Self – Reproducing Explosive Sensors for Buried Mine Detection

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African Giant Pouched rats trained to sense explosives and bred for their training capacities, these animals could revolutionize the way buried minefields and individual mines are detected and eventually cleared.

INTRODUCTION

Recently, Office Of Naval Research International Field Office (ONRIFO) conducted a site visit at the University of Antwerp and APOPO, to learn about the research and applied work being conducted by these two organizations, using rodents as animal sensors for mine hunting and detection of other agents of interest. African or Gambian Giant pouched rats are being trained to detect landmines by APOPO, a Belgian research organization. This is part of their rodent Explosive Vapor Detection Program. APOPO has been developing two complementary systems for landmine detection using rodents. These are: (1) Training of rats in an experimental set-up to respond on vapor samples. (2) Training of African Giant Pouched rats to detect the location of buried mines by tracing

hidden TNT under the soil surface where they clearly point to the vapor source. These types of rats have certain advantages over explosive detection dogs. Also, there are animal researchers who believe to have found proof that rats can pass on trained knowledge within a few generations. Trained to sense explosives and bred for their olfactory capacities these animals could revolutionize landmine detection. APOPO has deployed the animals to Tanzania and are conducting field tests on a training mine field that they and the Tanzanian government have set up and calibrated for this purpose. In addition to the mine hunting work they are conducting experiments on the rat's ability to detect TB in saliva samples and also PCB's in the ground. The Newsletter is designed to inform national and international scientists, research and governmental institutions and international organizations about potential research collaboration.

LONG TERM GOALS

APOPO's research goal is to develop and deploy landmine detection technologies using trained rats as biosensors. The Belgian government provides funding for the research, hoping to find a less expensive, but still effective, mine detector than those used currently.

OBJECTIVES

This particular project is aimed at:

1. Area reduction of suspected minefields.
    a. Determine minimum detection threshold of explosive vapors by rats,
    b. Define pre-concentration and field sampling standards and procedures,
    c. Testing of vapor collector,
    d. Evaluation of test field vapor samples.
2. Direct detection of the landmines. Freely roaming African Giant Pouched Rats search for the exact location of the buried landmines within a specified area.
    a. To train a significant test group of African Giant rats according to the developed training protocol,
    b. To train the rats to search within a marked off area,
    c. To move the training base to open air test minefields in Africa,
    d. To improve the animal capacities by selective breeding.

APPROACH

About 6 years ago APOPO began working with the African Giant Pouched Rat. The African Giant Pouched rat (*Cricetomys gambianus)* grows to between 10 and 17 inches long, with the tail about the same length or longer, weights from 2 to 6 pounds, and lives on fruit and nuts. This rat, like many rodents, has an excellent olfactory system that is very useful since they are food hoarders. This particular rat also takes the food it finds and buries it in the ground then comes back at a later time to dig it up and eat it. So the ability to locate this food in the natural background odors associated with the ground and vegetation is very valuable. They live 7-8 years and can be trained for the mine-hunting

task in 12-16 weeks. The young are weaned at about 24 days and start training soon after.

APOPO uses operant conditioning training techniques based on positive reinforcement. The rats are initially trained for this task using a high concentration of TNT. They then reduce the concentration of TNT to determine the sensitivity of the animals. In the field upon the detection of the vapor signal the rats are trained to sit as the conditioned response, after seven seconds they are given a secondary reinforcer in the form of a click, and then given a primary reinforcer of food.

APOPO developed an integrated system for both training the animals on spiked samples as well as presenting vapor samples from suspected minefields. Rats evaluate the occurrence of explosive trace vapors in field samples. A special vacuum collects air samples, and soil samples of suspected mined areas. The sample filters are brought to the lab, and presented to the rats to determine if explosives are present. The rats can detect very small levels (picograms) of explosives in the sample. Positive samples are reconfirmed using several rats to provide a very high level of detection accuracy, comparable to dogs. Lab rats have demonstrated the ability to evaluate 340 filter samples from various areas in 30 minutes.

For outdoor field applications, a three months training protocol by which lab rats were taught to trace TNT in a sandbox of 4 by 2 meters, has been developed. Trainers spray the ground with diluted high explosive and if the rats find the correct spot they are each given a positive reinforcement.

Over a hundred rats are already trained, through four generations. An aggressive selective breeding program (about 300 in breeding) for the brightest and best "mine-detecting rats" is underway to facilitate training of future generations. It is evident through empirical data, that talented trained rat mothers, instinctively train their offspring (to some degree) to detect the "rewarded" scent. Additionally, there are animal researchers with preliminary findings indicating that trained rats can pass their training through genetic information within a few generations. Whether or not this is the case with the APOPO rats is still under investigation, but definitely there appear to be advantages in selective breeding.

