Bioacoustics

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Introduction

Bioacoustics

Bioacoustics is the study of the adaptive basis of animal sound signals: how, (when, where) and why animals make sounds. Animal's signaling behavior is a complex of structural and behavioral features that had adaptive consequences in previous generations. Bioacoustics is the investigation of these adaptive consequences.

Acoustic animals

A number of taxa make very extensive use of sound signals and in a loose sense it may be convenient to consider them 'acoustic animals'. The **acoustic insects** are the crickets and katydids, the grasshoppers and cicadas, all noteworthy sound signalers. Though the extent of the literature addressing Orthoptera and cicadas justifies the use of the term *acoustic insects*, in fact the incidence of sound signaling in insects, especially if one expands 'sound' to embrace 'mechanical disturbances in water and solid substrata' as well as air, is catholic.

Among vertebrates sounds are produced extensively by fish and mammals but the frogs and birds are especially studied from an acoustic perspective. The birds are perhaps the pre-eminent acoustic animals. But anyone studying bats or cetaceans could find many arguments for disagreement.

A final comment: we greatly underestimate the numbers of taxa that make an important use of sounds in their daily lives, particularly so if we include vibration in terrestrial substrata and sound and vibration in water.

Signaling mechanisms

Sending: generation of signals

To a large extent the peculiarities of sound signal generators derive from the unique features of the group in question. For example arthropods are characterized by exoskeletons: the polymer chitin, tanned to varying degrees, creates their body surface. This diagnostic feature of arthropods has strongly channeled the evolution of their sound signal generators. They use primarily frictional means, rubbing together two parts of the skeleton. And since externally so to speak the exoskeleton is everywhere, frictional sound generating devices have arisen everywhere on the body in the course of arthropod evolution: anywhere where one body part can move in contact with some other nearby part: legs on wings, wings on wings, antennal base on antennal base, mouthpart on mouthpart, genital part on genital part, even major segment on segment. If you count up the number of times that signaling by stridulation has evolved independently in Arthropods you would get a very high number.

By the same token it is not unexpected that sound generation by vertebrates such as frogs, birds and bats came to involves the placement of vibrating structures under muscular control into the respiratory air stream. Ritualization is the process by which what is not a signal initially takes on signal function, i.e. is selected because of its transfer of useful information. While moving and behaving vertebrates inevitably increased the activity of their respiratory systems; this heavy breathing made the sounds of an expired air stream a constant accompaniment of activities and where these initially incidental sounds of no signal value were able to affect the survival and reproductive success of their emitter, they became signals and ritualized (if they benefited the sender) into sound signals.

Receiving: hearing of signals

An ear can be defined as an organ that detects the mechanical disturbances (sound) occurring in air and water. Ears detecting the pressure changes associated airborne sound waves almost always involve a thin low-mass membrane backed internally again by air. Air on the outside of the membrane and air its inside, within the body. In the case of insects a tracheal sac behind the tympanum achieves this inside air and avoids damping by body fluids. An ear moving in response to air pressures and having to displace the high-density of a water-solution would be quite insensitive, so it is backed by air instead of blood.

Sound waves have associated with them both pressure changes and air particle displacement. Arthropod bodies are covered with hair sensible that can function as ears by detecting the displacement of air. The rear antennae of cockroaches, the cerci, are covered with such hairs and these are, if simple, still functional ears. Collectively they can have a very important role in monitoring environmental information about approaching predators. Though they are concentrated on the cercus they occur at all sorts of body location. Such displacement receivers are also inherently directional, that is, they move in the same direction as the displaced air particles.

If the space backing an eardrum is isolated the ear effectively compares the pressure externally against an internal reference pressure and this is termed a pressure receiver. But for most animal ears the space within is not isolated from the external environment and these ears are termed **pressure gradient** ears. The sound being processed has access simultaneously to the front and to the back of the ear and so there is potential for interaction at the eardrum and interference between outside and inside conducted sound. This relates to the effectiveness of ears in localizing sound sources. Small animals, lacking body shadow effects, achieve effective localization by **destructive interference** through an inner and outer path of different length: crickets, frogs, small birds. Our own ear is a pressure gradient ear (Eustachian tube) and frogs hear via their lungs.

Communication: the basic function of a signal

The basic function of arthropod sounds is **communication**: i.e. their adaptive consequence is the transmission of information between a sender and a receiver. That information exchange can be classified according to whether it confers a selective advantage on both or only one of two communicants. (see table Wiley, p. 166).

Mutualism

In ‘true’ communication there is mutual benefit, both animals improve their survival and reproductive success: the fitness of both sender and receiver is enhanced e.g. a male sender calling to a female receiver successfully form a pair for reproduction.

Eavesdropping: ‘overhearing’

Sometimes only the receiver benefits as when an owl receives the incidental sounds of a scurrying mouse (sender) and uses these to locate the mouse and capture it, or a bat receives the calls of a frog (sender) and uses this information to achieve prey capture. The signaler’s fitness decreases and the receiver’s increases. Eavesdropping is manipulation by the receiver.

Deceit

Perhaps a sender benefits at the expense of a receiver, as for example if a male can send a signal encoding misinformation about his size to a rival male or about his ability to provide a large food gift to a potential mate. Deceit is manipulation by the signaler.

Spite

In this under-represented category both sender and receiver experience a reduction in fitness.

Acoustic adaptations: functional categorization of bioacoustics

The body of information that is bioacoustics, all the diverse aspects of the system by which animals exchange sound signals, are the result of a historical process (selection). Selection acts on all aspects of the signaling process, on the sender and the receiver, on when it is adaptive to emit and receive information, on the mechanism used to generate and receive the sounds, on the physical parameters of the signal most effective in overcoming channel noise. Selection acts on ears, tuning them to enable them to filter out biologically relevant sound parameters. Selection acts to minimize noise: all those phenomena within the channel (all the other sounds that occur in a particular locality at a particular time) that act to promote errors by intended receivers. Errors of omission as well as errors of commission: the most obvious error is that the animal doesn't hear the signal above the background noise. Selection acts to make signals louder so that they reach receivers at a greater range and in some cases it acts to make the sound signal softer, to conserve energy for other purposes (sound generation is a costly energetic activity) or to make it more difficult to be exploited by an eavesdropping parasite or predator.

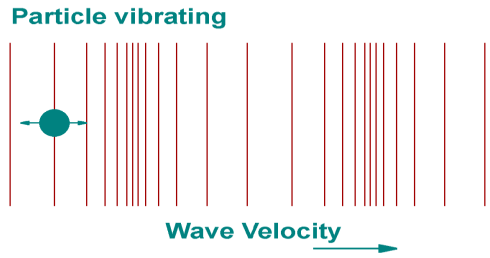
Adaptive contexts of selection on sound signals

1. localization
2. aggregation
3. noise
4. species recognition
5. mate choice
6. rivalry
7. group recognition
8. individual recognition
9. eavesdropping
10. alarm
11. startle & distress
12. Deceit and acoustic mimicry.

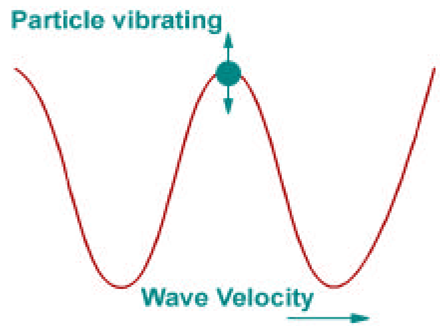
Introduction of sound waves

Sound is any disturbance that travels through an elastic medium such as air, ground, or water to be heard by the human ear.

When a body vibrates, or moves back and forth, the oscillation causes a periodic disturbance of the surrounding air or other medium that radiates outward in straight lines in the form of a pressure. The effect these waves produce upon the ear is perceived as sound. From the point of view of physics, sound is considered to be the waves of vibratory motion themselves, whether or not they are heard by the human ear.



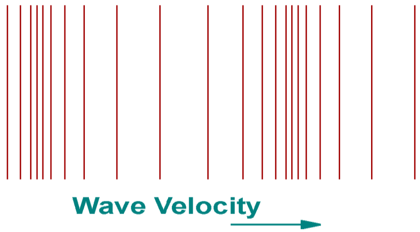
Velocity of Sound Waves: The velocity of sound is not constant, however, for it varies in different media and in the same medium at different temperatures. For example, in air at 0. it is approximately 1,089 ft (326 m) per second, but at 20. it is increased to about 1,130 ft (339 m) per second, or an increase of about 2 ft per second for every centigrade degree rise in temperature. Sound travels more slowly in gases than in liquids, and more slowly in liquids than in solids. Since the ability to conduct sound is dependent on the density of the medium, solids are better conductors than liquids; liquids are better conductors than gases.



Sound wave motion

Longitudinal Waves: In a longitudinal wave the particle displacement is parallel to the direction of wave propagation

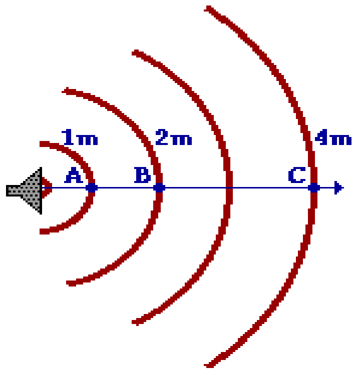
Transverse Waves: In a transverse wave the particle displacement is perpendicular to the direction of wave propagation.

