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Research Innovation

USING GIANT AFRICAN POUCHED RATS (*CRICETOMYS GAMBIANUS*) TO DETECT LANDMINES

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Within the past decade, giant pouched rats have been used successfully to detect landmines. This manuscript summarizes how these rats are trained and used operationally. The information provided is intended to be of practical value toward strengthening best practices in using Cricetomys *for humanitarian purposes while simultaneously ensuring the well-being of those animals.*
Key words: landmine detection; African pouched rats (*Cricetomys gambianus*); remote explosives scent tracing (REST); signal detection; animal learning

Many species have sensitive chemical-detection systems. For millennia, dogs' exquisite sense of smell has assisted human beings in hunting and in thwarting intruders. Trained dogs have detected landmines and other explosives, illicit drugs, pipeline leaks, and melanomas (Furton & Myers, 2001). Although *Canis familaris* is far and away the species whose chemical-detection abilities most often benefit humans, a few other species have been used (Habib, 2007). For example, personnel of Anti-Persoonsmijnen Ontmijnende Product Ontwikkeling (APOPO), a nonprofit organization devoted to social entrepreneurship, have trained rats to detect landmines and had them accredited as de-mining animals under International Mine Action standards. APOPO's work recently has garnered positive media attention in, for example, *National Geographic*, *Business Week*, *The New York Times*, *BBC News*, and *African Geographic*. In 2009 APOPO won a Skoll Award for Social Entrepreneurship. Skoll Awards recognize innovative and sustainable approaches to resolving urgent social issues.

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Clearly, APOPO's use of pouched rats for landmine detection is promising. To date, no published report details how APOPO trains rats to detect mines. The present manuscript reviews how the rats are trained and deployed in the field, with special emphasis on challenges posed by the tasks they are required to perform and their unique characteristics.

Pouched Rats as Mine Detectors

Giant pouched rats, which are native to sub-Saharan Africa, are nocturnal and omnivorous members of the *Nesomyidae* family within the *Muroidea* superfamily. They are large colony-dwelling rodents, with adult body lengths of 25 to 45 cm and tail lengths of 35 to 45 cm. Adult females typically weigh 1 to 1.5 kg. ; males are somewhat larger. Both sexes reach reproductive maturity at 7 to 8 months. Pregnant females give birth to 1 to 5 pups following a gestation period of 27 to 36 days; in the wild and in captivity, several litters can be produced each year. *Cricetomys* live up to 8 years in captivity. They are agricultural pests in the wild and an invasive species in Florida (USA). In Africa, they are sometimes hunted and eaten.

Ten years ago, Bart Weetjens founded APOPO. Because of the high cost of canine training and husbandry, Weetjens and his colleagues searched for an alternative to dogs for use in de-mining operations. They chose to study *Cricetomys* because the species has a good sense of smell, and is long-lived, easy to maintain, large enough to work on a lead, and native to Africa, the intended location for de-mining activities. Their initial attempts to work with animals caught in the wild failed because the rats were aggressive and easily startled. To produce more tractable rats, a breeding colony was established in which wild-caught males and females lived under conditions as close as possible to their natural environment. Pups were taken from their parents at various ages and handled extensively in an effort to socialize them. Through trial and error, APOPO personnel developed a standard procedure for producing gentle, easily trained rats (Verhagen, Cox, Mauchango, Weetjens, & Billet, 2003; Verhagen, Weetjens, Cox, Weetjens, & Billet, 2006).

In this procedure, the rats are weaned at 4 weeks of age and thereafter housed in pairs in cages with unlimited access to water and a nest box. To allow for easy identification and to emphasize the importance of individual animals, each rat is named and fitted with a subcutaneous passive integrated transponder tag. By ensuring that individual animals can be identified accurately, these tags play a key role in quality assurance in rats that are employed for mine clearance operations and undergo accreditation through a National Mine Action Authority (NMAA), as described later. The rats eat a varied diet of fruits, vegetables, grains, and commercial rodent chow. During weekdays, when training occurs, they consume most of their food during training sessions. A veterinarian regularly examines the rats and provides health care as needed. At present, APOPO's Tanzanian facility maintains 167 rats, and 34 other rats are involved in the mine action program in Mozambique.

