Noise, stress and annoyance

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Summary
The effects of sound on man are reviewed with emphasis on the physiological reaction mechanisms and the ultimate stress reaction. It is seen that energy related noise levels are poor predictors for the reactions in man as noise is always interpreted in the central nervous system, generating secondary and tertiary reactions that are not controlled by the brain cortex. The stimulation of these reaction pathways in acute situations lead to involuntary reflexes and feelings of fright and despair. In chronic exposure situations a give-up stage may develop with reduced corporal and mental functions. In the acoustical panorama peak level noises usually cause the most pronounced effects as they stimulate reactions of fear and flight. The practical consequences of these reaction patterns in terms of prevention are discussed.

1. Introduction

Sound is an important part of man's contact with the environment and has served as a critical means for survival in evolution. Sounds around us can arouse reactions of fear or delight, influence our nervous system and also serve as a source of enjoyment. This review will highlight some of the characteristics of sounds and the human reaction with the emphasis on our interpretation and reactions after exposure to different sounds. As the effects discussed in the following mostly refer to sounds that are generally considered as pollution by the individual, the term noise will be used although that term in reality includes an interpretation that has taken place after the stimulation of the auditory system.

2. Sounds and central nervous system reactions

Sounds stimulate the hearing nerve through the mechanical function of the middle ear. The ensuing nerve impulses go both to the brain cortex for conscious interpretation and to centres in the deep parts of the brain with further connections to the autonomous (independent) nervous system and the neuro-endocrine system. This wide dispersion of the sound stimulus carries a message of the character of the sound to different defence and adaptation systems, including muscular functions, and many of these systems are preparing the individual to escape. The secretion of different hormones induced by the reflexes generated by the sound will affect different functions of the body but will also influence emotional reactions. A hymn in the church during a funeral can make us cry; a melancholy song on the beach will fill us with happiness.

There is a large variation between individuals how these central nervous reactions are initiated and how strong they become. Some of these differences depend upon genetic factors but previous experiences of the sounds, the simultaneous presence of other environmental stimuli and the health state of the individual also play important roles. Air displays by the air force at festivities might make the ordinary citizen proud but they will evoke deep emotions and fear reactions among those who have experienced these sounds during wars and personal sufferings. Persons with fever or who are under great stress for social or work related reasons have an augmented reaction to sounds that they would normally tolerate or even appreciate.

3. Acute effects of sounds

The acute effects of sound exposure are an orienting response, a startle reflex and a defence/flight reaction. The orienting response comprises a mental and physical orientation towards the source of the noise. The startle reflex is an involuntary contraction of the muscles around the eyes, in the abdomen and the legs, designed to turn the person in a position that protects the most vulnerable parts of the body. The defence/flight reaction, finally, involves the muscles in the legs and the arms, preparing the person to flee away. All these effects become particularly pronounced when the sound is sudden and unexpected; for some sounds there is a habituation but for others not. Even among policemen who regularly train with gun shooting and are

accustomed to the sound, the muscular contractions appear, particularly around the eyes.

The reflexes described above are for the protection of the individual – alertness against the source of sound and a readiness to escape if the sound is interpreted as dangerous. The nervous system reactions also incorporate a temporary increase in blood pressure and pulse rate – sudden deaths from heart failure have been described after intense exposure to unfamiliar sounds.

The automatic focus on the source and location of the sound may interfere with an ongoing task because of over-saturation of the capacity of the central nervous system. Is has been shown that persons engaged in a demanding visual task temporarily interrupt this if they are exposed to a sudden, intensive and unknown sound. Disruption of reading or thinking when exposed to sounds in the environment is an experience common to all of us.

The character of the sound is of great importance. An illustrative example is a family that lived closed to a newly erected water tower in a rural area. The tower was placed on pillars and the bottom had a dome shaped form. Soon the population discovered that sounds emitted under the tower became grossly amplified and reverberated, making it a local tourist attraction. The farming family was thus almost continuously exposed to screams, whistles and cries from the sightseers, implying danger or cries for help which severely disrupted their normal lives.

The ability to relax and to sleep is of great importance for the normal functioning of man. The auditory system, however, continues to function and sounds can thus interfere with sleep and recreation. An unknown sound at night might, even if the sound level is very low, cause an intensive reaction of fright. Even if there is no awakening, such sounds may disturb the normal sleep rhythm and cause long term fatigue and possibly depression.

The different reactions to sounds also determine our judgement of the sounds. Unwanted or disturbing sounds are usually referred to as noise. This is a subjective classification as exemplified by music where one kind of music can be a noise to some persons and not to others. The owner of a transportation company is pleased by the sound of his trucks passing by, a sound that most of us would characterise as noise.

4. Chronic effects of sounds

A repeated exposure to sounds over longer time periods may lead to the development of a number of different effects. A common reaction is a feeling of disturbance of ongoing activities or interference with the quality of the environment. This feeling is usually referred to as “annoyance” and has to be determined using questionnaires. In these the subjects grade their annoyance in quantitative terms such as “none/a little/rather much/very much”. The subjective nature of annoyance means that there are large differences between