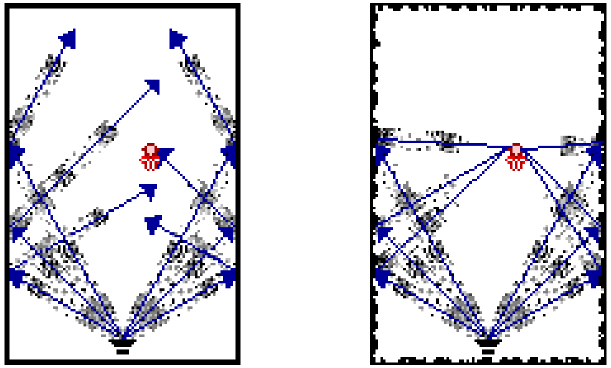


Types of sound wave:

The plane wave: it is a parallel beam of sound this would mean that the flow of energy is the same through ay cross section. This type of sound beam travels without loss of energy.

The spherical wave: in this type of sound, the wave propagates in all direction in spherical form the intensity of spherical wave does not remain constant as in plane waves. Hence the quantity of the energy passing per cm square of the surface of any shell is inversely proportional to the square of the radius of the shell





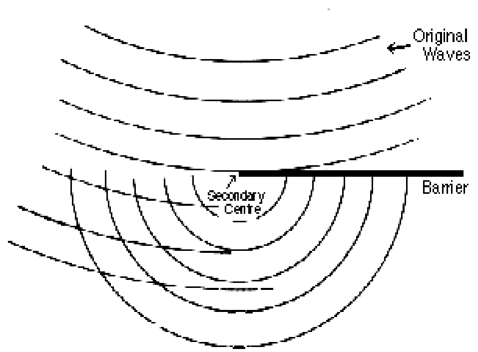
Behavior of Sound Waves

Like any wave, a sound wave doesn't just *stop* when it reaches the end of the medium or when it encounters an obstacle in its path. Rather, a sound wave will undergo certain behaviors when it encounters the end of the medium or an obstacle. Possible behaviors include reflection off the obstacle, diffraction around the obstacle, and transmission (accompanied by refraction) into the obstacle or new medium.

Reverberation

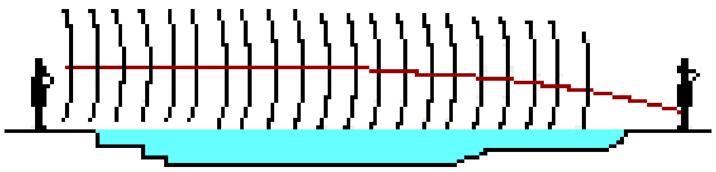
often occurs in a small room with height, width, and length dimensions of approximately 17 meters or less. Why the magical 17 meters? The effect of a particular sound wave upon the brain endures for more than a tiny fraction of a second; the human brain keeps a sound in memory for up to 0.1 seconds. If a reflected sound wave reaches the ear within 0.1 seconds of the initial sound, then it seems to the person that the sound is *prolonged*. The reception of multiple reflections off of walls and ceilings within 0.1 seconds of each other causes reverberations - the prolonging of a sound. Since sound waves travel at about 340 m/s at room temperature, it will take approximately 0.1 s for a sound to travel the length of a 17 meter room and back, thus causing a reverberation, t = v/d = (340 m/s)/(34 m) = 0.1 s). This is why reverberations is common in rooms with dimensions of approximately 17 meters or less. Perhaps you have observed reverberations when talking in an empty room, when honking the horn while driving through a highway tunnel or underpass, or when singing in the shower. In auditoriums and concert halls, reverberations occasionally occur and lead to the displeasing garbling of a sound.

Echoes: Echoes are different than reverberations. Echoes occur when a reflected sound wave reaches the ear more than 0.1 seconds after the original sound wave was heard. If the elapsed time between the arrival of the two sound waves is more than 0.1 seconds, then the sensation of the first sound will have *died out* . In this case, the arrival of the second sound wave will be perceived as a second sound rather than the prolonging of the first sound. There will be an echo instead of a reverberation.



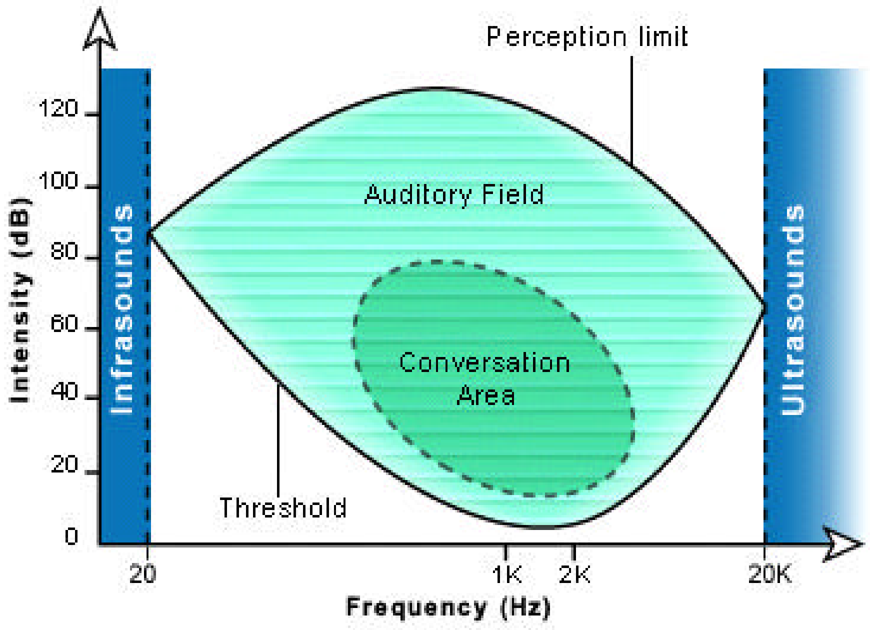
Diffraction involves a change in direction of waves as they pass through an opening or around a barrier in their path. The amount of diffraction (the sharpness of the bending) increases with increasing wavelength and decreases with decreasing wavelength. In fact, when the wavelengths of the waves are smaller than the obstacle or opening, no noticeable diffraction occurs.

Diffraction of sound waves is commonly observed; we notice sound diffracting around corners or through door openings, allowing us to hear others who are speaking to us from adjacent rooms. Many forest-dwelling birds take advantage of the diffractive ability of long-wavelength sound waves. Owls for instance are able to communicate across long distances due to the fact that their long-wavelength *hoots* are able to diffract around forest trees and carry farther than the short-wavelength *tweets* of song birds. Low-pitched (high wavelength) sounds always carry further than high pitched (low wavelength) sounds.



Refraction of waves involves a change in the direction of waves as they pass from one medium to another. Refraction, or bending of the path of the waves, is accompanied by a change in speed and wavelength of the waves. So if the medium (and its properties) are changed, the speed of the waves is changed. Thus waves passing from one medium to another will undergo refraction. Refraction of sound waves is most evident in situations in which the sound wave passes through a medium with gradually varying properties. For example, sound waves are known to refract when traveling over water. Even though the sound wave is not exactly changing media, it is traveling through a medium with varying properties; thus, the wave will encounter refraction and change its direction. Since water has a moderating effect upon the temperature of air, the air directly above the water tends to be cooler than the air far above the water. Sound waves travel slower in cooler air than they do in warmer air. For this reason, the portion of the wave front directly above the water is slowed down, while the portion of the wave fronts far above the water speeds ahead. Subsequently, the direction of the wave changes, refracting downwards towards the water.

Sound range

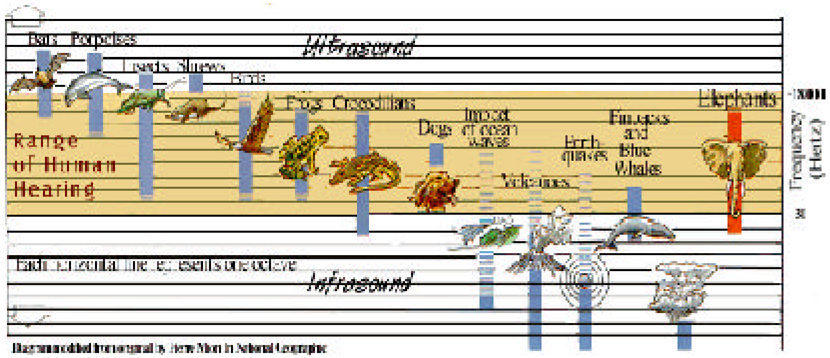


The intensity of a sound

The decibel (abbreviated dB) is the unit used to measure the intensity of a sound.

- Near total silence - 0 dB
- A whisper - 15 dB
- Normal conversation - 60 dB
- A lawnmower - 90 dB
- A car horn - 110 dB
- A rock concert or a jet engine - 120 dB
- A gunshot or firecracker - 140 dB

Eight hours of 90-dB sound can cause damage to your ears; any exposure to 140-dB sound causes immediate damage



Sturdy of bioacoustic animals

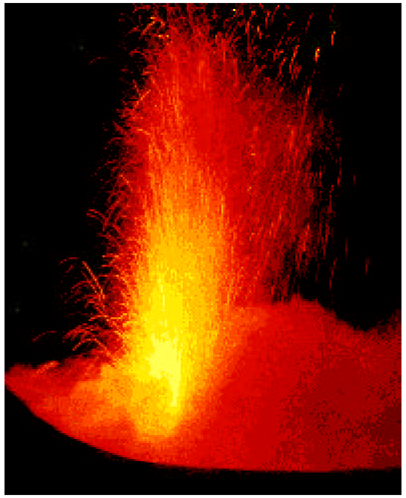
Infrasonic communication:

Infrasound, therefore, is a vibration with frequencies composed of short wavelengths, which travel for long distances through air and particularly through earth, where deeper infrasound travels further. Due to the way in which sound travels through the atmosphere, infrasound possesses the ability to travel further than ultrasound which is composed of longer wavelengths. The study of infrasound waves may be known as “infrasonic” or “infra acoustics”,

Infrasound: Seismic Waves

Although there would seem to be no apparent connection relating infrasonic sound waves and seismic “ground” waves, there does exist a relationship between the two: seismic waves are infrasonic, however they are a specialized type of infrasound, or acoustic, wave which is capable of traveling great distances and as frequencies as long as several months a cycle within the earth. Seismic waves are energy waves generated by the sudden movement of earth, breaking of rock, or an explosion- they are a means by which energy may be transferred between two points within the earth. Although there are several forms of seismic waves, the focus is upon two main forms: body waves, which travel through the inner earth, and surface waves, which move solely along the surface of the planet such as a water ripple in a pond.