From 4 weeks to approximately 6 weeks of age, the rats are handled by trainers and other people three times a day and exposed to a wide variety of objects, sights, sounds, and smells. People also hand-feed the rats preferred foods, such as bananas and peanuts. This process gentles the rats so they do not bite or attempt to escape when handled, and it habituates them so that they do not exhibit a startle response upon encountering novel stimuli. Early on, the rats are exposed to transport cages and taken for rides in vehicles. They also are harnessed and leash-trained to follow a handler. Such pre-training continues until an individual rat does not exhibit a startle or escape response upon encountering an unfamiliar place, sound, person, or odor. The experiences provided to rats at APOPO approximate what is often termed "environmental enrichment," which is known to improve several aspects of the neurochemistry and behavior of domestic laboratory rats (*Rattus norvegicus*), including their ability to learn and to remember (e.g., Hutchinson, Avery, & VandeWoude, 2005; Nithianantharajah & Hannan, 2005; Van Praag, Kempermann, & Gage, 2000).

Once the rats have been socialized, training begins. The goal of training is to produce rats that consistently emit an easily observed indicator response when they smell a landmine and do not emit this response at other times. This is a signal detection task (Green & Swets, 1966), in which the scents of compounds that landmines release constitute signals and all other scents constitute noise. There are many different kinds of landmines, and the scents they release depend on the kinds of explosive compounds and other materials they contain. APOPO's work has focused on teaching rats to find mines that contain 2,4,6-trinitrotoluene (TNT), which is the main explosive charge in most types of landmines. To do this, trainers expose rats to an operant stimulus discrimination task in which a designated response is reinforced in the presence of TNT, but not in its absence. Such differential reinforcement establishes TNT as a discriminative stimulus (S^D) that reliably engenders the operant response, which rarely occurs in its absence.

In signal detection terminology, emitting the indicator (operant) response when the signal (S^D) is present on a given trial is termed a "hit," and emitting that response when the signal is not present is termed a "false alarm." Indicating that the signal is not present on a given trial, either by withholding the response indicating a signal (as in our procedure) or by emitting another response (as in procedures used by others), is termed a "correct rejection" if the signal is not present and a "miss" if the signal is present. As illustrated in the 2 × 2 contingency table (see Table 1), hits and correct rejections are correct responses, whereas false alarms and misses are incorrect. In operational mine detection systems it is essential to have a high rate of hits and a low rate of false alarms. Performance standards have been established with regard to both measures, as discussed later with respect to accrediting rats and their handlers.

Table 1
Contingency Analysis of Rats' Responses

		True State of Affairs	
		Mine present	Mine absent
Rats' indication	Mine present	**Hit**	False alarm
	Mine absent	Miss	**Correct rejection**

Note. Correct responses appear in boldface type.

APOPO's training facilities are located in Morogoro, Tanzania, on the campus of Sokoine University of Agriculture. They include laboratories and a 280,000 m^2 simulated minefield. About 140 people work for APOPO;

more than 90% of them are residents of Tanzania or Mozambique. Trainers conduct sessions both in the lab and in the field 5 days a week at about the same time each day. Field training typically occurs between 7 a.m. and 9 a.m., followed by training in the laboratory. Discrimination training begins when APOPO's rats have been socialized, at roughly 2 months of age. Laboratory and field training activities prepare the rats for actual landmine clearance. Brief descriptions of these activities follow.

Laboratory Training

Insofar as possible, trainers immediately reinforce the indicator response when it occurs in the presence of the S^D; delaying reinforcer delivery impairs learning the discrimination. Pilot work at APOPO showed that mashed bananas mixed with crushed commercial rat food pellets (to enhance nutritional value) was an effective unconditioned reinforcer even when rats were only mildly food deprived. Trainers deliver this mixture—hereafter called "bananas"—through a 20-cc syringe with an attached feeding tube.

Clicker Training

Trainers cannot present bananas immediately following correct responses in the field, because the rat will often be a considerable distance (e.g., 2–5 m) from them when the response occurs. To solve this problem, trainers arrange respondent conditioning similar to that described by Pryor (2002) to establish a loud click as a conditioned reinforcer. Each time the rat, placed in a open cage, approaches the trainer, he or she sounds the clicker and immediately presents food. Such pairing of the clicker and food occurs 15 to 20 times per session, until the rat appears satiated. Two sessions are conducted daily for each rat. In addition to establishing the click as a conditioned reinforcer, this training establishes it as an S^D for approaching the handler, who provides food.

