Mine Detection Rats: Effects of Repeated Extinction on Detection Accuracy

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This article describes the performance of Giant African Pouched Rats where reinforcement (reward) or extinction (no reward) conditions affected landmine identification. Accuracy deteriorated quickly in the absence of reinforcement, suggesting that reinforcement is essential.

The mine detection rats in Mozambique work on training fields and actual minefields (operational sites). The training field comprises several 100 sq m, 200 sq m and 400 sq m boxes indicated by ropes along each side. Between zero and four deactivated landmines are buried within each box. The rats are attached to a rope (via a harness) held by two handlers on either side of the box. The rats walk across the box they are searching. When an indication response (passing and digging) occurs within 1 m of a landmine, the trainer clicks to signal reinforcement and food is delivered.

When the rats are used operationally, the location of mines (and other explosive remnants of war) is unknown prior to clearance operations. Therefore, knowing whether an indication response is correct (i.e., within 1 m of a mine) or incorrect is impossible. To avoid the possibility of reinforcing incorrect responses and thereby potentially reducing the rat’s subsequent detection accuracy, no reinforcers are delivered when the rats are used operationally.

In technical terms, the rats work under extinction (no reinforcement) conditions when used operationally and under differential reinforcement (food reinforcement for correct responses, no reinforcement for incorrect responses) conditions during training. Extinction inevitably weakens previously reinforced responses. For this reason, the rats rotate between the training field and the operational site. The rationale for this arrangement is that reinforcement of correct responses on the training field will sufficiently strengthen such behavior to compensate for the response weakening effects of extinction at the operational site. The rats’ performance at the operational site strongly suggests that this is the case, but we have not systematically evaluated the extinction effects, though studies output raster map for each degree of operational difficulty. For example, the overall surface with a low degree of difficulty is directly read into the output raster. This kind of information may be significant for decision-makers and operators, especially in financial terms. Further work, in fact, this model opens the possibility to estimate the financial implications of their operational choices.

Conclusion

The 5D model is a first approach for modeling an operational difficulty of demining at a macro level. The model was developed in ArcGIS® Desktop, which is readily available in most mine-affected countries. Users interact with the model via an intuitive and graphical interface by setting a series of parameters that can be modified through the program runs, especially the area of study and input factors. Even if the workflow may seem complex, using the model does not require intensive GIS skills.

The resulting map is a good starting point for decision-makers and operators to refine their evaluation of the degree of operational difficulty and improve efficiency in their work. However, this tool is intended as a guide, and real-world political or economic factors may lead to or prevent demining activities in a way that may disagree with the tool. In addition, deminers should be aware that modification of one parameter could affect the outputs of the model significantly.

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Figure 6. Parameters provided to users at the execution of the model. Figure courtesy of the authors.
are under way. In an effort to gain information of value to maximize the effectiveness of APOPO's MDR team, the present study evaluated the effects of extinction on the detection accuracy of five rats performing under controlled conditions that allowed for accurate assessment of their performance.

Setting, Subjects and Materials

Trials took place in Morigoro, Tanzania on the APOPO training field, which contains approximately 1,210 landmines buried in a fenced 283,276.85 sq m area. In the portion of the training field used, one mine was buried in a marked 100 sq m box. Some of the boxes in APOPO's training field have markings to indicate landmine locations and some do not. The boxes without markings were used in the present study to provide blind testing conditions, under which the trainers were unaware of mine locations. The tests used six boxes, each containing just the one mine. Each test took an average of 17.8 minutes with a range in time of 8 to 25 minutes. Five rats participated in this test. Each rat had previously passed a blind test in which it located each of eight unmarked mines in a 400 sq m area with no more than one false alarm. The rats were distributed between two trainer in a test team comprised of two trainers and one notetaker. The notetakers were APOPO minefield supervisors. APOPO certified all trainers and selected them because they demonstrated good adherence to standard operating procedures. Materials included clickers to signal availability of the food rewards, data sheets, a banana (the food reinforcer) and mine detection training box materials.

Training box materials consisted of measuring tape stretched along one side of the box and a rope that stretched across the box between the two trainers and guided the rat as it walked in the box. The rats were attached to the rope via a harness and lead cord and could walk back and forth along the rope. The trainers held two measuring tapes between them. One end of each tape was attached to the rat's harness at zero. Thus, the exact location of the rat's indications could be determined through the coordinates of the measuring tape value in the trainer's hand and the measuring tape value at the trainer's feet. After the rat walked down the rope in one direction, the trainers took a 0.5 m step forward and the rat walked in the opposite direction across the box. In all tests, the rats were allowed to traverse the rope only once before they were moved forward.