Body waves are called so as they travel through body of material in all directions and not merely at the surface; they may be classified as either a primary wave (P wave) or a secondary wave (S wave). P waves are known to be the fastest seismic waves, longitudinal waves which may travel through both solid and liquid material, including the molten core of the earth, with short wavelengths and high frequency. They are also known as compression waves, as they rely on the compression strength and elasticity of substances to propagate, traveling generally at



approximately 6.0 km/s (approximately 3.7 miles/s) in the earth's crust, which is more than seven times the speed of sound. P waves provide pushes and pulls on rock as they move through the earth, just as infrasound waves in the air push and pull on the air. An analogy is thus: when thunder sounds, only to rattle a glass window, it is due to the sound waves applying pressures and releasing the window, very much like P waves on the earth. In accordance with P waves, there are S waves, which are known to move slower than the P waves and only through solid material, however with short wavelengths and high frequency, similar to the P waves, traveling the same at approximately 3.5 km/s (approximately 2.2 miles/ s). They are transverse waves, which move up and down, or side to side in forward travel in the solid earth, dependant on the strength of the material. An analogy of such waves may be found in observing a slinky: if the slinky is shaken side to side, a longitudinal wave is produced, however if given an abrupt sideways deflection (by snapping one's wrist), a transverse wave result, which travels at both ends.

Zoological Subjects and Seismic Waves: Communication and Survival

Much biological and zoological research has been focused on the auditory and optical systems of organisms as they are senses possessed by *Homo sapiens*, where no specially designed organs to detect terrestrial vibrations are existent. However, research is now being pursued in biology and perhaps even increased in zoology as to such organs and how they are employed. For instance, there is at present an interest in whether lions possess the ability to utilize infrasound and vibration detectors in their paws.

Such seismic sensitivity may be found in species of mammalian, insects, amphibian, and reptilian as means of communication, defense, location of prey, social interactions, and mating, signals which may be discovered by use of computers and geophones, as used in the Vietcong jungles of Vietnam to observe foot steps. Prairie mole cricket males sing from burrows to females, sending ground vibrations to other males in warning to maintain reasonable distances; some rodents use seismic communication by drumming their feet; Leafcutter ants use vibration to signal for aid when buried alive or to recruit foragers; snakes and other reptiles which lack external ear openings detect ground vibrations, allowing for the assumption that a rattlesnake never hears its own rattle; and vibration is also employed in spiders, frogs, bison, the rhinoceros, hippopotami, alligators, and kangaroo rats. However, one of the most prominent examples of seismic communication and infrasound utilization may be observed in elephants: when frightened, elephants employ seismic waves to send messages of warning to other herds by stamping their foot to the ground, from where shock waves are sent out, traveling up to 48.2 km (30.0 miles) away.

Species : Domestic Pigeon

Although bio-magnetism may be a method by which the birds navigate and determine their location, it has also been discovered that pigeons are capable of perceiving infrasound waves, which may aid them in determining the precise location at which they may find themselves. A form of support of this theory comes from a pigeon race which was held in 1997: pigeon races are an international sport, where pigeons are bred and trained to be taken from their homes to a distant location with other competitors, when are released. The return speeds of the birds as they find their way home are timed, where over 90% return in a few days, followed by the rest, with a few exceptions. However, in 1997, one particular race turned into what was considered a catastrophe for pigeon racers but something of interest to zoology.

June 29, 1997: to celebrate the centenary of the Royal Pigeon Racing Association, a race of more than sixty thousand homing pigeons began at 6:30 am from a field in Nantes, France. The birds were to fly to their lofts in southern England, 643.7 to 804.7 km (400.0 to 500.0 miles) away. The majority of birds left France and began their trek over the English channel with the expectancy that they would have arrived home by early afternoon, but when most did not return that day nor any days following, the race was labeled as a disaster. One bird would inevitably find itself lost, but what could explain the disappearance of thousands?

It was observed by an American Geological survey researcher, Jonathan Hagstrum, that as the pigeons made their way across the Channel, a Concorde supersonic transport (SST) airliner flew over the Channel at the same time from Paris to New York. When in flight, the SST generates an intense shock wave down towards the earth: pigeons below the SST could not have escaped the sound wave and the birds that had still been in France at the time were the birds to return to their lofts. As an explanation, it was suggested that the birds determine their location by use of atmospheric infrasound which they are able to hear well since

their hearing apparatus is designed to detect low frequency sound wave. Infrasound travels for extremely long distances from the source. It could of senses which are different from the human senses.be possible that the low frequency shock waves produced by the ocean waves crashing against one another in the Channel- as well as the infrasound reflected from cliffs, mountains, and other steep-sided characteristics of the earth's surface- were what can guide the pigeons to their lofts in England. However, if the SST's sonic boom obliterated the infrasound, the birds would have easily become disoriented and changed direction, never being able to finish the race.

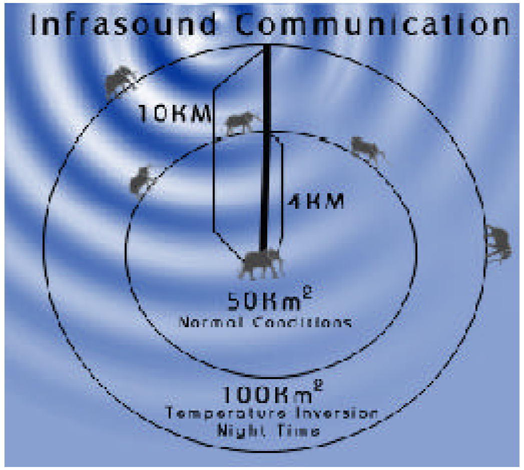
Another notable incident to address occurred in 1995, when France detonated a nuclear device that affected the rest of the world through reverberation. From the source in France, near Paris, infrasound waves traveled at the speed of sound for a radius of 1287.4 km (800.0 miles) in the first hour. Eleven hours later, the infrasound waves arrived in North America, and went undetected by *Homo sapiens* ears. However, it was observed that pigeons found in the United States were disturbed by the waves, which they could detect very well with their ability to hear infrasonic sound waves. In essence, although humans may not be aware what other humans are doing as "secret tests", other living organisms are more than aware of the changes in the environment through the use

Species: Indian (Asian) and Ceylon elephant

Sound and infrasound: Elephants are a source of much noise and communication, employing a variety of sounds, both audible and inaudible to *homo sapiens.* The most popular sound acknowledged as that of an elephant is the loud, impure-toned “trumpet” sound of approximately 1000.0 Hz, and if such a sign is ignored, the elephant may charge, however, elephants are known to mostly give false charges, where they turn or stop at the last second.

Elephants also emit loud, constant sounds which had been believed to come from the stomach, as their diet is of large proportions, however the noises were discovered to be controlled, stopping suddenly when the elephant was approached. It was discovered that such sounds are not in relation to digestion but are to keep the herd in contact, a type of “purr” or “gargle” which is silenced when a possible danger approaches to alert the rest of the herd, which, too, grows silent. The purring resumes when the threat retreats.

However, elephants possess an extraordinary sense of hearing and emit infrasonic calls with overtones, with which they can both hear and determine the origin of the call. African elephants are known to emit infrasound calls of between 15.0 and 40.0 Hz, which are produced in the throat where sinuses and trunks may manipulate the sound texture. Most elephant communication is infrasonic, rumbles which may be heard by other elephants in herds at least 10.0 km (approximately 6.0 miles) away as calls of warning, greeting, rally, mating, food location, excitement, fear, or other calls, the rumbles traveling further in the dry savannah during the night. This is their long-distance communication system which aids in keeping herds together in coordinated movements without losing contact or meeting with scarce resources. It also allows for males to locate fertile females in order to mate and for cows to keep track of their calves.



Seismic communication: As elephants send infrasonic calls to one another, a replica of the signal is sent as seismic waves, which are able to travel through the ground more than 1.5 times further than the infrasound in air (between 16.0 to 32.0 km or 10.0 to 20.0 miles), meaning that the elephants communicate over longer distances than previously believed with a well developed communication system. Vibrations in the earth may also be generated through stomping of the foot and flapping of the ears, both of which are used in the defense mechanism of mock charges. Such vibrations may be used to greet or warn other herds, to locate mates or resources of water and food, or convey basic details about the location and moods of the herds, perhaps invoking anger or fear in other herds, many of these calls seemingly more received by the cows in the herd.

Theories on how elephants are able to detect such seismic waves and use them for their benefit have been proposed, mostly based on two physical properties of the elephant: their toes and their trunk. The feet of elephants are more than mere simple, leveled cylinders, but they are composed of fatty tissue which creates a "water-bed" effect, allowing for silent movement, as the elephant walks on their toes. Vibrations from the ground cause the tissue to oscillate, which triggers Pacinian corpuscles (vibration sensors) within the elephant, which are much like an onion with layers and a slimy gel between each layer. Vibrations manipulate the layer and transmit signals to the brain. It is also believed that they may sense vibrations through the toenails which carry to the ear via bone conduction to receive messages from. When discussing the trunk, there is believed to be a sensitive tip on the trunk with very sensitive tissue, consisting of a large amount of Pacinian corpuscles, which can detect vibrations when touched to the ground. However, it is difficult to attain such a part of the trunk as it is a sacred relic, used as a charm for good luck in South-east Asia. According to geophysicists, details sent in a seismic wave become diluted after traveling a long distance, however elephants have been found to possess a mass of brain cortex, which allows for increased processing power of weak signals.