Sniffer Training

In the second stage of training, each rat learns to sniff at a hole (2 cm in diameter) centered in the floor of a metal test cage (66 × 66 × 45 cm) and to pause when it smells TNT. To present TNT, the trainer places a small plastic pot containing 2 g of sandy soil spiked with up to 5 drops of aqueous TNT solution (100 ng per microliter) on a shelf immediately below the hole. The trainer sounds a click and presents bananas if the rat places its nose in the hole for 2 consecutive seconds. The rats typically learn to do this rapidly. With some rats, the trainer must shape correct responding by reinforcing progressively longer durations of nose-in-hole. Multiple daily trials occur until the rat places its nose in the hole within 5 seconds of being put in the box and keeps it there for 2 consecutive seconds on 10 consecutive tests. Subsequently, the time the rat is required to keep its nose in the hole to earn a click and food is gradually increased across training sessions to 5 seconds. Training continues at the 5-s level until the rat meets the criterion just described.

A three-hole cage is used to establish TNT as an S^D in Stage 3 training. This cage (66 cm long × 66 cm wide × 45 cm high) is similar to the one-hole cage but contains three sniffing holes located 10 cm apart, below which pots can be placed. During initial discrimination training, half of the pots contain TNT-contaminated sand and half contain plain sand. The trainer sounds a click and delivers food on each trial that a rat keeps its nose in a hole above TNT for 5 seconds, but not at any other time. Rats are always placed in one end of the cage and learn to move quickly to the holes, sniffing each in turn. Trainers test the rats multiple times each day, typically exposing them to 60 to 90 pots. Training continues under this procedure until they consistently emit the indicator response on 100% of occasions when TNT is present and on no more than one occasion when TNT is absent.

Next, the rats undergo a procedure in which perforated stainless steel balls (tea eggs), some empty and some containing TNT, are placed with the rat on a 0.75 × 3 m solid platform with high sides and covered with approximately 1 cm of TNT-free (neutral) soil. The rat receives a reinforcer (click and bananas) only if it bites or digs at a tea egg containing TNT. Once it reliably does so, it is moved to the next step, whereby the neutral soil is spread on a 4 × 7–m floor and the tea eggs are buried up to 1 cm deep. Once again, the rat receives a reinforcer only if it bites or digs near a buried tea egg containing TNT. When rats complete this stage by making the indicator response to all tea eggs containing TNT and to no tea egg without TNT, they move to field training.

Field Training

Field training occurs in the simulated minefield. Field training begins in 3-m wide × 10-m long areas, conventionally termed “boxes” in the demining literature, cleared of all vegetation. Five to 10 tea eggs containing TNT are partially buried around each box, and the rats’ task is to detect them. A similar number of tea eggs containing nothing or one of a variety of other chemical compounds are also buried in each box. The locations of eggs containing TNT and eggs containing nothing or another compound are recorded.

The Axle System

An important first step in field training is to teach the animals to move systematically across a designated area, searching it thoroughly. To accomplish this, the rats initially learn to move back and forth along the length of a metal rod (axle) that is suspended between two trainers who slowly move the rod forward. The rats wear a nylon harness with a metal snap connector to which one end of a thin nylon line is attached. The other end is looped around the axle, which is suspended between two metal wheels. This arrangement allows the harness cord and rat to move along the length of the axle. The trainers hold in their hands thin lines attached to the rat’s harness cord. The trainers can gently direct the rat to move in either direction along the axle by pulling on one line and feeding out the other. After a very short time, pulling becomes rarely necessary, however, because the rats are already leash-trained and learn quickly to move independently from side to side along the axle. The wheels are six-sided, not round, and each side is 0.5 m long. As soon as a rat moves all the way from one side of the axle to the other, having searched the area between them, the trainers push the wheels forward, moving the axle 0.5 m. This process continues until the entire box is searched.

If a rat pauses at a tea egg containing TNT and scratches (i.e., digs with its forepaws) or bites at or near that egg for at least 5 seconds, the trainer sounds the clicker and presents bananas. If this indicator response occurs near a tea egg that does not contain TNT, the reinforcer is not presented and the rat is pulled away. Note that the indicator response differs in laboratory and field settings. In the lab, save when tea eggs are presented, the rat is required to pause for 5 consecutive seconds with its nose in or near a sniffer hole. In the field, the rat is required to pause and scratch (dig) or bite for 5 consecutive seconds. Digging and biting the ground are natural food-procurement responses for *Cricetomys*. Because the smell of TNT predicts food (in the sequence TNT–click–food), it soon comes to elicit these responses in the same way that tokens followed by food elicited rooting in domestic pigs in Breland and Breland's (1961) seminal demonstration of elicited species-typical responses intruding on required operant responses. Rather than viewing it as an intrusion, we take advantage of rats' easily observed and consistently engendered species-typical response of scratching and biting as the indicator response in our field work.