Data were recorded on graph paper that depicted the box measurements. Each test box was displayed as a grid comprised of 0.5 m x 0.5 m squares. Shaded gray squares corresponded to the mine locations. The indication response was scratching the ground for any length of time within 1 m of the mine. Upon a rat indication, the trainer informed the notetaker, who recorded the location of the indication and whether or not the trainer should sound a click and deliver food to the rat. In the reinforcement condition, the trainer was instructed to sound a click and deliver food (i.e., provide a reinforcer or reward) each time an indication response occurred within 1 m of a mine. Reinforcers were never provided in the extinction condition.

Experimental Design

A multiple baseline with reversal design evaluated detection accuracy under reinforcement and extinction conditions: 1 In a multiple baseline design, different subjects are initially exposed to the conditions of interest on different days. This design demonstrates that the changes observed when conditions change are the result of the change in conditions and not the result of some other factor (e.g., weather conditions, day of the week, time of exposure to a condition). A reversal design calls for returning to a prior condition, which in this case was the reinforcement condition. Thus, all of the rats were exposed to a reinforcement condition, then extinction, reinforcement and finally extinction.

When performance remained at 100% accuracy under the reinforcement condition over at least four consecutive days, the extinction condition began. Since there was only one mine per box, if the rat found it, the detection accuracy was 100%; if it did not indicate a mine, the detection accuracy was 0%. The rat worked under the extinction condition until detection accuracy fell 9% for at least two consecutive days.

This sequence was then repeated.

All rats worked in one box per day, and sessions were conducted up to five days per week. Sessions were not conducted on weekends, holidays or days with heavy rain. Data recorded each day for each rat were the location of indications, the number of hits (indication responses within 1 m of a mine), the number of false alarms (indication responses further than 1 m from a mine) and the number of misses (mines with no indication response within 1 m).

Reinforcement Condition. In this condition, when an indication response occurred within 1 m of a mine, the trainer produced a click sound using a handheld clicker. If the rat began to approach the trainer within 3 seconds of the click, which usually occurred, the trainer delivered food. If the rat did not approach the trainer within 3 seconds of the click, the trainer did not present food. If a rat walked over a mine without indicating, the rat remained in the box and the trainer continued cleaning the rest of the box. Each rat searched each area of the box only once.

Extinction Condition. Extinction sessions were the same as reinforcement sessions, with the exception that neither a click nor food was presented following either correct or incorrect identification responses.

Second Reinforcement and Second Extinction Conditions. The second reinforcement condition, which was identical to the first reinforcement condition, occurred after the first extinction condition. The second extinction condition was the same as the first one and was the last condition arranged for each rat. Figure 1 shows the number of days that each rat was exposed to each experimental condition.

Independent-Observer Agreement. A second observer independently collected data during 21.5% of sessions. The second observer agreed with the primary data collector on 98.1% of rat indications.

Results

Figure 1 (page 62) shows the percentage of hits (correct identification responses) per day by individual rats during reinforcement and extinction conditions. Because each box had one mine, accuracy was either 0% or 100%. During the initial reinforcement condition, the rats identified all mines except for a single mine missed by Nijad in the third session. In general, because accuracy was 100% on the first day, the rats did not appear to learn from the use of the same six boxes. The trainers may have learned the location of the mines, and at some point they may not have been operating under blind conditions. However, a second observer was present every session to verify 60% of the sessions to ensure that procedures were followed as written and that there was agreement in recording.

When extinction was introduced, accuracy declined for four of the five rats within three sessions. Enda's performance did not fall until the seventh session but remained at 0% for six of the next seven sessions. Typically, the rats continued emitting an indication response over the mine on some days during extinction, but failed to indicate on about as many days as they indicated. Upon return to the reinforcement condition, detection accuracy for Toyota remained variable for six days while performance for Mar remained at 0% for eight out of nine days before improving to the initial reinforcement-condition level. Performance for Nijad and Bila recovered to 100% accuracy in two days, and Enda's performance improved to this level after three days. Upon return to extinction, responding fell within two to four days for all rats. Performance again took several days to recover to prior reinforcement levels for Enda and Mar, although the performance of Bila, Toyota and Nijad recovered in zero to two days.