In studies of elephant communication, seismic communication became a theory when it was observed that the elephants would lean forward with one leg raised and freeze for “no apparent reason”: this lead into tests in Africa, India, and Texas, using advances in technology to record, study, and manipulate sounds and vibrations produced. In one experiment, two microphones and geophones- located under the microphones- were situated outside an elephant closure, which detected and measured underground vibrations. Signals recorded were played back to the elephants through specially adapted seismic transmitters with a mixture of elephant calls, synthesized low-frequency tones, rock music, and silence to observe the reactions of the elephants (change in behavior) to such signals. Such experiments and observations have also been compared to other zoological specimens that use, or are thought to use, seismic signals in communication, mating, and prey location: some moles (Golden mole, et cetera), seals (Elephant seal, et cetera), insects, fish, reptiles, amphibians, and perhaps bison and lions, however, the elephants use a more complex system which travels further than other organisms.

Through the use of infrasound and seismic waves, elephants may have the ability to hear grinding rock during an earthquake and feel the tremors. Herds also use seismic waves to find water, as thunderstorms in places such as Angola generate both air-infrasound and seismic waves, which the elephants in Etosha may detect as far as 160.0 km (100.0 miles) away, responding by moving towards the storm. However, it follows that if elephants are able to detect thunderstorms and other herds from such far distances by sensitive detectors, it is a serious issue regarding how *homo sapiens* affect the herds with use of artificial infrasound waves. A small town is able to produce noise within the ground for a 100.0 km (62.1 miles) diameter, where traffic on one road may be detected 30.0 km (18.6 miles) away, constituting concerns regarding elephants found in zoos. Jets, water pumps, construction, explosions, helicopters and rotating blades, and loud city noises are also sources of noise and ground pollution, which may be liable to play an important factor in the well-being for an elephant, as it applies stress upon communication.

Species : Black Rhinoceros

Very similar to the elephant, the largest pachyderm, the rhinoceros is also known to use infrasonic communication, however not for as long of distances as the elephant, as the species are not as widespread. Infrasound is particularly used when warning offspring.

Species: Hippopotamus

The hippopotamus, Greek for "river horse", is known as the third largest mammal, just after the elephant and rhinoceros, and also is known to use infrasonic calls. Sounds emitted above the surface are from the nostrils which we can hear except for the infrasound undertones, but as the waves travel through the air, infrasound calls travel through the water. Sounds in the water are not audible to the human ear, though they may be in the audible range, and are detected by the jaw of the hippopotamus. In the air, the calls travel for 6.4 km (4.0 miles) and are received by the ear, where sounds in the water travel five times faster and are received first, traveling up to 32.2 km (20.0 miles). Using such a system enables the hippopotamus to judge the distance of objects and other living organisms, including their rivals. In the case of an earthquake, they, too, may be able to hear grinding rock under the earth's surface.

Species: Leptodactylus albilaris (White-lipped Frog)

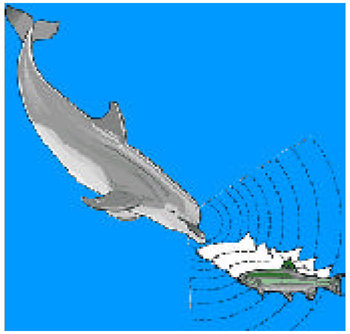
Found in Puerto Rico, these ground-dwelling, nocturnal frogs approach communication with the strategy of using seismic vibration. They are found along marshes, mountain streams, and ditches, where males are known to call from their location in dense grass, under vegetation, or every from burrows in the mud. Females, however, are silent and camouflaged from the males. They are sensitive to footfalls: it was discovered that existing in the inner ear of the frog there are nerve fibers that respond when vibrated at frequencies of 20.0 to 160.0 Hz. It was then discovered that the frogs have a hearing apparatus which makes them at least one hundred times more sensitive than the inner-ear apparatus of mammals. In the white-lipped frog, there is a sac filled with dense calcium carbonate ($CaCo_3$) crystals that rest on six hundred sensory hair cells. When the frog vibrates, the upper surface of the hair cells and hair roots oscillate, where the sac at the hair tips remains stationary due to inertia. The result: the hairs bend and modify the normal rate of discharge found in the nerve fibers.

It was found that after rain, the male frog buries its posterior into the mud and leaves its head and forelimbs exposed, then, as he croaks, the vocal pouch expands and strikes the ground. The impact produces a Rayleigh wave of vertical oscillations that travel along the surface of the earth at approximately 100.0 m/s (328.0 ft/s) which may then be detected by females and other males.

Ultrasonic communication:

Sound may be expressed an oscillation produced by vibrating objects which may be heard, assuming a proper medium is present to transmit the sound, such as water or air (SPH1). Sound may be addressed in wave form, consisting of wavelengths, the distance a wave travels before the motion begins to repeat, and frequencies, the number of vibrations per second (denoted “f”, measured in Hertz, or Hz). Humans are capable of hearing frequencies between 20.0 Hz and 20.0 kilo Hz through the use of the cochlea found in the ear and, when sound is measured in decibels (dB), it is observed that humans are able to hear from 0.0 dB, the lower range of hearing, to 160.0 dB, where there occurs the instant perforation of the eardrum in many mammalian species (SPH1). However, several zoological specimens are able to hear sounds beyond *homo sapiens* and into the ultrasonic range- 16.0 kHz to several billion Hz- some of which may be detected by recording on an audio cassette tape and playing the machine back at a slower speed than was previously recorded, as has been observed with bird calls (Halsey1 225). Such examples of organisms who are able to hear beyond the human sense of hearing include monkeys (limit of 33.0 kHz); cats (limit of 50.0 kHz); mice (limit of 80.0 kHz); dolphins (limit of 150.0 kHz); and bats, who are the only organism known to possess keener hearing than dolphins at 175.0 kHz, or 175,000.0 vibrations per second (Cousteau 169). It is through the use of the ability to hear ultrasound waves which allows for several species to use what is known as “Sound Navigation and Ranging” (SONAR), or echolocation.

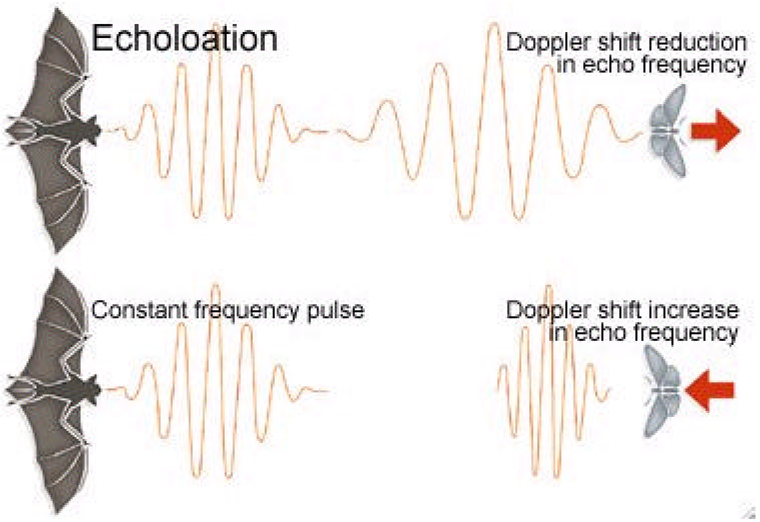
Echolocation is recognized as a method utilized by a variety of aquatic, nocturnal, and cave-dwelling zoological subjects to localize objects and perceive the environment by means of reflection of ultrasonic sounds, where sound pulses are emitted by the auditory system and reflected from objects in the environment as waves, which may be interpreted by the auditory system, similar to the visual system. The process was termed, “echolocation” by Donald Griffin, who pioneered a breakthrough in studies of the auditory system upon discovering the use of ultrasonic by bats in order to avoid obstacles, although echolocation used by bats was observed in the early 19th century by Lazzaro Spallanzani, an Italian scientist . The use of echolocation provides for an increase in independence from strict use of the visual system, aiding in navigation, orientation, and location of prey in poor light or the dark. Species to use echolocation include bats and dolphins, primarily, but not exclusively, as birds, rodents, insectivores, Megachiroptera, fish, seals, cetaceans, large aquatic mammals, the platypus, and blind humans have been found to use echolocation .



Echolocation and Sonar Process

To locate objects in poorly lit or dark environments, users of echolocation may use ultrasonic beams, which are greatly directional. By emitting ultrasound waves in a given direction, the waves reflect off an object in the ultrasound path, which produces an echo effect, sending the waves back to the organism. Through determination of time between emission and receiving of the ultrasound pulse, the distance to the object may be measured and location figured, or, if targeted towards the bottom of a body of water, the depth may be calculated (Halsey5 578). In solid materials, the pulse penetrates the solid without disturbing it and is reflected from the far end, then, through time measurement, the density of the material may be determined (Halsey5 378). The pulse also indicates irregularities of the solid, including holes or flaws. Through the use of what is known as the Doppler Shift, or the shift in frequency produced by a moving source, the speed of the object may be derived as well as the distance: if the reflected signal is Doppler shifted, a change in beat frequency results, where beat frequency is proportional to speed, meaning the greater the frequency, the greater the speed of the object (SPH1). This is particularly useful in locating prey, as in the case of a dolphin, which employs the use of echolocation to catch fish and navigate. [3]

When addressing ultrasonic waves, a distinction must be made between the two forms of ultrasound, being low-intensity waves and high-intensity waves. Low-intensity waves are known to pass through a material without disturbing its physical nature, however high-intensity waves are capable of producing chemical and physical changes by generating bubbles, followed by the abrupt collapse in liquid due to high-speed agitation (sonochemistry)(Halsey5 579). Intense ultrasonic pulses may kill bacteria and make significant impacts upon the brain of another organism, or organs found in the body, as dolphins have discovered to be a benefit when catching fish by disorientating the fish and its swim bladder. Cavitations may result in solids due to high-intensity waves, where the particles are subjected to large alternating accelerations which may reach up to 1,000,000.0 g (g denoting gravity in this case). Capitation in liquids is also possible, where cavities form and collapse violently during compression, with high pressure and high temperature .

