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EXPERIMENTS WITH SOUNDS IN REPELLING MAMMALS

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ABSTRACT: Since its introduction for use in repelling birds, a number of people have found that Av-Alarm is effective for control of certain mammals. This includes not only those familiar to North Americans (deer, elk, coyotes), but also various less familiar species, even anthropoids (baboons) and bats. A number of example cases are described. A concept theory is presented in order to explain why certain sounds are more effective than others, and why sounds originally meant for bird control are also effective with mammals. The theory helps to predict untested situations, and also suggests when complex repelling sounds can profitably be augmented by other sounds or by visual harassment.

INTRODUCTION

As many of you may know, quite a few Av-Alarm sound generators are used for repelling birds. A few people have found that Av-Alarm also repels mammals. To better illustrate this, I can cite an example from South Africa where all sorts of animals, which we consider exotic, romp and play.

It seems that a fellow put an Av-Alarm in his vineyard, with immediate satisfactory results for birds. It so happened that next to the vineyard was an area with mammals in it--in this case a vacation trailer park. It took two days to clear the place.

A few days ago, I got word of an unusual application. An orchardist talks of a friend of his who (and I quote) "is using one of your units as a burglar repellant at his summer home on the coast. It is installed inside the house to produce an intermittent screech that is hard for the human ear to endure." This man goes on to inquire about equipment for similar use in his seaside home.

Now that I have cited applications for the hairless apes, I can quote one for the hairy kind. Our South African distributor says: "We also had the opportunity to try Av-Alarm against baboons and it worked perfectly." He did not elaborate on what he meant by "perfectly."

We can drop somewhat further along the phylogenetic scale. Again my example is South Africa. In this case, Av-Alarms are in experimental use for wildlife control in the National Parks system. One application is to keep animals from overgrazing areas after use of fire for brush management. Also of interest is prevention of overgrazing in special areas, such as around waterholes, and generally to promote rotational grazing. It is also desired to guard unfenced borders or make animals accustomed to a new fence. Initial experiments for grazing control are reported to be very encouraging. A big impact was made upon grazing habits, especially of the impala. Interest is primarily in the ungulates (springbok, impala, bontebok, zebra, and the ever-popular gnu). In connection with these initial experiments, the following comment was made: "It also became quite clear during my investigations that the irritation caused by the sounds had a progressive influence, over time, upon the movements and behaviour of the animals."

In our own country, a number of Av-Alarms are used in deer control. And we are beginning to see some rather successful applications for coyotes too. A few reports on effectiveness with raccoons and others have also come to us. I don't want to discuss rodents here--experiments for the most part are quite limited. But use with bats may be of interest because it shows the wide range of beasts that will respond to sounds. In an experiment of ours, we demonstrated rather complete ability to disrupt bat landing radar for a small insectivore using an Av-Alarm with frequencies raised to the 12-15 kHz range. In Australia, an Av-Alarm above treetop level was reported to be quite effective in repelling the flying fox (a fruit eating bat) from a 40 acre orchard. The Av-Alarm was a standard one with frequencies in the 2-5 kHz range. These examples are significant also because it is believed by many biologists that bats will not attend to such low frequencies. I think I can give some explanation for this a little later.

Clearly, ample evidence exists that sounds such as Av-Alarm can repel a wide variety of mammals--including people. But at the same time, we use Av-Alarms in and about cattle, sheep, pigs, and even turkeys. These domestic animals appear to adapt quite well--they are certainly not repelled.

Most of the domestic applications to mammals involve nighttime pests. At night, vision is hampered, which makes the sense of hearing more important for threat detection and general environmental monitoring than is the case during the day. Perhaps the same applies to a would-be burglar. In the case of deer control, we find sounds to be less effective as the so-called wild animals develop a familiarity with man. Generally, no wild mammal seems to like to be around an Av-Alarm--and when acoustic control is insufficient, men with flags or guns or BB's or lights can have an exaggerated effect. Just why domestic animals tolerate Av-Alarm so well remains unanswered. The only partial exception that appears to exist is that sows tend to get a little meaner than normal.

AN EFFORT TO DESCRIBE CAUSAL FACTORS

Efforts to repel birds and mammals often are directed at producing some stimulus which directly signals danger or threat. In this, I include natural recordings of alarm and distress cries, tiger sounds, hawk-shaped kites, panther "juice", and a host of others. Although perhaps useful in part, I don't really think that these stimuli are generally too good except for an initial reaction--there are too many examples of adaptation. What is it, then, in a stimulus, that repels over a long period of time? Is it simple annoyance, or discomfort, or jamming in the sense that the animal is deprived of the practical use of his ears? Unfortunately, we can't apply a stimulus to a lesser animal and receive a report on what he thinks or feels. We can only use rather indirect evidence for this--and the observer of an experiment is all too likely to put down simple fear as the reaction.

