The principles of operation of the sign stimuli dummy applied in the device UOZ-1 for deterring animals from high-speed train traffic

Simona Kossak

Natural Forestry Department, Forestry Research Institute, 17-230 Białowieża

Abstract. The article presents ethological basis for functioning of prototype device for deterring wild animals which are inclined to cross express railway lines. A role of vision, touch, hearing and smell senses has been emphasized and an instinctive animal behavior discussed. The main objective of the device is an 'advanced warning', i.e. stimulation of animals to leave the given site several dozen seconds before a real threat occurs. The warning consists of at least one minute sequence of natural alarming and information sound signals borrowed from the nature and supplemented with a few 'supernormal' stimuli.

Key words: animals, railwy lines, instinctive behaviour, sign stimuli, deterring device, dummy

1. Introduction

For several years now, extensive modernisation of main national railway routes has been carried out. Poland leads European countries in terms of the richness of flora and fauna. There are many areas that will be intersected by trains well exceeding the speed of one hundred kilometres per hour that are national and landscape parks, nature reserves, or areas included in the NATURA 2000 network. In line with the requirements of the European Union, any investment planned needs to take the good of the natural environment into account. In this particular case, the point is to reduce the risk of collision of wildlife with trains, while making their fairly normal functioning in the environment possible. In view of the above, the plans for modernisation of subsequent railway line sections envisage a series of railway underpasses for small animals and spacious culverts for larger mammals. By the force of events, mainly due to the considerable cost of completion and technical problems, the passages will be located at large distances one from another. Therefore, in the sections of the line that are strategic for animals, in particular in wooded areas and areas under legal environmental protection, as well as in places where culverts are not feasible, other solutions should be applied.

Protecting an animal that has entered the tracks from colliding with a train is easier than protecting it from colliding with a road vehicle: (*i*) trains arrive at a given point at a specific point in time; and (*ii*) in between these moments the tracks are free and can be safely crossed. It is enough to motivate an animal, using appropriate stimuli, to refrain from entering the railway line embankment for the period of just a few moments prior to the arrival of the speeding train.

However, to effectively control the behaviour of animals, one needs to have the appropriate knowledge in the field of zoopsychology. If the concepts of 'dispersers' are conceived in the heads of laymen or ecologists who are not specialists in ethology (animal psychology), and if, in addition, the investor wants to cut down on some of the costs, the outcome will be easy to foresee – the devices designed and constructed this way will be practically useless. Let us take as an example round

pieces of aluminium foil that reflect the lights of the coming train, installed with the naive faith that the animals, strongly convinced that these are the eyes of predators, will be scared to death and run away.

The Department of Natural Forests of the Research Institute of Forestry [DNF RIF] in Białowieża developed an original concept of stimulating the desired behaviour of animals, fully grounded in the latest achievements of zoopsychology. The principles of the sign stimuli dummy were: (*i*) high effectiveness of signals transmitted at a specific time and place; (*ii*) preventing the animals' becoming dulled to the transmitted stimuli; (*iii*) eliminating the need for erecting fences along the railway line, that is, creating ecological barriers and fragmenting the habitats of mammals.

In order to explain the principle of the apparatus's operation, basic information of the behaviour of wild animals needs to be provided. This information is always the outcome of the nervous system's processing of the whole spectrum of visual, aural, olfactory, tactual, and many other types of stimuli simultaneously coming in from various directions.

2. Etological basis of the operation of disperser for wild animals deterring

2.1. Sense organs

Sense of hearing is an analyser of acoustic energy. From the whole range of incoming sounds, it selects the components to which it is evolutionarily sensitive. The localisation of the source of sound and the distance is in general less precise than when done using the sight organ; however, mammals locate a source of sound at least twice as precisely as humans. The range (low and high tones) and the sensitivity to sound waves are, on the other hand, many times higher than with humans.

Sense of vision. Mammals' ability to perceive still objects, the speed of moving objects, as well as to judge distance and the derived ability to build a three-dimensional picture of the surroundings, to great extent depends on the ability to see (in the broad range of light), whilst one of the principles is stereoscope vision obtained thanks to a pair of eyes and head motility. The determination of distance by means of other sense organs is of lesser importance (except for species which use echolocation for this end, for example).

Sense of touch is located on the soft tips of hoofs or paws that are rich in nerves, among other places and senses the vibration of the ground generated not only by the movements of the earth's crust, but also by movement of other animals or vehicles.

Sense of smell is extraordinarily effective with most mammals. However, because in the process of developing the theoretical foundations for the sign stimuli emitter, this sense was regarded as secondary, it needs no discussion, as with the whole range of senses that animals have.