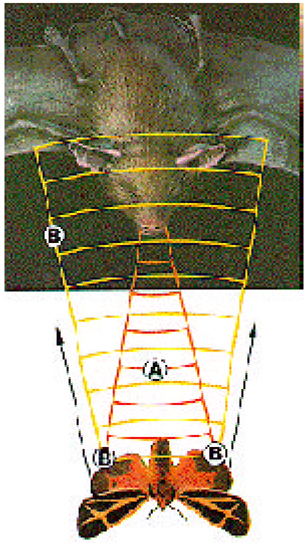


Species: includes Rhinolophus ferrumequinum (Horseshoe bat), Myotis bechsteini (Bachstein's bat), Kerivoula picta (Paintedbat),andMyotismyotis(Mouse-earedbat).

Echolocation: Bats are recognized as small, nocturnal mammals that are able to truly fly, not merely glide as the flying squirrel demonstrates, and form the second largest mammalian order, outnumbered only by the rodent order, which has more species. However, bats are also known specifically for their use of echolocation to navigate and catch prey in the darkness: they are constantly releasing ultrasonic waves during the whole time they are awake, using it to enhance their sight, which exceeds the sight of *homo sapiens* on its own. By emitting and receiving ultrasonic sound waves, they retain the ability to see further distances than many other organisms and can derive information which is much more refined. Although not all bats use echolocation, such as some mega bats (large bats), many bats, many known as "micro bats" do use sonar, however, the use versus no use suggests different ancestors.

Bat sonar may be expressed as a general process: ultrasonic waves are emitted from the bat as cries which then travel and are reflected back to the bat upon interacting with a moving or non-moving object of varied density. By measuring the delay in time from the wave emission and the return of the echo, the bat is able to determine the distance of the object, where amplitude is used as an indication of the size and shape of the object. With that information, the bat is able to locate precisely its prey with knowledge of how large or small it is, and thus it is able to hunt for its prey.

However, the process is not really as simple as explained, as there are other factors to be considered. The sound waves emitted may be of varying frequencies, varying by species and individual, and different sound waves used may collect more refined information: *Eptesicus fuscus*, the brown bat, uses sound waves classified as 'broad-band FM",

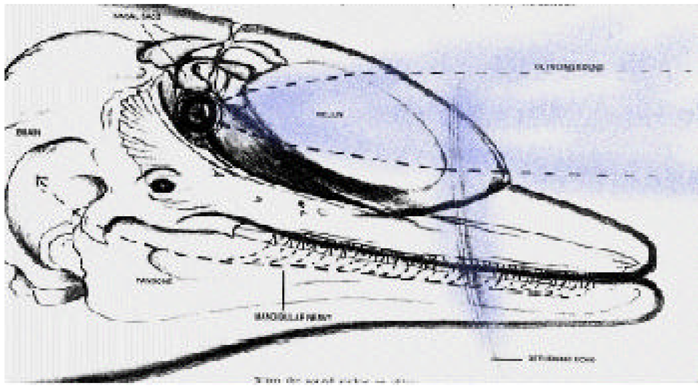


which are measured to be approximately 100.0 to 20.0 kHz, which allows for good echoes of distance, size, and shape. It has also been found that the production of ultrasonic cries demands from the bat a large amount of energy, particularly if the bat is flying, which would suggest that the hunt for food is an exhausting activity. However, it has been found that to bypass the affects of participating in the two activities at once, bats who use sonar inhale oxygen to use their flight muscles and exhale air pulses in order for the ultrasonic waves to be transmitted.

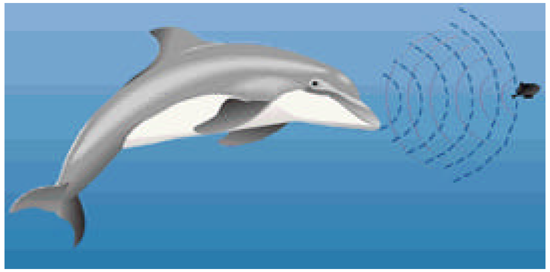
Another issue to consider is when the bat begins to move in a chase after its target: how does the echolocation function at that time? Through research, it has been found that bats possess a mechanism called automatic gain control (AGC), which provides the bat with the perception of a fixed echo intensity level as it approaches its target: where echoes will change based on the change in distance and echo strength, contractions of muscles in the bat's middle ear diminishes after ultrasound emission, which produces changes in the bat's hearing and balances the echo changes due to distance. Amplitude would also change as the bat moves; however, it is believed that the AGC regulates the amplitude as well.

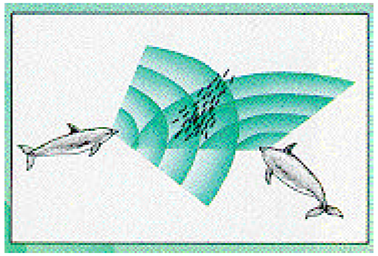
Species: Of the several species, included are: Tursiops truncatus (Bottlenose dolphin), Platanista gangetica (Ganges dolphin), Orcaella brevirostris (Irrawaddy dolphin),

Ultrasonics - echolocation: The most notorious characteristics of dolphins which are usually observed is their playfulness and their intelligence, which often sets them apart from other organisms studied by homo sapiens. However, their reliance upon ultrasonic waves is not discussed as often, where many humans are not aware that the dolphin employs a system of ultrasound which has been found to be four times more powerful than that used by humans. The dolphin is sensitive to sounds and it uses such sounds perhaps more effectively than any other organism, although the bat and the elephant possess their own well-developed sense of sound and its many uses.



Dolphins are known to emit an array of sounds and noises beneath the surface: they are known to sound moans, cries, whines, barks, squeaks, whistles, yelps, grunts, clicks, rasps, mews, squawks, “rusty hinge” and “motor boat” sounds. Such sound may be emitted as low frequencies of the homo sapiens audible range to ultrasonic wavelengths, which are ten times higher in pitch than sounds which are audible. With ultrasonic sounds, the dolphins are able to navigate, communicate with one another in pods, and locate prey, mostly at night, in darkness, or when acute sight lacks in the gathering of surrounding information. It was found in studies that if the dolphin is placed in a tank of colourless water and they are familiar with the walls and the tank size, echolocation is not used excessively. However, if the animal is unsure, many clicks of ultrasound waves are emitted. In communication, studies have discovered some of the particular sounds used by dolphins to communicate particular



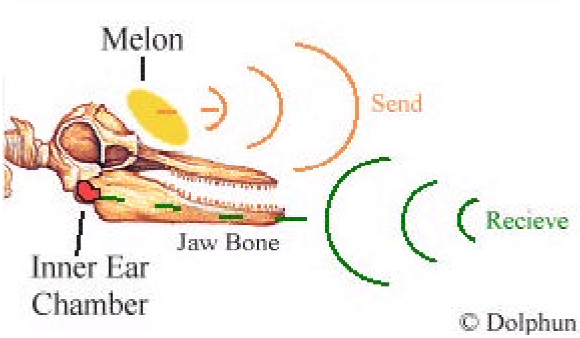


messages: a short, flat whistle proceeded by a high-pitched, muscle whistle is a distress signal; a yelp is a mating call; barking is the expression of angry dolphins; and the whistles from a mother are always answered by the offspring.

The echolocation of the dolphins is like that of bats, however the dolphins are marine mammals with specially shaped heads to focus on objects, which does not change the general concept of echolocation: sound waves of high frequency are emitted, which reflect off an object or prey and upon return, the dolphin is able to process the information and even receive "pictures", also measuring the time it took for the sounds to be send and returned. From the waves they direct out from their body, dolphins can derive the location, distance, speed, direction, and size of the object, which are often fish who are unaware that they are made to be a target. The sonar involved increases the pulse rate of the prey, as well as penetrating it, similar to x-rays used in medicine: the sonar of the dolphins also penetrates humans to display the skeleton just as it is able to penetrate through a pregnant female, allowing the dolphin to perceive the image of the skeleton of both mother and fetus, as well as the heartbeat of the fetus, much like the ultrasounds used to do the same for humans.

The echolocation system employed by dolphins has been of interest for many years, where there was curiosity regarding the origin of the ultrasonic "clicks" and the ability for dolphins to perceive and process the waves and their information. These clicks are not constant in loudness nor quality and are found in many forms of sounds, such as whistles or moans, however it was realized that none of the changes in sounds produced bubbles. Because there were no bubbles formed, it was determined that sonar signals do not come from the blow hole. However, dolphins possess no vocal chords, which leads to the belief that the ultrasound waves are produced from the snout as continuous chains of vibrations at approximately 3000.0 to 200000.0 Hz, produced as air is blown through the nasal passage and over two, flap-like structures inside

the blowhole. The sounds are then manipulated by tension increase and decreased of the nasal flaps and by maneuvering the plugs in the airway and blowhole. To perceive sounds, a form of beak (known as the rostrum) which acts like a "sonic brush" when another organism is near, which works for short distances. For long distances, it is possible dolphins use an organ common to toothed whales like themselves: a hollow, located in the frontal region of the head, containing wax-like fat consisting of a tissue network that may amplify and magnify sound at a higher rate than the surrounding tissue. To focus, it uses successive reflections and sonic waves that occur within a given incidence. The origin of the clicks may be attributed to a larynx-like muscle, where the tongue plays no part, producing sounds at rates between 800.0 to 1200.0 clicks per second, faster than could possibly be produced by muscles or any naturally occurring vibrating membrane.