Inasmuch as people may have suffered through evolutionary changes akin to those of lesser animals, there is reason to think that humans have some similar reactions--and humans can report back. Although sometimes a dangerous scientific procedure, I nevertheless think that anthropomorphism is a useful tool in this case. In fact, some process of likening people to lower animals may offer the only meaningful tool that we have! This leads us to ask: What sounds are stressful to humans in terms of annoyance, producing anxiety, or simply imposing discomfort?

There is a sizeable effort going on today in the field of noise pollution. Lots of dollars are being spent. Lots of apparatus for measuring sounds are being purchased. (It would be so nice if wildlife people could get a small fraction of this sort of money and equipment!) But would you believe that questions bearing on what constitutes annoyance or distress or anxiety in sounds have not yet been answered? If we can not answer these questions for people, then how can we possibly answer them for dumb animals? What is it in such sounds as fingernails on the blackboard, or shrieks, or moans, or rustling and creaking noises at night, that promote anxiety, nervousness, or discomfort? Actually, Av-Alarm sounds contain many of the elements of these--by intent. So how did we know what to do while the noise pollution industry remains in the dark? I can only answer this by discussing some of our theories for sound processing in the human or animal ear--which I have put into the Appendix of this paper in order to spare the reader the need to get involved in some rather complex details.

I would like to define three basic types of sound. First is the "commanding" sound. This is one which is able to cut through environmental noise and distortion and be heard clearly and distinctly while preventing much hearing of any other sound. A commanding sound also has the property of being difficult to adapt to. The 'whoosh" of a jet aircraft may be loud, but it is not particularly commanding. Birds have learned to use rather commanding sounds in their alarm and distress cries. Certain short hisses and gutteral vocal cries are commanding. The second kind of sound, as it relates to humans, is what might be called "psychological" jamming. This type is structured so as to efficiently cover up sounds that the human might wish to hear. Rustling and creaking noises, perhaps some moans, would probably do an excellent job of keeping kids out of a cemetery at night. A third kind of sound can be called "simple" jamming--just a lot of cover-up noise which does not have the elements found in psychological jamming. Simple jamming is inefficient--and the animal ear has an automatic adapting mechanism for perceiving differently structured sounds through this sort of jamming.

PRACTICAL FACTORS THAT INFLUENCE REPELLING

The ambient noise level establishes the weakest sounds that can be heard, typically 30-60 db (re 0.0002 dynes/cm^2) during the day, perhaps 10-15 db less at night. The animal ear appears to effect an automatic adaptation to the ambient level such that sounds rising briefly above this level will be apparent. Psychological jamming will put danger-like sounds into this environment, which makes the perceiving of real danger sounds difficult unless these rise to and above the level of psychological jamming noise.

An Av-Alarm in an open environment produces a sound level of about 70 db at a range of 700 feet when speaker power is 30 watts (average). This can be taken as a "nominal" effective range, albeit, in some cases effectiveness is observed to two or three times this range, and sometimes the effective range is considerably less. The speaker horn that we use has been selected so that the sound pattern is broad in the horizontal plane, and less so in the vertical plane--sort of a pancake pattern. The area of coverage to the 70 db level from one speaker is about 8 acres. At night, greater effective range and coverage area can be expected because the ambient sound level is reduced. (Note in this regard that animals tend to move with greater stealth at night.) A greater nominal range than 700 feet can be achieved by using a more directive horn than the one on which foregoing figures are based--one with a "pencil" beam pattern rather than a pancake one.

If the area contains many echoing surfaces, sounds tend to be scattered. In part, this attenuates the sounds and thus reduces range to the 70 db level. But also, scattering invokes what mathematicians call "The Central Limit Theorem of Statistics." The quality of the sounds gradually tends towards Gaussian noise as the complexity of multiple reflections increases. What happens is that a psychological jamming sound tends towards simpler jamming and the animal ear starts to adapt the same as to the ambient noise.

Mammals have several warning senses, mostly hearing, sight, and smell. When one is compromised, reliance for security can sometimes be shifted to the others. It is then logical to expect that sounds will be more effective during the day if vision is hampered by obstructions. This may in part counteract scattering effects. The repelling ability of a sound at night can be expected to be better than during the day, partly because the ambient sound level is likely to be lower, but also because vision is hampered.