Each rat searches two boxes for tea eggs containing TNT each day. Training continues until every egg engenders an appropriate indicator response and no other indicator responses occur. At that time, the rat is moved to a 3-m-wide box that contains defused landmines (PMN, PMR1, PMR2, No. 4, PMD-6, T-59, TM-57, M16, M14, and MK-5 types) that the Tanzanian military buried just below the surface in 2001. Individual boxes used for training contain 0 to 5 mines, and rats are assigned at random to training boxes on a daily basis. Since 2001, all boxes have been kept clear of tall vegetation (>5 cm) by hand-cutting with machetes.

Numbered metal stakes define the boundaries of individual boxes, allowing specification of a rat's location at any time in terms of two coordinates. Painted stakes placed at the side of training boxes identify the coordinates for and the type of each buried mine. Trainers record correct indicator responses occurring within 1 m of a mine and immediately reinforce them with a click and, after the rat approaches one of the handlers, a mouthful of bananas. Trainers also record indicator responses farther from mines (false alarms) but do not reinforce them. If a rat fails to indicate a mine, it is led repeatedly across it until an indicator response occurs or the trainer judges, typically after four to six exposures, that the rat is unlikely to respond correctly. Training continues in this fashion, with rats exposed to two boxes per day, until a rat completes a box having correctly identified all of the mines and having no false alarms. At that point, it moves to a 5-m-wide box and training proceeds as just described. When the same performance criterion is met, the animal is moved to 100 m^2 (5 × 20 m or 10 × 10 m) boxes and the procedure is repeated.

The Rope System

When rats move to the 100-m^2 boxes, trainers replace the wheels-and-axle apparatus with a rope system. In this system, one end of 10.5-m nylon rope with elastic loops at each end is placed around the leg of one trainer at calf level and the other end is looped around the leg of the other trainer. The trainers pull the rope taut from opposing-side box boundaries. The rat's harness cord slides along this rope, rather than the axle, and the trainers move the rope forward via synchronized steps (c. 0.5 m in length) each time the rat completes a traverse of the rope. Apart from the device used to direct the rat, training conditions in the 100-m^2 box are the same as in the smaller box. Once criterion is met in the 100-m^2 box, the rat is given a blind test, in which the trainers do not know the location of mines. To pass, the rat must correctly identify all of the mines in a 100-m^2 box with no more than two false alarms. A rat that passes this test is considered ready for operational service and is designated a "Jackpot" rat because its trainers receive a financial bonus. Rats that fail the blind test are retrained. In 2008, APOPO's trainers produced 38 rats that passed the final blind test. On average, 252 training days were required for individual rats after the socialization and gentling period was complete; the range across rats was 164- to 590 days (see Figure 1).

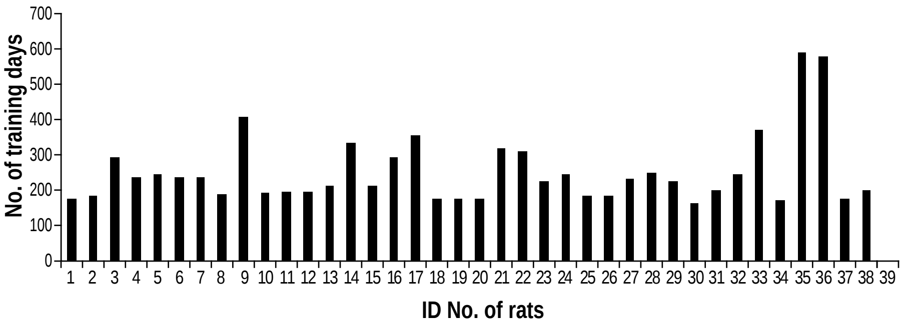

Figure 1. Number of training days required for individual rats to be certified as "Jackpot" animals ready to be sent for de-mining work in Mozambique or elsewhere. Data represent the 38 rats meeting criterion in 2008.