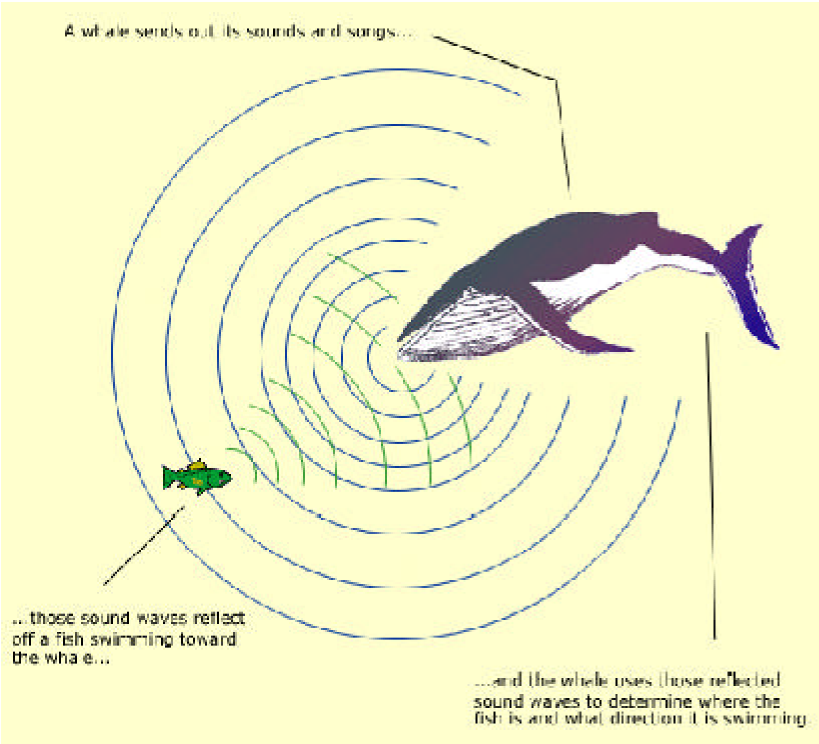
Dolphins are capable of perceiving sounds of 200000 Hz by use of their ears, which are merely openings found behind the dolphin's eyes, leveled with the skin, which may be accredited to water pressure. Echoes are emitted and received through the intermediary of the highly sensitive lower jaw, which contains fatty, liquid-like tissue and major nerve terminals that connect to tissues, all of which transmit sound to the inner ear, where the cochlea is the same size as that of a human, but the acoustical nerve is larger with thicker contact fibers. This distinguishes the dolphin as a primarily audile organism, where it depends on sound to survive (as well as sight), also proven by the species of Ganges dolphins, who are blind and rely explicitly on sonar to locate prey and navigate, as well as avoid capture by nets. It has also been found that the auditory nerve, the eighth cranial nerve, of the dolphin is highly-developed and is the largest of cranial nerves, where in the cortex, the auditory center is enormously large and the ear modified for use in water. The sensory cells used to perceive the highest frequencies are large, each possessing their own nerve fiber, where humans only have connection with one fiber: it is similarly developed in relation to other organisms that depend on their sense of hearing to survive.

This sonar system is very important and is very sensitive, allowing the dolphin to even distinguish two fish from a distance of 4.6 to 5.5 m (15.0 to 18.0 ft). Experiments have shown that the dolphins are capable of detecting a 7.5 cm (approximately 3.0 in) target at a distance of 110.0 m (360.9 ft) in cloudy water, which poses the following question: how much time passes between the moment the dolphin emits an ultrasonic click and the moment at which the dolphin receives the reflected click which allows the dolphin to process the information about the target? The answer may be derived by acquiring the use of mathematics and physics

Species: include Balaenoptera cetacea (Blue Whale).

Infrasound: Blue whales are known to use infrasonic wavelengths to communicate with each other, where the infrasound travels thousands of kilometers through the ocean water, which acts as a superb conductor due to its salty content. Temperature and pressure variations found at the varying depths of the oceans will act as voice tubes and channel whale calls further than is usual, which allows for whales on the other side of the ocean to hear the calls. It is in such a fashion that pods may keep in communication with one another. Many other whales also use infrasound to communicate, whether it to used as a method to attract mates, warn rivals, communicate between the individuals of their own pods or of another pod, or to find food. Such whales include the Humpback whale, which has been found to have the most complex song of all organisms, where they can use “rhyme” such as humans in order to recall the complex tunes- their infrasound may travel more than 965.6 km (600.0 miles).

However, manipulation of the sounds the whales transmit or receive may interfere with their normal activities, which could affect an individual but, macroscopically, affect whole populations of whales, as well. This addresses the problem of large amounts of noise pollution found under the water surface: sound, especially low frequency wavelengths, travels very well in water and loud noises could enforce serious impacts upon the whales, from subtle behavioral changes- like the shortening or lengthening of activity- to physiological impairment- like permanent hearing loss. Regarding the pods, it could be that they may suffer disturbances in migration, feeding, or other critical activities. Although marine mammals are accustomed to the occasional subjection to loud sounds and pressure changes, the extent of their toleration of vast amounts of excess noise pollution is unknown, just as the extent of impairment done to individuals and their pods is not understood.



The excess noise pollution being referred to is that which is generated by homo sapiens, who insist on machines and processes that produce large amounts of noise and infrasound (and ultrasound). Shipping, oil drilling, research equipment, navy sonar, and submarines jam the signals of whales and other organisms and the noise has increased during the last few years without the comprehension that human interference is liable to effect every individual whale found within a 650.0 square mile radius, a diameter of 1300.0 square miles. In some cases, the whales consider the sources of such loud noise, mostly ships, as an enemy, from which cows will protect their calves, keeping them from the open sea in fear a ship will harm them. It is also believed to be a possibility that certain beaching cases may be credited to human interference, such as the navy sonar, but thus far, the cases have not yet been proven, except for at least one case which was directly linked to navy sonar. It is hard to say how much excessive noise it will take from homo sapiens to discover the extent of damage done to the whales which are now protected from extinction by whalers but may find themselves too deaf and unable to communicate if not horribly disoriented.

Ultrasonic: Besides using infrasound to communicate, the blue whales (and all other whales) may also employ the use of ultrasound: they are capable of transmitting and receiving sound such as clicks, grating, “rusty-hinge creaks”, “muffled smashing sounds” and several high-pitched ultrasonic wavelengths which are believed to be for echolocation purposes, as well as communication in attempts to keep the pods together as the group moves on, particularly during migration. The sounds may be used to signal warnings, greetings, as part of defense mechanisms, or as general signals.

Species: Aves Strigiformes Tytonidae Tyto alba (Barn Owl)

The Barn owl is notorious for possessing the ability to navigate and direct itself through complete darkness with sensitive hearing. It is a quiet bird of prey which utilizes echolocation to catch prey in the dark, where the facial discs that distinguish it from other owls allows sounds to be localized with which the bird can pinpoint a precise location of movement and its direction.

The physiology of owls ears and hearing

Because Owls are generally active at night, they have a highly developed auditory (hearing) system. The ears are located at the sides of the head, behind the eyes, and are covered by the feathers of the facial disc. The "Ear Tufts" visible on some species are not ears at all, but simply display feathers.

The shape of the ear opening (known as the aperture) depends on the species of Owl - in some species, the opening has a valve, called an operculum covering it . The opening varies from a small, round aperture to an oblong slit with a large operculum. All owls of the family Tytonidae have rounded openings with large opercula, while in Strigidae, the shape of the outer ear is more varied.

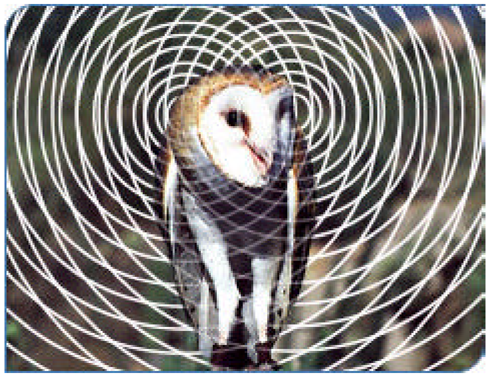
An Owl's range of audible sounds is not unlike that of humans, but an Owl's hearing is much more acute at certain frequencies enabling it to hear even the slightest movement of their prey in leaves or undergrowth.

Some Owl species have asymmetrically set ear openings (i.e. one ear is higher than the other) - in particular the strictly nocturnal species, such as the Barn Owl or the Tengmalm's (Boreal) Owl. These species have a very pronounced facial disc, which acts like a "radar dish", guiding sounds into the ear openings. The shape of the disc can be altered at will, using special facial muscles. Also, an Owl's bill is pointed downward, increasing the surface area over which the soundwaves are collected by the facial disc.

The owl's large ear opening is hidden behind the facial disk.

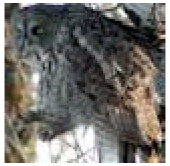
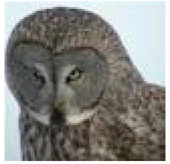
An Owl uses these unique, sensitive ears to locate prey by listening for prey movements through ground cover such as leaves, foliage, or even snow. When a noise is heard, the Owl is able to tell its direction because of the minute time difference in which the sound is perceived in the left and right ear - for example, if the sound was to the left of the Owl, the left ear would hear it before the right ear. The Owl then turns it's head so the sound arrives at both ears simultaneously - then it knows the prey is right in front of it. Owls can detect a left/right time difference of about 0.00003 seconds (30 millionths of a second!)