2.2. Instinctive behaviour

Innate (instinctive) and genetically passed-on forms of animal behaviour came into being as a result of evolutionary anatomical-physiological-psychological changes, as a response of living creatures to signals coming from the surroundings. The entire, unimaginably complex set of innate (fixed) behaviours of individual species and animals is controlled by three basic instincts: self-preservation, feeding, and breeding instincts.

The study of theoretical foundations of the 'sign stimuli' dummy was based on the strongest of instincts. This was the imperative to run for life. Contrary to reason (originating from the rational assessment of situation and from experience), this self-preservation instinct forces an animal, with amazing and blind power, to do everything to save its life in most situations. The compulsion to save oneself is evident in its simplest form through the motor reflex to run away, triggered by an appropriate stimulus (a signal from the surroundings). In an unconstrained environment, this means in

most cases running away from another animal (friend, predator, human being) and intensive abiotic phenomena (an earthquake, rock and snow avalanches, a storm, flood wave, fire, etc.).

The adaptability of the responsiveness of senses and motor activity, consisting in such a connection of the receptor (organ of sense) and defensive reaction (flight, seeking shelter and, as a last resort, attacking the enemy), in order to increase the chances for the preservation of life, is primarily based on the organisation of the central nervous system, created in the course of evolution. This is an axiom which cannot be disregarded when making any attempt to control the instinctive behaviour of untamed animals.

2.2.1. Fixed action mechanisms sign stimuli

Knowledge of the potential of sense organs, obtained in laboratory experiments based in principle on training (the process of learning or acquiring conditioned reflexes), consisting in coupling any chosen stimulus with prize or punishment, answers the question as to whether the nervous system of a given animal receives the tested signals at all. However, a positive response does not suffice to automatically interpolate the results onto the behaviour of wild animals. Without the knowledge of functioning of a given species in its natural environment, as a highly conditioned component of the specific biocenosis, with a number of evolutionary interrelations, with its biotic and abiotic elements, it cannot be assumed that analogous stimuli will trigger any reaction in the animals. Animals will not react to the predominating part of signals that come from the natural environment. They are neutral to them: they do not worsen nor improve their ecological situation. This is the basic characteristic of behaviour of all animals (including man).

The key element of visual stimuli is detecting the movement of the observed object and a sessing the distance to the object. This is primarily aimed at preliminary assessment of a threat. The shape of the object, its size, and sometimes the colour are of secondary importance. On the other hand, reaction to sound may be completely independent of the associated image/vision. For example, an alarm sound triggers the flight reflex, despite the simultaneous reception of visual stimuli evidencing the complete absence of any threat. This is because the feature of instinctive behaviour is its conditioning upon one or at most a few sign stimuli picked out from among the neutral stimuli incoming simultaneously in much greater numbers – the neutral stimuli are not related to the threat signal (e.g. no connection of the moving shadow cast by a tree and the sound of the river with the incoming scent of a lurking predator).

Conditioning the reaction of an animal to a precisely specified signal or a set of signals (sign stimuli) coming from the outer world results from the existence of a special nervous-sensory mechanism. In zoopsychology this is referred to as a ‘fixed action pattern’. The dependence of instinctive actions on sign stimuli enables triggering reactions of animals that are desirable for men through presenting an appropriate dummy. In the case of stimuli triggering reflexive locomotory activity, knowledge of the ecological system of oppressor/ oppressed that functions in the habitat of the given species is indispensable.

The natural sensory stimuli that inform about threats trigger a ‘chain reaction’. These are increased watchfulness, wariness, fear, and flight. Many apparently very simple behaviours (flight among them) in fact consist of a chain of separate reactions, of which each depends on a specific set of sign stimuli. Of paramount importance is their configuration, compatible in terms of quality, intensity, and duration with the string of psychophysical reactions of an animal. This means that the stimuli to which an animal reacts are not simple measurable units. With their proper configuration comes new quality and only then – like a key fitting in a lock – the configuration chain reaction is triggered. In such a situation, we talk about ‘the comprehensive stimuli situation activating the motivation’. This is related to a considerable extent to all stimuli, not only those related to preservation of life.

Usually, the first indicator of the chain character of response is the sudden break of its circle. In natural conditions, if the response took place as a result of a mistake, the animal stops reacting to the still-incoming stimuli, e.g. first drops of rain scare off the fish floating just under the water's surface, but after a few minutes of continued rain, the fish become indifferent and return to their normal actions. This is because only one signal is repeated over and over again (monotonous), which means that there is no consistent sequence in the chain of sign stimuli that would generate instinctive flight: stimulus A – reaction A (increased watchfulness, alertness), stimulus B – reaction B (physiological readiness to flight) stimulus C – reaction C (flight at a safe distance), stimulus D or fading off of stimuli – reaction D (interrupting the flight and atrophy of emotions). In other words, the change of location is a spontaneous behaviour triggered by a sequence of events matching a specific pattern of concrete organisational features internally arranged into a logical flow.