WORK COMPLETED

Last year APOPO relocated to Tanzania to continue their research collaboration with the Sokoine University of Agriculture in Morogoro where an 250 by 150 m training and test minefield with 30 different types of mines, has been established in order to further develop and evaluate the performance of the rats in a close-to-reality environment. They periodically test the ground for levels of TNT at various distances from the mines. The rats are trained to trace the spot where the explosive is buried, either by smelling the TNT, or by investigating freshly dug ground. They place a line or cable from one side of the field to the other and have the rat transit from on side to the other in a zigzag pattern. The swath that is cleared is then the length of the line (width of the field) by 1 meter.

The field rats are placed on a leash attached to an overhead line/rail that allow them to detect mines a half of meter, on each side of rail. The animal indicates the location by sitting at the location for 7 seconds. Their accuracy for field detection within the 1 meter searched is 85 - 92%. When the horizontal clearance lane was extended to 2 meters, the reliability reduces to ~72%, mainly due to natural distractions and increased nervousness. The field rats have achieved a clearance speed of 100 square meters in 30 minutes.

IMPACT / APPLICATIONS

The consolidation phase of the mine-hunting project commences in November (partly funded by the EC). During this phase, rats will be used in the lab, and out in the fields of Mozambique to help identify and clear mines. The project should be fully operational by the end of the year. APOPO's researchers plan to use the rats in two different scenarios or concepts of operation. The first is to identify large areas that contain TNT or to clear something like a road or path. It is accomplished by using a large vacuum to suck air through a filter. They then present the filter to the rat for detection purposes. Once a mined area is located, they can identify individual mines by using the rats in the second scenario. Field rats work best in dry cool environments with limited vegetation. Heavy

vegetation, muddy, sluggish, or sticky environments, rain, or extremely hot weather, are limiting environment.

TRANSITIONS / FUTURE RESEARCH INITIATIVES

Menschen gegen Minen (MgM), and Norwegian People's Aid Mine Action, are the trial partners for the "free-running" rats. In December, MgM will take a small team of rats to Angola to clear mines along suspected roadways. They are convinced that the rats are better than dogs and are planning on getting into the field to prove it and seem to have the financial support to do this.

Other future work will attempt to train the rats for rescue works, using a combination of a remote camera, and light source that transmits position, the rats are being trained to return to "home" or a cage when presented with a recall signal.

In addition to the mine hunting capability APOPO scientists have discovered that these rats have the capability to detect something associated with tuberculosis bacteria in saliva. TB detection is a huge problem in Tanzania and other parts of Africa. It takes 5-6 weeks to get the results back from the traditional laboratory tests. The detection capability of the rats and the speed with which they can screen a lot of samples is the reason that this avenue is being explored. They also have discovered that the rats can detect PCB's in ground water and soil samples and see this as another avenue of investigation and potential use of these animals.

ASSESSMENT AND POTENTIAL COLLABORATION

Explosives are likely to leak from mines and broadcast their presence before the device is touched. From the above research description rats appear to be faster to train to detect explosives than dogs, using traditional methods of exposure, detection and reward. They are well suited to repetitive tasks and are conditioned to respond to a food reward so they have a strong motivation to remain attentive. Gambian Giant pouched rats live as long as dogs, are easy to train, have a better sense of smell, are more resistant to tropical disease, are cheaper to maintain/feed and, since they are smaller, they are more easily transported. Rats are too small and light to trigger mines, making them ideal as mine detectors. Although the achieved speed of 100 sqm in 30 minutes is substantially slower than a dog, it still remains much faster than manual (human) clearance by prodding/metal detector. Taking the costs in account, to beat the rather expensive dogs in effectiveness, one simply uses more of the relatively cheap pouch rats. APOPO claims it will take another two years until free-running rats can be sent into demining operations to work in parallel with the dog teams.

We were impressed with the candor and enthusiasm expressed by our host for these animal sensor systems and their capabilities. When approached with the idea of bringing some of their trained rats to the U.S. to exercise them on established ranges such as the one at Ft. Leonard Wood, they responded positively. There also were discussions about the potential for these animals working in the shoreline/high watermark areas. There is

some question about whether this would be an area that would be possible to work in, however they are willing to operate their animals in minefields set up in this type of environment, if presented with the opportunity. If the rat's sense of smell is more effective than a dog's, then APOPO's research may impact the development of future biosensors mounted on UAVs for rapid/real-time detection of minefields. Furthermore, with the introduction of the robot rat (known as Ratbot) semi autonomous technologies may be employed to decrease the timeline in the detection of minefield.

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