Field Operations

After a rat has passed the blind test in APOPO's minefield, it is sent to the country where it will engage in actual mine clearance. APOPO is currently involved in de-mining operations in Mozambique and is tasked by the Mozambiquan National Demining Institute as the main operator for Gaza province. A team of 50 APOPO personnel and 34 rats, outfitted with a variety of equipment, works on the project, which is slated to conclude in 2013. Rats trained in Morogoro, Tanzania, are flown to Mozambique and moved into a colony area, where they are maintained much as they are in Morogoro.

In field operations, an armored bush cutter removes vegetation from the area to be checked by the rats. Humans (manual de-miners) wearing protective gear and equipped with metal detectors then manually clear safe lanes, which they conspicuously mark. In field operations, the rats are worked on a rope stretched between two trainers wearing protective equipment. The handlers move along the safe lanes previously described. The location of each indicator response is recorded. Two different rats examine every area. All locations where either or both rats made an indicator response are checked by a manual de-miner using a metal detector. De-miners dispose of all located mines and Explosive Remnants of War (ERW; e.g., grenades, mortar rounds). In the first 9 months of 2009, APOPO's team cleared 199,318 m^2 in Mozambique, finding 75 landmines and 62 ERW and allowing more than 750 families to return to their land. Figure 2 shows the cumulative number of m^2 cleared and explosive devices (landmines plus ERWs) located by month.

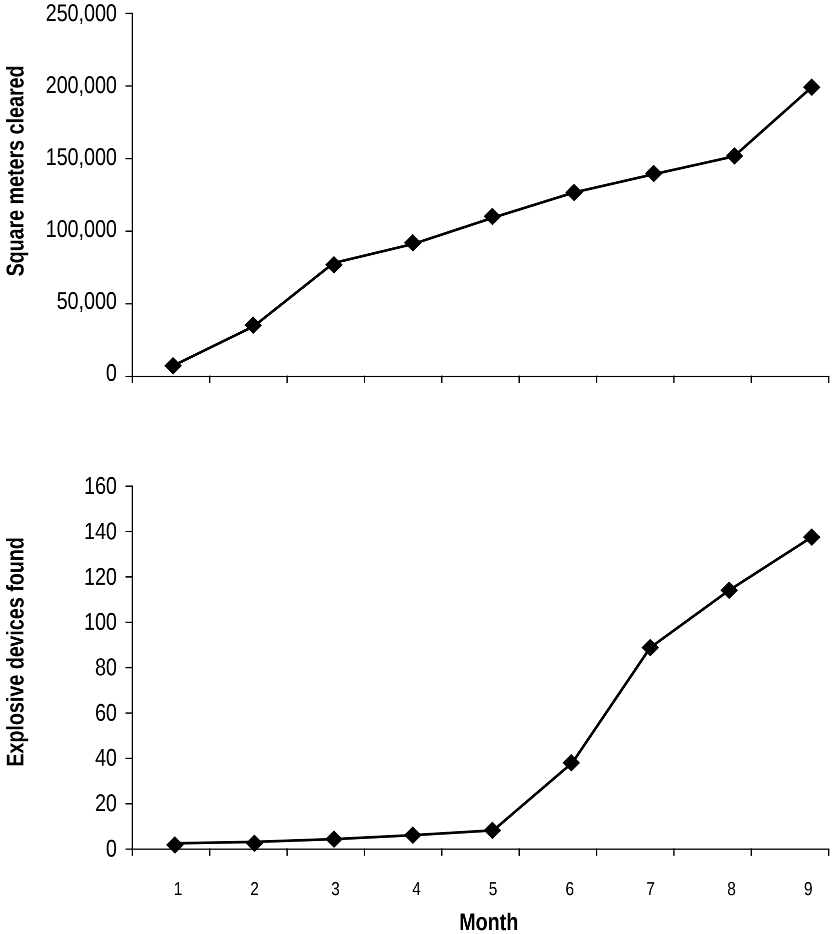

Figure 2. Cumulative number of square meters de-mined (top panel) and explosive devices (landmines and ERWs) located by APOPO's de-mining team in Mozambique during the first 9 months of 2009.