An Owl can also tell if the sound is higher or lower by using the asymmetrical or uneven Ear openings. In a Barn Owl, the left ear left opening is higher than the right - so a sound coming from below the Owl's line of site will reach the right ear first.

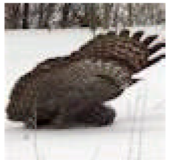
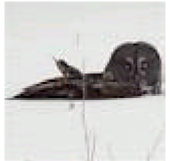


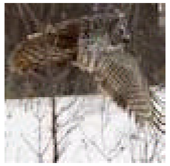
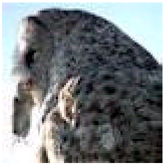
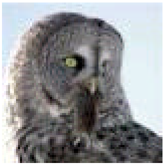
The translation of left, right, up and down signals are combined instantly in the Owl's brain, and create a mental image of the space where the sound source is located. Studies of Owl brains have revealed that the medulla (the area in the brain associated with hearing) is much more complex than in other birds. A Barn Owl's medulla is estimated to have at least 95,000 neurons - three times as many as a Crow.

Once the Owl has determined the direction of its next victim, it will fly toward it, keeping its head in line with the direction of the last sound the prey made. If the prey moves, the Owl is able to make corrections mid flight. When about 60 cm (24") from the prey, the Owl will bring its feet forward and spread its talons in an oval pattern, and, just before striking, will thrust it's legs out in front of it's face and often close it's eyes before the kill.

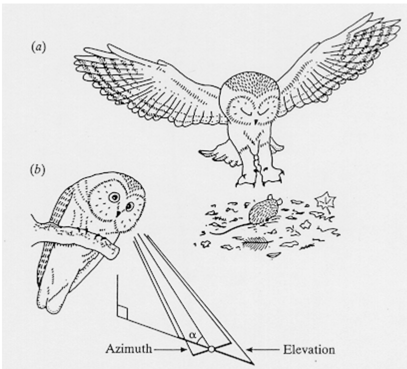


Sound Localization in the Barn Owl

As a nocturnal hunter, the barn owl has a highly developed sense of hearing and sound localization. It has been studied extensively by neurobiologists to determine the mechanisms by which sound is processed in its brain. the accuracy of the owl's sound localization capabilities was tested under a variety of conditions. The owl in the experiment used both interaural spectrum and interaural onset time for localization in azimuth, with better accuracy resulting when onsets were available as compared to continuous sounds. Localization accuracy in elevation was found to depend heavily on ear shape and feather placement to filter the sound, as opposed to timing information. the detection of interaural time differences is performed by the meeting of nerve signals from each ear at the nucleus laminarus. Nerve axons carrying signals that originated in each ear enter the nucleus laminarus from opposite sides. Since the distance that an action potential travels is a function of time, the position in the nucleus laminarus at which action potentials from opposing sides meet is a function of interaural sound delay. This interaural delay corresponds to localization in azimuth. Postsynaptic coincidence detecting neurons are thought to detect the meeting of action potentials in order to form a map of auditory space, and relay this information to other parts of the brain.



the processes of the nucleus laminarus and other structures create computational maps of space, and how these spatial representations converge with one another at the optic tectum. There, visual and acoustic maps combine to create an integrated perception of the world, and computation of motor signals for appropriate interception movement originates. Thus the function of sound localization in the brain appears not to merely choose the direction of the loudest sound, but to create a map of sound sensations in space which may be related to other sensing modalities.

Possible application of owl principle

- Military application
- Zoological study (finding animals)
- Hearing aid in traffic

User survey

According to user survey 40% motor bike accidents happened because of helmet

Hearing is the second important sensory system for communication & all the time we see & hear & relate the auditory signal with visuals & when the visual is out of site still we can recognize it by sound.

& the same thing happened while riding on motor bike; when you are not able to see the vehicle coming from back side at that time u try to visualize it by its sound & try to locate the sound.
Also changing intensity & frequency of sound source give u the feeling of speed of the vehicle. (Doppler Effect)

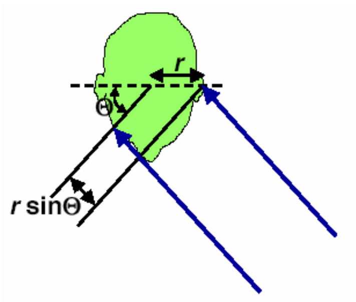
But when a rider wear his helmet he hardly listen any sound so while riding he can't locate other sound sources around him, special vehicle coming from back side

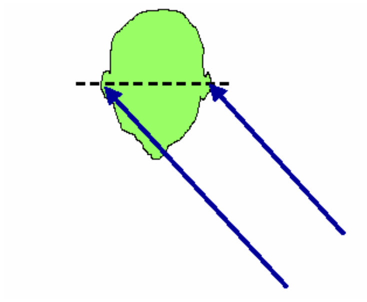
Project brief

The study is aimed to develop an aid inside a helmet to judge the traffic around the rider
& able to locate sound sources around him in moving condition

It may also take care about noise pollution by filtering unwanted frequencies & intensity of sound

The output of hearing aid may be audio or visual





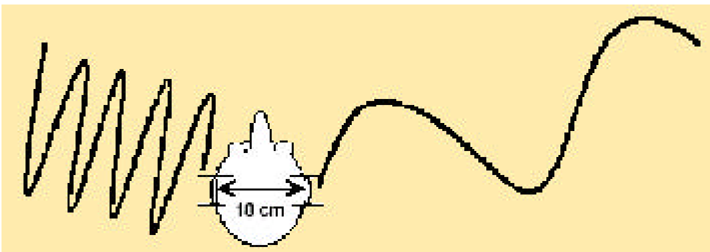
Sound localization ability in human

Determining the direction and distance of a Sound source

- Tied to binaural abilities (two ears)
- Similar to stereo vision with two eyes (triangulation)
- Not that much like bats - they are active - we are passive (and do not use echoes, Doppler shift, or frequency modulation)
-

The Localization of Pure Tones

Assume steady sinusoidal sounds Sound located to one side of the head, when
Reaching the farther ear, this sound will be:
1) Delayed in time
2) Less intense
Two possible cues to the location of the sound source because of the physical nature of sounds, these cues are not equally effective at all frequencies



The Frequency of the Head

Head = 18 cm = .18 m
Speed of sound = 340 m/sec
Cycles per second (frequency)
(1/.18 m) x (340 m/1 sec) = 1888 hz
Differences across frequency

Low frequency sounds wavelength is long compared to the size of the head (1888 Hz)
1) Diffraction: sound “bends” very well around the head (little or no shadow is cast by the head)

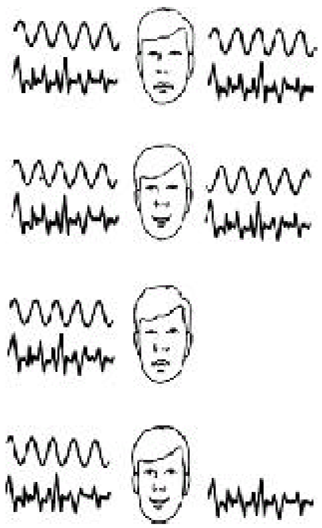
2) Phase differences: delay at one ear relative to the other ear produces a phase difference relative timing of nerve impulses at the two ears will be related to the location of the source
Intramural Time Differences
(ITDs)

High frequency sounds wavelength is short compared to the size of the head
1) Little diffraction occurs
2) Shadowing an acoustic shadow (like a beam of light there is a decrease in intensity) occurs
Interaural Intensity Differences (IIDs)

You also get an ambiguity in phase differences
1) Occurs when wavelengths are less than the size of the head sound with a wavelength 1/2 the size of the head and at the side of the head produces waveforms to the two ears that are in the opposite phase relationship (180° off)

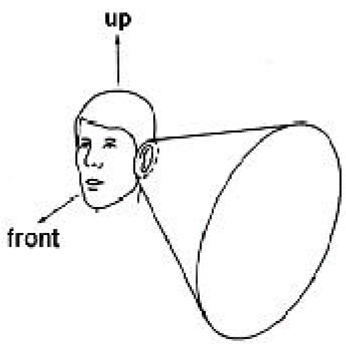
2) This is ambiguous since the waveform might be 1/2 cycle ahead or behind (more ambiguity at smaller and smaller wavelengths)

3) Resolved by head or source movements Two systems for localization "Duplex Theory" Does not necessarily hold for complex sounds only for pure tones
• Intensity (IIDs) - higher frequencies (> 1500 Hz)
• Timing (ITDs) - lower frequencies (< 1500 Hz)



The Localization of Transients

• Natural sounds consist of complex waveforms
• Onsets and offsets are critical
•when a sound changes the interaural differences in time of arrival at the ears provide unambiguous cues for localization
•works for both low and high frequency sounds
• Acuity as a function of frequency
•
wideband noises and clicks
•
Lateralization is good for these sounds lowpass filtered (<1500 Hz), but poor for these sounds highpass filtered (>1500 Hz) < 1500 Hz the phases of the decaying oscillations on the



The Cone of Confusion

Treat the head as a pair of holes separated by a spherical obstacle (ignoring the Pinnae)

If the head is kept stationary, then the interaural time difference will not be sufficient to uniquely define the position of the sound source Cone of Confusion Any sound source on this cone would give rise to the same interaural time difference

How are ambiguities resolved?