Figure 2 summarizes findings across the five rats. This figure clearly shows that overall the rats' accuracy in detecting landmines was high during the first reinforcement condition and quickly declined when extinction was introduced. Accuracy remained inconsistent and relatively low after reinforcement was again arranged but eventually reached a high level. The rats' accuracy again declined even more rapidly when extinction was introduced a second time. For this reason, these rats will not be used in actual future detection operations.

Few false alarms (incorrect identification responses) occurred under any condition, and the number of false alarms per session did not consistently differ under reinforcement and extinction conditions. None of the rats emitted more than three false alarms on any given day, and an individual rat typically emitted zero or one false alarm each day.

Discussion

This study evaluated the performance of APOPO's MDRs under reinforcement and extinction conditions and found that, in general, the rats demonstrated high accuracy and stable performance after sufficient expo-
between training (reinforcement) and operational (extinction) conditions. The success of this procedure depends upon how well the rats discriminate between reinforcement and extinction.11 Though APOPO has not yet evaluated the manner in which reinforcement was arranged prior to extinction, the rats’ accuracy in detecting mines fell, on average, after 3.1 days of exposure to extinction, although their false alarm rates did not change systematically. Furthermore, recovery of the asymptotic accuracy level following extinction took up to nine days.

To maximize experimental control, the present study only used 100 sq m boxes containing a single mine. In operational density in Morambique, the overall density of landmines is substantially lower. For example, in one study the Ordnance Disposal Office began its operations in El Fasher in 2005 and had cleared 96,400 sq m area, which yields an average of 0.04 mines per 100 sq m box, although in some cases a rat made one to two or sometimes three correct detections within a small area. The effects of extinction on the performance of MDRs under such conditions, where target density is a highly variable but low overall, remain to be determined. Of course, performance in extinction depends on a number of environmental variables. These variables seemingly would include the number of responses emitted without reinforcement and the manner in which reinforcement was arranged prior to extinction.

Future research in this area might investigate the effects of training with intermittent reinforcement, which is well-known to prolong accurate performance under extinction. Though APOPO has not yet evaluated this methodology, it has used intermittent reinforcement, with trainers rewarding 85% of indications. APOPO plans to study intermittent reinforcement and evaluate optimal parameters and effectiveness.

APOPO is currently investigating the utility of exposure to reinforcement conditions, prior to or following the extinction conditions.12 The success of this procedure depends largely upon how well the rats discriminate between training (reinforcement) and operational (extinction) conditions. These tests were conducted for experimental purposes to provide relevant information to APOPO management. Prior research conducted under operational conditions indicates that APOPO rats are accurate in detecting landmines under the conditions arranged in Morambique.10 APOPO draws upon these means of reinforcement delivery in operational conditions: frequent quality control checks, data collected regularly on individual rat performance and ample opportunity for reinforcement on the nearby training field. How the rats would perform under other conditions, for example, if they worked for longer periods each day or in areas with different landmine concentrations, is speculative. The present data strongly suggest, however, that their accuracy would decline significantly if they worked for periods during which several indication responses occurred and were not reinforced. This study and previous ones provide a research base that informs APOPO’s operating procedures in a way that usually optimizes operating procedures and ensures the rat’s performance is maintained at high levels under operational settings.

APOPO’s primary goal is using poised rats effectively and efficiently for humanitarian purposes, not conducting scientific research. Such research is, however, the best means to that end and for that reason is given high priority by the organization. Conducting a research uses personnel, time and financial resources that could go directly toward mine clearance or land release. Therefore, we attempt to choose research topics carefully and to design studies in ways that minimize cost. Small-N research strategies characteristic of behavioral analysis have proven extremely valuable in this regard, and we recommend them to the humanitarian de-mining community. See endnotes page 67

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Endnotes


3. The Ordnance Disposal Office began its operations in El Fasher in 2005 and had cleared 96,400 sq m. See endnotes page 67

4. Sudan’s National Mine Action Authority (NMAA) was established through Presidential Decree No. 299 in December 2005 and adopted the Sudan Mine Action Bill in 2010. In 2012, NMAIC and UNAMID ODO signed a letter of cooperation, and NMAIC started establishing offices in Darfur. More information can be found at http://sudan.mineaction.gov.


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16.3 | fall 2012 | the journal of ERW and mine action | endnotes