Rats for demining: an overview of the APOPO program

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Abstract

APOPO, a Belgian demining research organization, has been developing technologies for landmine detection using rats since 1996.

For the reduction of vast suspected mined areas, rats evaluate filters adsorbed with vapors from the suspected minefields in a laboratory setting. This technique, also known as Residual Explosive Scent Tracing (REST), has the potential for a wider application in the field of area reduction, especially due to its relative cost effectiveness.

In a second approach, African Giant Pouched rats (Cricetomys gambianus), attached to a search bar, systematically search 0,5 m wide lanes for the exact location of a buried landmine. Several demining organizations have supported the development and implementation of this new technology.

1. Introduction

APOPO started its search for a comparatively cheaper and efficient landmine detector in 1996, with particular interest in rodents as a potential detector. With the support from the Belgian Directorate of International Co-operation in 1997, APOPO carried out preliminary studies in Belgium before moving its research team and operational center to Tanzania, in May 2000.

APOPO has developed most of the training methodology and equipment itself. Currently the project team consists of more than 40 people who are training over 100 rats on a daily basis, both for the REST and the direct detection systems.

1.1. Why rats?

Rats show a number of desired characteristics that can be exploited for landmine vapor tracing, the most prominent being there highly developed olfactory system.

APOPO tested the rats' vapor detection threshold for purified TNT in water solutions at increasingly dilutions. Four rats were tested for 6 days, each evaluating 100 samples per day. The rats could reliably detect up to 1 femtogram of TNT/liter of air or 1,3E-03 parts per trillion (ppt), with an average success score of 80 % and an average false positive rate of 4% [1].

Rats are also trainable to perform repetitive tasks. In APOPO's experience, it takes between 4 to 10 months to train a rat, with training for REST being significantly shorter than for the direct detection [2]. Due to its small size and posture, the rats' nose is always close to the ground where the explosive vapor concentration is highest. Their small weight makes the rats unable to cause a big enough impact to detonate a landmine. Further they are easy to maintain, easy to breed and carry around. Rats are abundant and relatively cheap.

1.2. Which Rat?

APOPO selected the African Giant Pouched rat (*Cricetomys gambianus*) for the mine detection task.

This is a nocturnal rat that has a wide distribution in Africa South of the Sahara, which was the initial focal area of the APOPO project. This rat is calm and easy to handle, and has a bodyweight between 0,9 and 2,8 kg. It stores its food underground, which it traces back by smelling, a characteristic exploited in the mine detection task. Furthermore, the rat has a lifespan in captivity up to 8 years.

2. APOPO 'research and training'program

APOPO established its central research and training facility at the Sokoine University of Agriculture (SUA) in Morogoro, Tanzania, in the year 2000, through a long existing research co-operation between the University of Antwerp and SUA in the field of rodent biology.

2.1. Animal stock capacity

At present APOPO has a kennel facility of over 200 animal cages with two big outside pens. It has a breeding capacity of about 50 *'Cricetomys'* pairs, and houses a total number of 300 rats. Of these animals, 130 are in training, of which 50 are for REST and 80 are for direct detection.

2.2. Training and research facilities

With the logistic support of the Tanzanian Peoples Defense Forces (TPDF), APOPO established 26 ha training and research fields just outside the SUA main campus. These contain 1026 training boxes of 100m^2 for direct detection, with 0 to 4 landmines in each box. The test field contains 16 different types of landmines and UXO, and a variety of dummy targets. There are 27 low-density boxes of 1600m^2, of which 20 contain only one mine in the center, for REST research. Other research programs within the International Test and Evaluation Program (ITEP) framework could use these fields.

At the SUA main campus, APOPO has besides its kennel facility, training rooms and cages, both for pre-training, REST training and evaluation. APOPO established a chemical lab for analysis and quantification of explosive vapor distribution and for the control of training samples.

2.3. Training methodology

Though the training sequence is different for the two detection systems, both training methods are based on positive reinforcement of desired behavior of the rats. APOPO applies the clicker training method [3], and uses food as reward. The rats are weaned and petted at the age of 5 weeks, than immediately conditioned to the clicker sound, which is associated with a food reward. The training proceeds with odor discrimination tasks, where TNT is used as the positive target. The complexity of the training is gradually increased over time. This includes introducing a higher variety of target and non-target smells, diminishing the reward ratio, increasing the positive feedback signal and reducing the vapor levels of the targets. When consistent search and positive feedback signals are achieved, the animals will be subjected to series of blind tests.