2.2.2. Social and inter-species triggers

The overall stimuli situation not only triggers the reaction, but also gives it a direction, depending on the characteristics of the surroundings. In open air, this means moving away from the source of the signals, and in the case of forest animals, leaving the open air and trying to hide in canopy. An important role is played here by the phenomenon of widely understood 'mnemotaxy' – moving away for any reason from a place previously remembered as dangerous, towards known and safe shelters. As time goes on (recurring situations), a partly memory-induced reflex of elevated readiness to flight may appear when the animal enters a certain area or even with the first stimulus from the chain of reaction triggers.

This readiness, signalled with warning behaviour (certain posture, movement, expressions, or voice), can be passed on to their kindred. This is a so-called social trigger – the reaction of animals at an appropriate distance from one another – takes place as a result of receiving information, that is, a warning from another animal and not a stimulus coming from the environment (ethology knows instances of such distance reaching tens of kilometres). Information exchange, mimicry, and learning through mimicry are a widespread phenomenon, in particular with animals at higher level of organisation (birds and mammals). Many innate fear reactions are triggered by warning stimuli sent by more experienced (parents), most vigilant, or most sensitive individuals. The animal stimulated with a warning signal instinctively reacts with relevant behaviour or produces an alarm cry. The positive result of revealing the presence of the enemy, which means preserving the life of all members of the group or reducing the loss to a minimum, depends on how fast the most vigilant individuals react.

Ethology has recorded many instances of purposeful or involuntary cooperation of animals for protection against an enemy at inter-species level (birds-birds, mammals-mammals, birds-mammals). These are most often alternating watching and emission of information-alarming signals (inter-species triggers). Many animals produce two different alarm cries: one at the sight of a predator that is not yet attacking but is a potential threat, and another cry in the case of a sudden attack. The group reaction to the first type of cry is elevated watchfulness, and the reaction to the second type is all animals' quickly moving away from the source of danger or seeking a safe refuge.

To sum up: a signal (social or inter-species trigger) provided by the most vigilant animal triggers the reaction of other animals of the same or another species.

2.2.3. 'Supernormal' sign stimuli

When we test the triggering values borne by any sensory stimuli, we deal with variable threshold values. The variable threshold value of constant force stimuli is revealed in increasing or decreasing the internal motivation of an animal to exhibit the targeted activity. For example, hunting behaviour of a predator at the sight of potential prey is stimulated by the degree of hunger or estrous behaviour (the level of sex hormones).

The only instinctive behaviour that does not have a variable threshold value as a result of internal factors (in the animal organism) is life-preservation. On the condition, however, that the stimuli denotes such imminent danger that the effect of habituation ('immunisation', 'insensibilisation') cannot take place. Some examples of an animal's 'immunisation' to the stimulus initially triggering the flight reflex are a scarecrow on which birds brood, the sight of roe deer grazing on train tracks when the train is moving through, or the already-mentioned behaviour of fish during a rain.

Experimental research conducted on various species of birds and mammals indicated a possibility of constructing stimuli of supernormal force that trigger instinctive reactions in the tested individuals. This was confirmed by observations of wild animals living in a natural environment. This group of stimuli covers certain physical features of animals (lures and dispersers) as well as elements of hunting and parasite behaviour. Supernormal stimuli prove more effective than typical signals, which are not always optimal, thanks to which predators achieve hunting success and obtain food.

2.2.4. Reaction time, flight distance, attack distance

The time that elapses between the first signal from the chain of sign stimuli and the reaction of the animal is specific for the given species, particular animal, and external situation. In the case of life-saving behaviour, the speed of counteracting of the potential prey is closely evolutionarily related to the aggressor behaviour and the speed reached by the set of antagonist species living in the given climatic zone. This ranges from hundredths of a second (falcons' attack on birds) to tens of seconds (large carnivores hunting herbivores). The time the predator needs to travel a certain distance to the prey is known to the prey instinctively (and experientially); therefore, the prey adjusts its locomotory activity – the moment of starting and the speed of flight – to the particular situation.

