly as in baseline. If performance fell below a 33% hit rate in B1 but remained at baseline levels in B2 for three consecutive days, baseline conditions would be reinstated for that rat.

Phase 2: Discrimination with consistent order of conditions and differential box preparation. This phase replicated Phase 1 except that the boxes evaluated first (i.e., in the extinction condition) were prepared to mimic a brush-cutter prepared minefield. APOPO maintenance personnel carried out ground preparation by manually digging into each box using a hoe until the vegetation was removed and the ground was evenly exposed across the entire box. Special care was taken around the area of the landmines by digging into those areas last to avoid contaminating other areas of the box with TNT. All landmines were left undisturbed at least 5 cm below the soil. Forty boxes not used in Phase 1 were used in Phase 2. These boxes differed in no systematic way from those used in Phase 1 except that no boxes contained three mines in Phase 2, which used 14 boxes (seven prepared) with zero mines, 18 boxes (nine prepared) with one mine, and eight boxes (four prepared) with two mines.

Baseline. Baseline was conducted as in Phase 1, except that B1 was always a prepared box (i.e., one with disturbed soil). An FR 1 schedule was in effect for both boxes.

Extinction (B1) and FR 1 Reinforcement (B2). Extinction in Phase 2 was conducted similarly to Phase 1, save that the extinction condition was always arranged in a prepared box and was always followed by reinforcement in an unprepared box. That is, B1 was always a prepared box and B2 was always an unprepared box. As in Phase 1, baseline was reinstated after three consecutive days of performance below a 33% hit rate in B1 with no corresponding drop in performance on B2.

Results

For each rat, the cumulative number of missed landmines across test sessions is displayed in Figures 1 and 2 (next page). False alarm rates were not graphed because they did not vary systematically throughout the course of the experiment (Table 1).

Mean False Alarm Rates		
	B1	**B2**
Ndimalo	0.5	0.4
Bila	0.9	0.6
Evans	1.1	1.1

Table 1. The mean false alarm rates for Ndimalo, Bila, and Evans.
Table courtesy of CISR.

In Phase I (see Figure 1), there was no observed degradation of responses for four of five rats when an extinction condition immediately preceded a reinforcement condition within identical field conditions. Malindi was the only rat for whom extinction effects were observed, meaning that she missed the mine in the extinction condition (B1) across three consecutive days but did not miss the mines in the reinforcement condition (B2) on those days. The misses occurred after 48 days in the extinction condition. After the third consecutive miss in B1, the FR 1 reinforcement condition was reinstated and Malindi found six of seven mines in B1 (85.7%) after the first day. She found six of eight (75%) mines in B2.

One rat (Brenda) died during Phase 2; the corresponding data are not shown. Baseline performance during Phase 2 was at or near 100% accuracy for all rats. Unlike in Phase 1, extinction effects were observed for three of the four rats. For Evans, Ndimalo and Malindi, reduced accuracy in B1 was observed after 26, 21 and 18 test days respectively. Upon the reinstatement of reinforcement in B1, Evans' and Ndimalo's detection accuracy recovered to baseline levels within 1–2 test days, while Malindi's detection accuracy recovered after 10 days. Bila was an exception in that extinction effects were not observed after 40 days, although detection accuracy in B1 was slightly lower than in B2 during the extinction condition. Bila hit 87% of mines in B1 and 96.2% mines in B2 during this condition.

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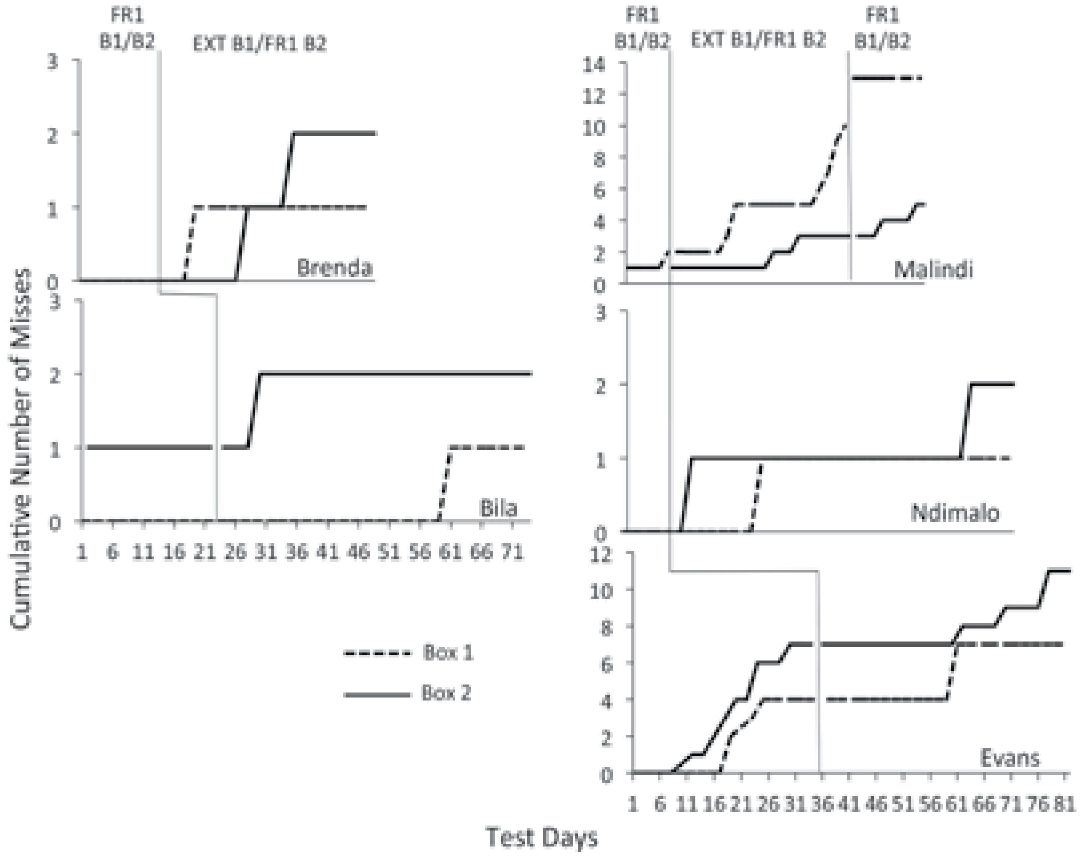