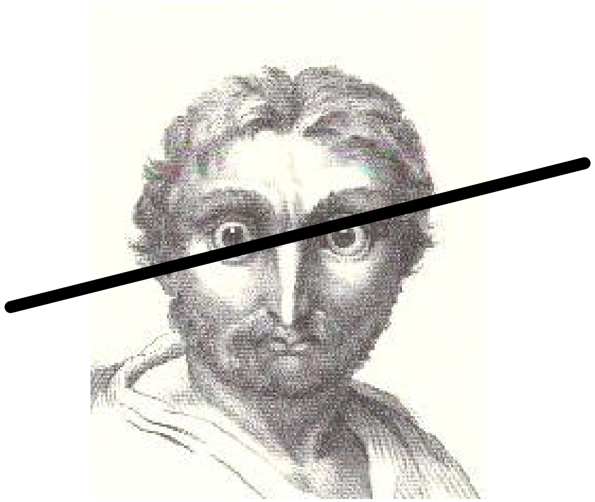
Head movements

1) If rotating our head results in a concurrent shift in the perceived position, then the source is in the horizontal plane

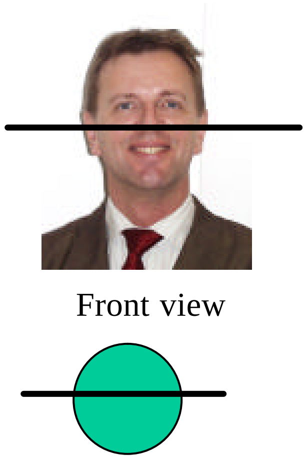
2) If rotating our head results in no change in the auditoryimage, then the source is directly above or below us

3) Intermediate shifts lead to intermediate vertical height judgments Head movement also produces changes in the spectral patterning at each ear - additional cues

Ears axis of human & owl

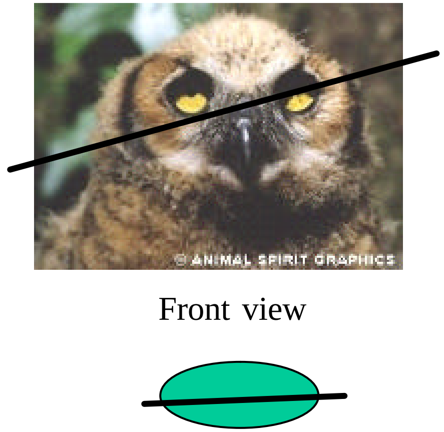


Ear angle of human & owl



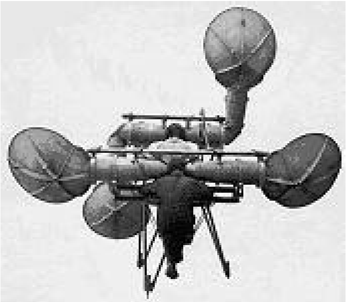
Front view

Top view (human)

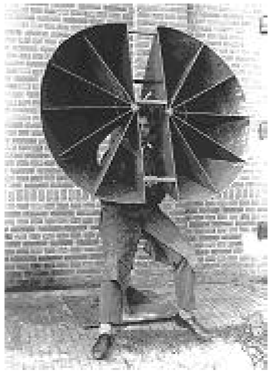


Front view

Top view (owl)





Experiments to improve sound localization

From the first world war until the 30's air acoustics played an important role in the air defense. Air vehicles carrying a weapon could not be located from the ground e.g. at night time or under cloudy conditions. As radar was still to be discovered, vision had to be supplemented by hearing using the sound of the engines.

The experimental use of listening equipment's of foreign make in the late 1920's did not satisfy the Dutch army. The nature of the complaints has not been found in writing. But one may safely suppose that the complaints were caused by the clumsiness of the equipment affecting transport, installation and accuracy of measurements. This caused loss of time which additionally was increased by the required cooperation with the other required equipment. Furthermore the acoustic properties were far from ideal due to e.g. mechanically caused noise during use of the equipment.

The study of this complex was the subject of an assignment of the Committee to the Measurements Building. A number of details and the progress of this first order are still known. Therefore the subject will be discussed to some extent to illustrate the working method of the Measurements Building. According to still existing documents a Czechoslvakian equipment of Goerz has been investigated. Because this equipment contained fundamental deficiencies it was decided to construct a new prototype. This development was subsequently compared with three different listening equipments among which a part of the Goerz equipment. Van Soest started with the simplest possible means to investigate the human capability of hearing the direction of a sound source. Remember that electronic means were either not available or primitive.

My experiments to study sound localization:

First I took two tin cans & cover my ears & try to understand the nature of sound nose creation etc.

In next step I took PVC pipes for different experiments like catching sound separately,
Creating more time lag between ears by separating the openings of pipes in opposite directions.

Next I started experimenting different lengths for better sound separation The length varies from 10 c.m. to 1 meter, & for better sound quality 30c.m. length was fine.

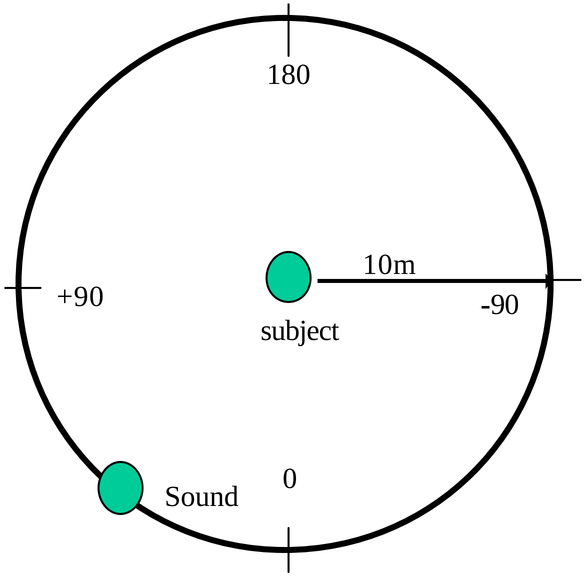
For better sound collection I attached fennel to the pipe

Experiment with 10 users

Aim: localization of sound

1) Mark a circle of 10 meters on ground
2) place the user at the center of the circle
3) Now user hold the collector pipes on his ears,
4) cover his eyes by cloth
5) I took different places in the circle & clap
6) Told him to locate me.
7) I tried this experiment with different lengths of pipe

The result I got
Long system 55% success in locating sound
Short system 70 % success



Hearing problems without helmet

- Noises of other vehicles
- diffraction of wind sound in speed
- Doppler effect with moving vehicle
  Noise pollution & related health problem

Hearing problems with helmet

- Reduces external sound
- Difficult to sense vehicle's sound & horn coming from back side
- Difficult to communicate
- Change in sound frequencies

Noise pollution

Noise is often defined simply as unwanted sound and thus is a subjective reaction to characteristics of a physical phenomenon. Measuring sound directly in terms of pressure would require a very large and awkward range of numbers. To avoid this, the decibel scale was devised. The decibel scale uses the hearing threshold of 20 micropascals as a point of reference, defined as 0 decibels (dB).Other sound pressures are then compared to the reference pressure, and the logarithm is taken to keep the numbers in a practical range. The decibel scale allows a millionfold increase in pressure to be expressed as 120 dB. Another useful aspect of the decibel scale is that changes in decibel levels correspond closely to human perception of relative loudness. Noise in the community has often been cited as being a health problem, not in terms of actual physiological damage such as hearing impairment, but in terms of inhibiting general well-being and contributing to undue stress and annoyance. When community noise interferes with human activities and contributes to stress, public annoyance with the noise source increases and the acceptability of the environment for people decreases.

Existing Noise Conditions

The primary existing noise sources are traffic on I-80 and local roads. The decibel (abbreviated dB) is the unit used to measure the intensity of a sound.

- Near total silence - 0 dB
- A whisper - 15 dB
- Normal conversation - 60 dB
- A lawnmower - 90 dB
- A car horn - 110 dB
- A rock concert or a jet engine - 120 dB
- A gunshot or firecracker - 140 dB

Eight hours of 90-dB sound can cause damage to your ears; any exposure to 140-dB sound causes immediate damage

Electronic system

Disadvantages in mechnical system

- Generation of diffraction of sound while moving is too much the frequency & intensity is directly proportional to the speed of the rider
- It amplifies background high frequency noise
- Difficult to capture low frequencies & big vehicle generates low frequency
- Long length of system creates reverberation
- It is difficult for mounting on ears
- No mechanical noise pollution filters are so effective

Due to problems in mechanical system i am trying electronic system but using same owl principle

Advantages in electronic system

- The size of microphone is too small it hardly creates diffraction of sound
- The amplification can be control very easy
- Unwanted frequencies & intensity can be control by electronic filters
- The electronic system is able to capture low frequencies too
- It is small & very compact

Disadvantage of electronic system

- It need constant electric supply.

Construction of hearing aid:

It the hair aid I used sound localizations principle used by owl owl listen detection of interaural time differences is performed by the meeting of nerve signals from each ear at the nucleus laminarus. Nerve axons carrying signals that originated in each ear enter the nucleus laminarus from opposite sides.

Accordingly I used two microphones separately, each for an ear the circuits are separate there is no connection between them, the signal process separately & gives out put to headphones mounted in the helmet

It creates a stereo sound effect because the microphone placed at different location on both the side of helmet it help to catch the sound from two different location to create 3D sound effect

Microphones are directed in opposite direction to get the sound from back as well as front. Knowing back vehicles sound is very important in traffic condition

Tests

During test I found the microphone is also picking up low frequency sound signals bumping on helmet hence now we are more able to get low frequency sound because of helmet diameter

10 users tested this hearing aid

6 users tested on motor bike & 4users tested stationary
The success rate is **94%** users are able to locate the sound source we can further improve this by adding electronics noise filters & sound amplifiers.

Power supply is the basic problem, but it can be solve by battery & solar panel mounted in helmet.