If an animal can shift security dependence to some alternative sense, being forced to do so leaves him in a somewhat nervous and anxious state. At this point, attacking a second sense will have an exaggerated effect. We might expect, for example, that persistent deer which are not completely controlled with sounds, may readily be "spooked" with lights or a vehicle or man patrol. I think a fairly general approach to vertebrate pest control is, first, to compromise the acoustic environment; and if this is not enough, then work on the other senses.

At least in the case of bird control, and I suspect it would also be useful for mammals, we have found that the Av-Alarm can effectively be augmented with quite different sounds. This includes the gas cannon, gunfire, aerial bombs, and an electronic hiss. Such things as horns and sirens have little augmenting effect for birds--I do not know how these might be interpreted by mammals.

I think that part of the reason why these other sounds have augmenting value, when by themselves they are comparatively ineffective, is because the sources of the sounds change. From the point of anthropomorphism, sounds bursting forth from different directions can be much more unnerving than when they come from the same location. There may be a kind of spatial adaptation at work here. We find that, using Av-Alarm alone, multiple installations are synergistic--the total effect is greater than the sum of the effects considered one at a time. Spatial confusion may be responsible for this (assuming that two or more Av-Alarms can be heard from the same location).

A few examples reported to us or resulting from our own experience may help to explain some of these things. We did a number of experiments attempting to repel deer from runways at Vandenberg Air Force Base. How this worked at night we do not know because observations were not made. During the day, we were not very successful using sounds alone--the deer would continue to pass through the rather open runway area. However, they would not feed there. But the deer could be chased off with a patrol more easily than without acoustic harassment. Vandenberg is almost like a wildlife preserve, with comparatively little hunting. The deer are semi-domesticated. Lack of daytime success (albeit, from a farmer's point of view repelling was effective because the deer did not feed) can be attributed to openness and semi-domestication.

A one speaker Av-Alarm was used for coyote control in a 10 acre lambing area in Sonoma County, California, with complete elimination of previously considerable losses. Unfortunately, we do not know if a larger area could have been protected; or if a reduced power level (below 30 watts) would have worked so well. I suspect that one speaker would have done a reasonably good job in 40 acres. This is a case where the animals are quite wild, fear humans, and operate at night. Other successful cases of coyote control have been reported to us from Arkansas (melons) and Washington (turkeys).

We have done limited experiments on wild boars, also at night. Although results must yet be verified (and we have started appropriate experiments), we found that Av-Alarm alone was inadequate. But control was good when combined with a flashing light. This is a case where the animal does not fear too many things, and is relatively intelligent. But attacking two senses was too much for him. Whether or not a gas cannon augmenter would have worked as well as a light I do not know--I suspect it would have.

In Colorado and Wyoming, experiments with Av-Alarm are underway for keeping elk out of overwintering haystacks. This is a case where the available feed is a strong attractant to the animals. Some promising results have been obtained; and also some less promising ones. This research has not as yet gone too far, and much remains to be determined. It should be noted that, when feeding gets to the point of survival, or near survival, control will become considerably more difficult--augmentations are then indicated.

I am often asked about ultrasonics, usually so as to avoid repelling people. For birds the answer is no--they do not hear even as high as a young human. For some other animals, perhaps a suitably modulated low ultrasonic signal would work because of mechanical nonlinearities in the ear. The practical problem is that high power ultrasonic radiators are very expensive, and low power units have very limited range. Even if ultrasonics did work as a technique, the per acre cost of control might be prohibitive.

A couple of years ago, we studied use of Av-Alarms for repelling waterfowl and sea birds from oil spills. We had a small underwater speaker which we wanted to try for getting diving birds to get up and travel by air. But what really happened was that seals popped to the surface all over the place. I suppose something could be deduced from this, such as repelling otters or sharks or some such other fish or mammal, but much experimentation remains to be done by someone.

MISCELLANEOUS COMMENTS

In my studies, I have made use of equipment that I built a few years ago which serves to model the ear and part of the nervous system, with specially constructed display apparatus so that I can actually see the patterns that I have talked about here. I believe this apparatus is rather unique; and thus what is said here cannot too well be checked on in the literature except for my own papers. (One group at Wright-Patterson Air Force Base in Dayton, Ohio is doing somewhat similar work, using analog ears that I made for them.) My equipment was not originally made to study sounds as are important to pest control. Rather, it was made so as to do research on various kinds of speech processing, speech recognition, speech aids for the deaf, and to improve ability to corrupt an enemy's radios using psychological jamming. But, fortunately, the equipment is general purpose, even having been modified at one time to represent the bat's ear.