With the speed of a non-natural aggressor (a plane, a car, or a train), the animal standing on the road seems to be reacting with considerable delay – because the set of instinctive behaviour of all animals is equipped with the so-called flight distance. This is a relatively small distance from the aggressor, only after which life is in danger (it is possible to catch up to and attack the animal). This is amazingly pragmatic behaviour, because escaping too early is a totally unnecessary waste of energy, whilst escaping too late means death. The manifestation of a fixed action chain – noticing, curiosity changing into fear, physiological mobilisation to move and then insensibilisation in the end – if the object was classified as 'not dangerous', or conversely – recognising the enemy and flight - often requires more time than the vehicle needs to travel the distance to the 'victim'. In addition, the delay of the moment of starting flight in the proper direction (to the side of the line along which the vehicle travels) is impacted by the type of stimuli – they do not belong to the group of instinctive triggers of life-saving action. Moreover, the vehicle motion itself is in principle different from that of natural terrestrial enemies. It approaches with steady and high speed, whilst predators traverse the large distance from potential prey in steps – at first this is marching, then gradual, with stops, approaching using natural cover, and only then, after reducing the distance to the minimum (the attack distance is characteristic for a given predator species), reaching maximum speed. The potential prey, which noticed the aggressor early enough, has time for observation, making the decision to flee at the optimum moment – before the aggressor reaches its full speed. In short – at the same distance, the danger from of another animal increases much more slowly than in the case of a high-speed mechanised vehicle. This is the main cause of collision of animals with high-speed cars and trains but never with cyclists, horse-carts, or even farming tractors. In other words: a vehicle travels a considerable distance in such a short time that the nervous system of the 'victimised' animal does not keep up with giving subsequent orders: 'it's far away: observe', 'recognise', 'run away!'. In such a situation, the last instinctive attempt at saving its own life can be made (the classic behaviour of 'a rat in the corner'): when there is not time for anything else, the 'victim' takes

the challenge and is determined to defend its life: the bison or the moose attacks the approaching locomotive or car head on.

2.3. The principle of operation of the dummy triggering animals' flight reflex

After taking into consideration the above-described behaviour of wild animals, the original prototype of the 'sign stimuli chain' dummy was developed in DNF RIF and recorded on a CD. Its sole task is a 'prevenient warning', that is, motivating herbivorous animals and predators to leave their current location a few tens of seconds earlier, before the real danger comes.

Three slightly differing variants of the 'sign stimuli chain' were developed. Each variant is composed of a string, at least one minute long, of natural warning-alarming-informing sound signals taken from the natural world, enriched with several 'supernormal' stimuli. Their configuration in terms of type, duration, and internal logic is in line with the sequence of warning sounds accompanying the growing danger, acts of intra-species aggression, hunting action of predators, as well as the death of animals of various species. The duration of each sequence is compatible with the time of occurrence of subsequent psychophysical reactions of the scared individuals. When developing the dummy, we did not at any time purposefully provoke, torment, or kill any animal.

The knowledge of the acoustic stimuli used in the dummy is fixed in the genetic base of birds and mammals (deer, wild boar, hares, as well as small and large carnivores). Its effective operation does not require the process of superficial sensibilisation (training) of the animals, which would be impossible anyway. The acoustic stimuli provoke the production of warning cries by 'real' animals, which makes the dummy even more believable.

The sequence of warning signals is produced directly following the broadcast of the dummy sounds and comes directly from the environment: ever-growing earth vibrations, sounds, and the sight of the approaching train. This is the tangible validation of the authenticity of threat – the proof of the existence of the 'enemy'. The enemy always comes shortly after the animal receives the sequence of warning signs. As the final verification of the appropriateness of the animals' psychophysical reactions, it rules out the possibility of decreased internal motivation to leave the track, that is, insensibilisation to 'artificial' sound stimuli.

The relatively short time of scaring the animals away, always concluding with the departure of the oppressor, that is the quickly departing train, and then the many times longer period of peace, should quickly lead to the creation of a ritual based on a conditioned reflex. The first earth vibrations sensed by "experienced" individuals and still faraway sounds of the locomotive can become further stimuli that trigger the flight reflex. At that time, we will at the same time deal with 'mnemotaxy' – moving away for any reason from a place previously remembered as dangerous and the so-called transferred stimulus: an ethologically neutral signal will take on sign stimulus qualities. This ritual, as the "social trigger" transferred to offspring and migrants, with time will become the local tradition of the animals that live near the high-speed train track.

During the time between the runs of trains, animals are not disturbed by the stimulation to run away. Thanks to this, animals can freely move all day and night all over their home acreage on both sides of the railway line.

The dummies are located only near the track-way. Wild animals can precisely locate the places permanently dangerous to them, but stationary. By keeping a certain distance from the source of warning signals (the flight distance and the attack distance) they can go about their lives without disturbance.

Thanks to the use of dummies and the rather densely located, spacious wildlife underpasses, located in natural land depressions and in river valleys, the particularly detrimental fencing of track-ways with impassable fences will no longer be necessary. The permanent fragmentation of home acreage and cutting off the migration routes of animals drastically limit their habitats and make the exchange of genetic material impossible, which in aggregate leads to the gradual disappearance of isolated populations and even of the entire species.