2.4 Detection systems

APOPO has been developing two complementary detection systems to be used in different phases within the demining process. The REST and direct detection systems are complimentary and similar to the use of dogs in landmine detection. The often-posed question of 'which is better, the rat or the dog?' is not of primary importance, since too many variables and situations have to be compared. Each detector has its own strengths and weaknesses, and therefore its own place within the "toolbox" approach. The quality issues, moreover, will as much depend on the follow up and methodology of the implementing organization, as on the animal.

2.4.1. Residual explosive scent tracing

In the REST concept, explosive vapors are preconcentrated on a filter and remotely analyzed. In this case, the air from above suspected minefields is aspirated through filters by a pump, and the rats evaluate these filters for the presence of explosive scent.

REST has proved to be a fast and cost effective way of checking suspected stretches of road or sectors of land for mines or UXO [4]. Big savings on costs have been made in demining operations by eliminating vast portions of suspected areas that were free of mines [6]. An important restriction in the implementation of REST by demining agencies is lack of information on its true potential and limitations [6].

The REST system has different components that have to be understood well to make the system work successfully. These include: the target scent, the detector, the filter and the sampling environment and procedures.

2.4.1.2 The target scent

Both for animal training, as well as for the development of artificial sensors, it is crucial to know which are the most prevailing scents emanating from landmines. Since most of the landmines contain Trinitrotoluene (TNT), this explosive is widely used as a training target. The headspace vapor above bulk TNT, however, contains a series of chemical compounds related to manufacturing impurities, of which some exceed the TNT compound by a factor 10 or 100. It was found that most prevalent compounds are TNT, Dinitrotoluene (DNT) and Dinitrobenzene (DNB) [7]. These parent compounds are degraded in the soil and form by-products such as amino-DNT, amino-NT and amino-DNB [7].

Apart from the explosive content, landmines produce a scent picture emanating from the casing material, which can be different kind of plastics, wood or metal, the latter ones are often painted.

It is difficult to exactly determine which compound is most recognized during detection by animals. It is generally accepted that the animal goes for the scent bouquet, which can be a combination of nitro aromatic compounds and casing materials.

Therefore, it is advisable that casing materials are included as training targets, and that animals are each time calibrated on the specific mines, which are found in the area they will be deployed on.

2.4.1.3 The detector

The detector is the trained rat in the evaluation setting. There are a variety of possible training and evaluation configurations to which the rat can adapt. During the past years, APOPO has been evaluating four different settings.

In the so-called ‘Skinner Boxes’, rats were trained to sniff a sample and subsequently press a choice of two levers, generating a yes/no response. This had the advantage of having a very clear feedback signal. The disadvantage was the relative complicated behavioral training requirement.

In another setting, samples were arranged in a 4 by 4 matrix and inserted under a square cage floor to be evaluated by the animals. This was easier for the animal to learn, but there was a random effect in the evaluation sequence of the samples.

Currently, filters are presented to the animals in a linear setting, whereby the cages are configured in an octagonal, square or one-line set up. The rats walk on a stainless steel surface or corridor, and sniff the filters that are inserted beneath a row of holes.

Important aspects that can vary among different training settings are: success score, occurrence of false positives, trainer effects, duration of the evaluation, total amount of filters per trial, total training time, production cost of the setting and its practical aspects.

APOPO is optimizing these evaluation units. Current results [8] show that one rat can evaluate up to 150 samples in about 20 minutes. With a good selection of sampling conditions and filter type, a close to 100 % probability of detection of the positive samples can be reached, using several animals in the evaluation process.

2.4.1.4 The filter

The filter consists of a vapor reservoir in a sealed container. The standard filter is made of coiled PVC gauze contained in a cylindrical box.

APOPO tested a variety of available filter materials for possible application that included the following:

- Open cellular polyurethane foam
- Cotton wool
- Rockwool
- Polyester wool
- Cellulose
- Polypropylene wool
- Steel wool

Three of the selected materials, which came out with the highest success scores, are now being further tested. Important aspects for evaluation of the filter are the optimal balance between vapor retention and release, cost price and handling. APOPO also investigates the effects of storage and handling during evaluation. One of the requirements which was not included in the first test is the retention time of the explosive vapor which is now also under investigation.