As you will no doubt appreciate, a small company such as Av-Alarm cannot afford to do much research of its own. On the whole, I think we do much more than characterizes companies such as ours, but it is really a rather inadequate reaction to the many fruitful studies in animal control that are now feasible. Much of our information comes from experiences and observations of Av-Alarm users, both customers and a few professionals to whom we have loaned equipment. We are always willing to consider loaning equipment for meaningful studies, in limited quantities, and I invite appropriate inquiries on this. The criteria which we impose are that the work be done by qualified individuals, that the experiment be reasonably well planned and staffed, and that we can enjoy a constructive two-way flow of information during the course of the work, and a reasonably descriptive letter-report on results.

I have tried in this talk to cover the major considerations in using sounds for repelling mammals. There is of necessity a lot of theory in this, and a paucity of hard field experimental data. Indeed, there is an enormous amount of worthwile work yet to be done.

APPENDIX I

MECHANISMS IN THE EAR

The mammalian or avian inner ear mechanically acts as a crude frequency resolver. High frequency components excite the entry, or basal region, medium frequencies the central region, and low frequencies the far end, or apical region. Low frequencies are attenuated quite significantly in going from outer to inner parts of the ear. Complex sounds are resolved such that higher frequency patterns are influenced by low frequency components, but not vice versa. A high audio tone will result in a stable region of activity and a corresponding steady neural discharge towards the brain. Low frequency tones also localize in the appropriate region, but they also result in neural volleys at the tone rate. Two mechanisms for frequency recognition exist, place of activity in the inner ear, and neural volley rate for frequencies below a kilohertz or so. (Above this, volleys tend to merge into a continuum.)

I rather doubt that the animal ear evolved to perceive pure tones. Rather, complex sounds, often of a transitory nature, are far more important to survival. Important sounds fluctuate in amplitude and frequency. This brings in another mechanical property of the inner ear: nonlinearities. A high frequency tone that is fluctuated at a lower frequency rate in either amplitude or frequency (or phase) will induce a physical wave at the fluctuation frequency. This wave travels along the inner ear and seeks its proper localization region much as if it had been present physically in the stimulus. I believe this is the basic method people use in perceiving fundamental voice pitch. And also I think it is the mechanism used by echoranging animals where the fluctuations at a high (perhaps ultrasonic) frequency, are converted to their physical fluctuation rates so as to excite the ordinary audio frequency parts of their inner ears. By going directly to their ears at middle audio frequencies, it is thus possible to corrupt their ability in echoranging. (The bat ear appears to have a basal region with special tissues that may enhance action of nonlinearities for ultrasonic frequencies.)

Suitably fluctuated audio signals can be much more efficient in reaching the low frequency parts of the inner ear than the low frequency itself, partly because of built-in attenuation of low frequencies (at the oval window interface to the cochlea), and partly because low frequencies are not often produced at high power levels, nor are they picked up too well using two physically small ears.

The nervous system appears to possess two principal adaptive mechanisms, each having a characteristic latency, or time constant. One of these, about 0.01 second, is called mutual inhibition. The other, at about 0.1 second, is called recurrent inhibition. The mechanisms appear to be well designed for adjusting to a background noise level while being particularly responsive to sounds having periodicities of the order of 0.01 second with durations of the order of 0.1 second. The system of phonemes we use in connected speech are rich in these particular intervals. And so is the bark of a dog or the moo of a cow. And so is the alarm chirp of a bird. The distress cry of a bird is rather like a prolonged alarm chirp; and so are fingernails on the blackboard. Environmental sounds such as are made by a sneaky predator often have 0.01 and 0.1 second rate fluctuations.

With the foregoing considerations in mind, it is possible to better understand how a sound can be structured so as to have commanding qualities and/or with psychological jamming. What is required is a sound that produces patterns in the inner ear that fluctuate up and down and otherwise dance about so as to create neural bursts and durations with 0.01 and 0.1 second periodicities. In addition, fluctuations shorter than 0.01 second are imposed so as to induce patterns which excite the apical region of the inner ear. Inclusion of low frequencies in the stimulus itself is not actually required.

Principal reference (with a bibliography): Stewart, J. L., "Theory and Physical Model for Cochlear Mechanics", Acta Oto-Laryngologica, Supplement 294, 1972.