Figure 1. Experiment 1, Phase 1 results. Cumulative number of landmine misses for five individual rats during extinction (Box 1) and reinforcement (Box 2) with two normal training boxes.
All figures courtesy of the authors.

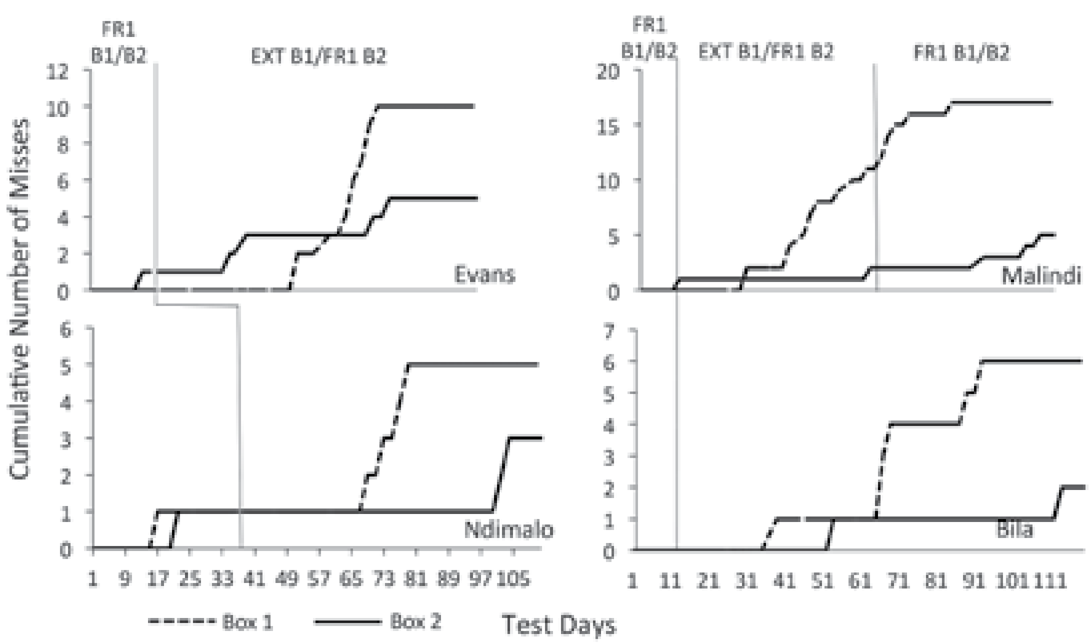

Figure 2. Experiment 1, Phase 2 results. Cumulative number of misses for four individual rats during extinction in ground-prepared boxes (Box 1) and reinforcement in normal training boxes (Box 2).

Sign tests were conducted on the hit rate in B1 and subtracted from the hit rate in B2 for each rat in each baseline and extinction trial in Phases 1 and 2. Trials in which one of the boxes contained no mines were excluded from this analysis. For Phase 1 baseline data, Phase 1 extinction data and Phase 2 baseline data, no statistically significant difference was found between performance in B1 and B2. A p-value approaching one was obtained from the sign test for each of these phases. For Phase 2 extinction data, a statistically significant difference was found between performance in B1 and B2 ($p < .001$).

Discussion

Results of Experiment 1 strongly support the conclusion that conducting post-operational training in boxes that differ substantially from operational boxes is not an effective method for maintaining good operational performance by landmine-detection rats. Although unsurprising given the well documented effects of signaled extinction, it is highly significant with respect to APOPO's operational activities in which rats search for explosives under extinction conditions in rototilled boxes while earning reinforcers in vegetated training boxes.[10,11] In such situations, it appears necessary to arrange reinforcement opportunities while the rats are engaged in actual mine-detection activities. Recent research suggests pouched rats can readily detect locations where plastic bags containing 2, 4 6-TNT, the active ingredient in most landmines, have been placed in contact with the ground for 16 hours, then removed, and can do so for several days following removal.[13] If the scent of TNT strongly generalizes to the scent of landmines, which contain TNT as well as other volatile materials, placing and removing bags containing TNT at known locations on a minefield and reinforcing indication responses near those locations would be sufficient to maintain the rats' indication responses near actual landmine locations, even though such responses would not be reinforced. We are currently examining whether this occurs.

Watch APOPO rats in action: http://bit.ly/YV979j.

See endnotes page 66

Close-up photo of a pouched rat in training.

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Bart Weetjens began the idea of training rats as an appropriate technology to detect landmines and screen for tuberculosis. With his years of experience as a product design and development engineer, Weetjens founded APOPO with support from Professor Mic Billet and his colleagues at Antwerp University. Weetjens is an Ashoka fellow and a Schwab fellow.

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