Since availability of TNT in the soil is much higher then in the air, it is argued that dust sampling could give better results compared to mere air sampling.

Another important aspect is the dilution factor. If sampling continues after collecting explosive vapors at the beginning of the process, there is a possibility that the collected molecules are partially removed from the filter.

2.4.1.5 The sampling environment and procedures

The REST concept depends on the availability of explosive vapors from the landmine. A series of studies have been carried out to describe certain variables that are influencing the vapor availability [8].
APOPO noticed big periodical changes in results, and is therefore investigating the effects of environmental factors on the vapor availability. Main influencing factors are possibly climate, topography, soil type, vegetation, mine type and burial depth.

A good assessment of the dynamics of the climatic factors is crucial for the application of REST. Factors that may influence vapor availability are: outside temperature, atmospheric pressure, relative humidity, soil temperature, soil humidity, wind velocity and precipitation [7]. Test results show a higher probability of detection at higher outside temperatures and lower humidity measured just above ground level [8].

There is also an effect of the vegetation cover and the topography on the vapor distribution. Vegetation acts as an adsorber or collector of the explosive molecules, and do have an effect on the microclimate of the air boundary layer above the soil surface. The topography, soil structure and local hydrology will further have an impact on the dynamics of the explosive chemicals in the soil.

Apart from environmental factors, the sampling procedures also influence the REST process. Important aspects here are the speed and duration of sampling, the sampling pattern and the height of sampling above the ground. Also the optimal surface to be sampled on one filter has to be determined.

Furthermore, safety considerations might have an important impact on the sampling procedures. While for road clearance, manual samplers walk in vehicle tracks, this might not be possible in the open field, and therefore sampling from within a vehicle will have to be considered.

2.4.2 Direct detection

Direct detection of landmines by rats has an immediate application in demining operations. On an experimental minefield with 1026 boxes, containing one up to four mines, rats have to evaluate the location of a buried mine. The rat works on a leash, which is attached to a glider under a 6m long bar, with a set of spokes at each end of the bar. One turn of the ends gives a search lane, 0.5m wide, which the rat searches before the apparatus is rolled for one spoke to give the next search lane. At both ends, the trainers operate the bar and observe the rats from the 'safe' lanes. The trainer rewards the rat upon indication of a mine. This involves clicking, after which the animal moves to the trainer to receive a food reward before searching the rest of the lane. The behavior of each rat is recorded and mapped in detail on a sheet for each box where the rat is working. After testing, the data are introduced in a computer and analyzed. Specific indication behavior like scratching or biting the soil within a radius of 1.25m around the position of a buried mine are interpreted as a positive score, while outside this radius these kind of indications are considered as false positives.

In training situations, the rats normally scan $100m^2$ within an average time of 21 minutes. Blind tests of 7 rats, over a two-month period showed an average indication rate of 76 %. The score however proved to be very dependent on many factors [2]. First there is individual variation between the rats ranging from 69% up to 84%. Another factor is the types of mine present in a test box. For instance, a PMD-6W mine had an average score of 94% (n = 48), while a T59DA mine reached only 71% (n = 33). Climatic conditions are much more important. Although results presented here were collected during the dry season (July-August 2002) there was enough variation in climatic factors to investigate their effect. We found that conditions with moderate wind speed (2-4m/sec) and relative high temperature (24-27°C) were better for the performance of the rats than cool (21-23°C) days with no wind. Under the given circumstances differences due to climatic factors are estimated to be around 25%. Other factors like soil texture, density and height of vegetation, topography appear to have an effect on the behavior and performance of the.

For the selection and licensing of rats APOPO proposes a 3-week blind testing evaluation, compared to the one-day evaluation of dogs, in order to give more reliable results of the detector.

First field tests are currently being done in Limpopo, south Mozambique, in cooperation with MgM, and further tests this year will be done in Chimoio, also in Mozambique, in cooperation with NPA. Feedback from these field tests will allow APOPO to write up the standard operational procedures (SOP's). APOPO plans to do field tests in at least three other countries in the coming three years.

3 Summary and conclusions

Whether REST or direct detection, the performance of either detection system depends on the quality of the trained animal and the vapor availability. APOPO is further optimizing its training methodologies, while establishing the optimal operational conditions. Together with the ongoing research, APOPO will focus on building a rat detection capacity in the coming years, which can have an impact on the demining process.

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