Challenges in the Field

Using the rats in field operations poses challenges, in part because behavior is context specific (O'Donohue, 1998). Rats that accurately detect mines in APOPO's minefield may not do so in actual field operations. Therefore, once rats arrive at the de-mining site, their training continues on a simulated minefield. Here, the emphasis is on ensuring that the accurate performance that was obtained in Tanzania can be repeated under the new environmental conditions that prevail in-country. Once a high performance level has been attained, both in training and in blind testing, the National Mine Action Authority (NMAA) performs an accreditation test. According to International Mine Action Standards 09.42 (2008), which describe operational testing for mine detection dogs and handlers and also apply to rats, the animal and its handlers, who are blind to mine locations, must detect every mine in a 400-m^2 field containing 5 to 7 mines with two or fewer false alarms, which are defined as indicator responses located further than 1 m from the nearest mine. Only after a rat has been accredited by the NMMA can it be used operationally.

Weekly Training and Blind Testing

A number of variables can influence a rat's performance in detecting landmines, and it cannot be assumed that all NMAA-accredited rats will continue to exhibit high levels of performance. Because consistent accuracy is essential from de-mining rats, all rats in Mozambique are continuously trained and tested, both before and after accreditation. Handlers use the resultant data to produce an up-to-date profile of each rat's ongoing performance. The results of blind testing, where the animal is observed working in an environment that realistically mimics the operational site, are a crucial part of the performance profile. Handlers conduct these tests every week on a simulated minefield, as described for the testing at APOPO's minefield. Only those rats that exhibit 100% detection and fewer than 5% false alarms are considered for operational use.

Daily Capability Testing on TNT Before Operations

Each day, any rat due to be deployed is tested by working it across a small area containing a single inactivated mine. A correct indicator response (hit), which is reinforced, ensures that the rat is capable of detecting the target odor, and is sufficiently lively, motivated, and focused to work (International Mine Action Standards 09.41, 2008). This testing gives the handler confidence in the animal's performance and reliability for that day of operations. Handlers record the results of this testing and do not use rats that fail the test in that day's operations.

Quality Control After Operations

Handlers use metal detectors to search for mines at every location where a rat emits an indicator response. This procedure allows the accuracy of rats' indicator responses to be determined. Quality control by manual inspection with metal detectors is also conducted on a percentage of boxes where the rats did not give any indications, to ensure that these areas truly contain no hazard. Supervisors record findings for all boxes, including the names of rats and handlers, to ensure a complete set of data. It is especially important that rats do not miss mines. Thus far, manual checks have not revealed any mines missed by the rats.

Dealing With Extinction

In actual mine clearance, handlers cannot know whether an indicator response is a hit or a false alarm. Because it is impossible to arrange differential reinforcement in the field, such that hits are reinforced and false alarms are extinguished, extinction is arranged for all indicator responses. This is done to avoid establishing a high rate of false alarms, which would be costly in terms of the time and effort required for manual checks. Of course, extinction inevitably weakens operant responding, and if sufficient hits occur without reinforcement, the indicator response will cease to occur reliably.

Fortunately, arranging intermittent reinforcement—reinforcing some but not all correct responses—is effective in generating persistent responding without diminishing discriminative stimulus control. As noted previously, in the operational setting, handlers regularly expose *Cricetomys* to simulated minefields, where it is possible to identify and reinforce hits, as well as to actual minefields. Moreover, each day begins with a performance test in which an accurate indicator response is reinforced. These procedures have proven adequate to produce consistent performance in de-mining rats.

Cricetomys as Mine Detectors

Although effortful, the procedures arranged in Mozambique ensure that the rats used on a given day are performing well and are highly likely to emit the indicator response when they encounter a mine or ERW. Using these procedures requires the availability of more trained rats than are used at any given time, due to the constant necessity of training. Moreover, now and again a rat becomes ill and unfit for work. Fortunately, trained rats are relatively inexpensive and are easy to maintain at a field site, making it possible to have a sizeable colony in Mozambique. This is one of their advantages as mine-detection animals. Another is that their small size allows them to walk over mines and ERWs without activating them. We have had no activations in Mozambique. A third advantage is that, unlike many dogs, the rats do not bond with individual handlers and will perform equally well for anyone who knows how to use them. This is especially important because human de-miners do hot, hard, and challenging work, and hence staff turnover can be high.

The main disadvantage of rats is that they do not work well when it is extremely hot and sunny. Therefore, de-mining starts early in the day. The handlers shift to other activities, such as brush clearing and manual de-mining, when conditions are unsuitable for the rats to continue working. Another option we examined was to use the rats at night, when it is coolest and they are most active. Unfortunately, issues relating to the medical attention available to personnel in case of an accident, as well as the difficulty of interpreting a rat's behavior in dim light, prevented systematic investigation of this option.

Early on, we discovered that some rats developed cancers on their ears, apparently as a result of exposure to the sun. Therefore, handlers coat the rats' ears and tails, which are also sensitive to sunlight, with sun block before field work. In some settings, obstructions such as large trees and rocks make the rope system difficult or impossible to use. We have developed a system for directing the rats by attaching their harness cord to the end of a long pole held by the handler that works well in such situations (Poling, Weetjens, Cox, Beyene, & Sully, in press). This system has the advantage of requiring only one handler per rat.

Remote Explosives Scent Tracing (REST)

During 2005–2006, deaths and injuries from landmines and ERW were reported in 58 countries and 7 other territories (Geneva International Centre for Humanitarian Demining [GICHD], 2007). Unless such tragedies occur, it is difficult to know whether a given location suspected of being hazardous actually contains mines, and many do not. For example, one study found that "only two percent of land cleared in 15 countries over a period of time was actually contaminated with mines and ERW" (GICHD, 2008, p. 9). There is real need for techniques that distinguish minefields from safe areas, allowing the latter to be released for civilian use. Many different techniques for land release are currently being explored (GICHD, 2008), including Remote Explosives Scent Tracing (REST) by pouched rats (and dogs).

REST refers to a method for detecting areas containing landmines and ERW in which samples of air, dust, and/or soil are taken from locations suspected of being contaminated and presented to mechanical or animate detectors in another location. For example, samples from Mozambique, Ethiopia, or Angola could be analyzed by pouched rats in APOPO's lab in Tanzania. An operational REST system would be invaluable for rapidly distinguishing between areas that do and do not contain explosives, allowing the former to be the focus of intensive de-mining efforts and the latter to be released for human use. REST might also be put to good use in detecting explosives, illegal drugs, and other contraband in cargo, shipping containers, and other contexts. Although a South African company, Mechem, reportedly developed a workable REST system years ago (Joynt, 2003), there is doubt regarding its effectiveness (Bach & McLean, 2003). At present, REST of landmines is more promising than proven. Research currently underway at APOPO is examining the feasibility of using *Cricetomys* in REST applications. Developing an operational REST system poses difficulties with respect to how field samples should be collected and presented and with respect to how rats should be trained and tested. Nonetheless, progress is occurring. For example, rats trained in a 10-hole cage to emit an indicator response to TNT presented in a variety of soil types emitted an indicator response to a higher percentage of samples containing soil brushed from atop a buried mine than to samples brushed from another location. These results are promising, but chemical analyses of soil samples taken over mines indicate that under some conditions they produce relatively low levels of the odiferous compounds associated with TNT. Although the rats apparently can detect these concentrations, actual field samples are unlikely to be taken directly over mines and therefore will contain even lower levels of TNT-related compounds.

From a human perspective, the most important chemical in a landmine is the explosive, which is TNT in many mines. From the perspective of a rat trying to detect a landmine by smell, however, that chemical may be a poor choice. In ongoing studies, we intend to make REST as easy as possible by allowing our rats to identify whatever compound (or combination of compounds) contained in landmines is easiest to detect and to learn the concept of "landmine." The animal learning literature provides abundant evidence that the proper way to teach such a concept is to provide an abundance of both examples and non-examples (e.g., Edwards & Honig, 1987; Herrnstein, 1979;

Herrnstein, Loveland, & Cable, 1976). We are taking this tack, and if we are successful, our rats will have no trouble identifying samples taken near landmines, even if those samples differ substantially from the training stimuli.

Summary and Conclusions

One purpose of the present article is to provide sufficient detail regarding how APOPO trains pouched rats to detect landmines to allow others to replicate those procedures, which should be effective in teaching rats (as well as other animals) to detect other stimuli as well. APOPO's research is directed toward developing an effective vapor-detection technology and investigating opportunities for humanitarian applications of that technology, regardless of the vapor in question.

The second purpose is to illustrate how APOPO has used the behavioral and physiological characteristics of *Cricetomys* to the benefit of humanity while ensuring the well-being of the animals. Rats are widely and appropriately viewed as pests that destroy food and property and harbor disease (e.g., Brown, Yee, Bjerke, & Østdahl, 2004; Brown et al., 2008; Joshi, Matchoc, Bahatan, & Dela Pena, 2000). Using them for humanitarian purposes is novel and noteworthy, and APOPO's success with de-mining has substantially improved how *Cricetomys* are perceived in Tanzania.

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