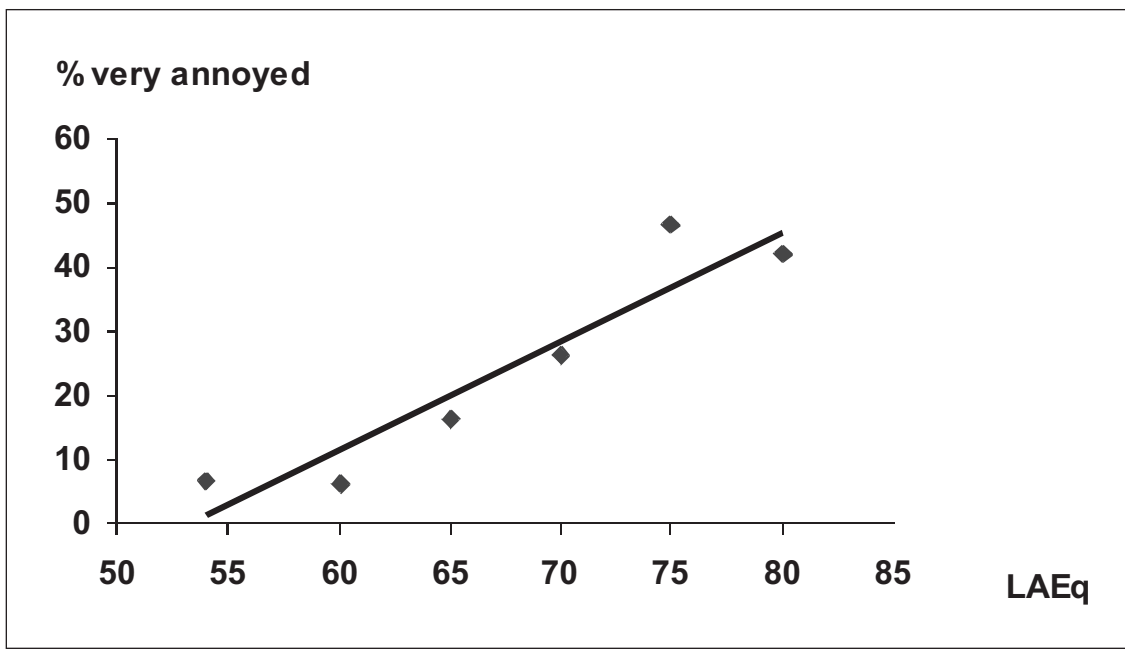

Figure 1. Relation between extent of annoyance and noise exposure from road traffic

individuals – some will be annoyed by a sound that others accept or even like. To overcome this variation, studies usually report the average annoyance in a group of persons. This measure of the proportion of the population expressing that they are "very annoyed" is related to the sound level and dose-response relationships for transportation noises have been reported in many publications. An example is given in Figure 1.

The repeated exposure to a noise over longer time periods may also cause effects on health. These can derive from the acute effects such as increased blood pressure, disturbances of hormonal secretion or from reactions in an exhausted central nervous system in terms of the defeat reaction.

A long-term exposure to unwanted or disturbing sounds might lead to a reaction of exhaustion or defeat. This is a stage when the individual gives up mentally – there is no way to influence the source of the sound and there is no way to escape from it. The ensuing effects are decreased muscular movements, a decreased secretion of hormones, possibly followed by a decreased function of the immune system and a mood change into apathy and decreased social contacts. Such reactions have been observed in populations living near airports or close to heavily trafficked roads.

Regarding the transformation of acute effects into persistent or chronic ones, the effect on blood pressure is of particular interest. A number of studies from industry have shown that a continuous exposure to high levels of noise at the workplace may cause an increased blood pressure over time. From a physiological point of view this reaction is easy to understand and it is likely that it exists also among persons exposed to noise in the general environment although only a few studies have been made. An increased blood pressure depends on many other factors such as diet, smoking and heredity and the relation to and relative importance of noise exposure is thus difficult to ascertain.

5. Prevention and control

Sounds are an unavoidable part of the modern society and a large segment of the population is exposed to high levels of noise, particularly from the transportation apparatus. From a public health point of view there is a need for improved control to decrease the risk for annoyance and health effects. A control system is highly dependent on the methods to determine the exposure which will be used to set exposure limits.

The exposure to sound is measured using equipment that records the acoustical energy (sound pressure). The sound pressure is transformed into a logarithmic scale that ranges from the acoustical energy at the hearing threshold to the levels which cause damage to the ear. The units in this arbitrary scale are Bels, divided into tenths (deciBel). Humans are less sensitive to the lower frequencies of sounds so these are adjusted by inserting a filter (the A-filter) to make the measured value better adapted to the human reaction pattern. The ensuing unit is the dBA value. At very low frequencies, however, the sensitivity to the sound increases and the dBA unit is no longer a useful measure of exposure.

When repeated sounds with different intensities such as road traffic noise are measured, the principle commonly used is to determine an average sound intensity over a specific time period eg 24 hours. This is against the physiological principles of sound reception where the highest noise level and the noisiest event determine the reaction. Several studies have studied the importance of peak levels and found good relationships to the extent of annoyance as illustrated in figure 2.

The implication of the peak level is important for understanding the results from studies on the effects of sounds in the environment. In some investigations the erection of barriers along heavily trafficked roads has resulted in an increased extent of annoyance instead of the expected improvement in the environmental conditions. While barriers can be very efficient, in this case the construction shielded the populations from the low level sound from the traffic but did not reduce the peak levels enough. With the barrier the acoustical environment thus transformed from a steady murmur of sound to periods of relative silence with sudden peaks of sound that were experienced as more annoying. In a study on school children in noisy areas it was found that the reading comprehension was decreased at higher levels of aircraft noise but episodic memory was increased after exposure to road traffic noise. As road traffic noise is a more or less continuous noise, the improvement in episodic memory could reflect a more intense attention on the test, shielding the noise in the environment, whereas aircraft noise with distinctive and irregular noise peaks would be more difficult to shield.

From a public health point of view, control of environmental sound exposure with the goal to decrease sleep disturbances and severe annoyance has a high priority. The goals can

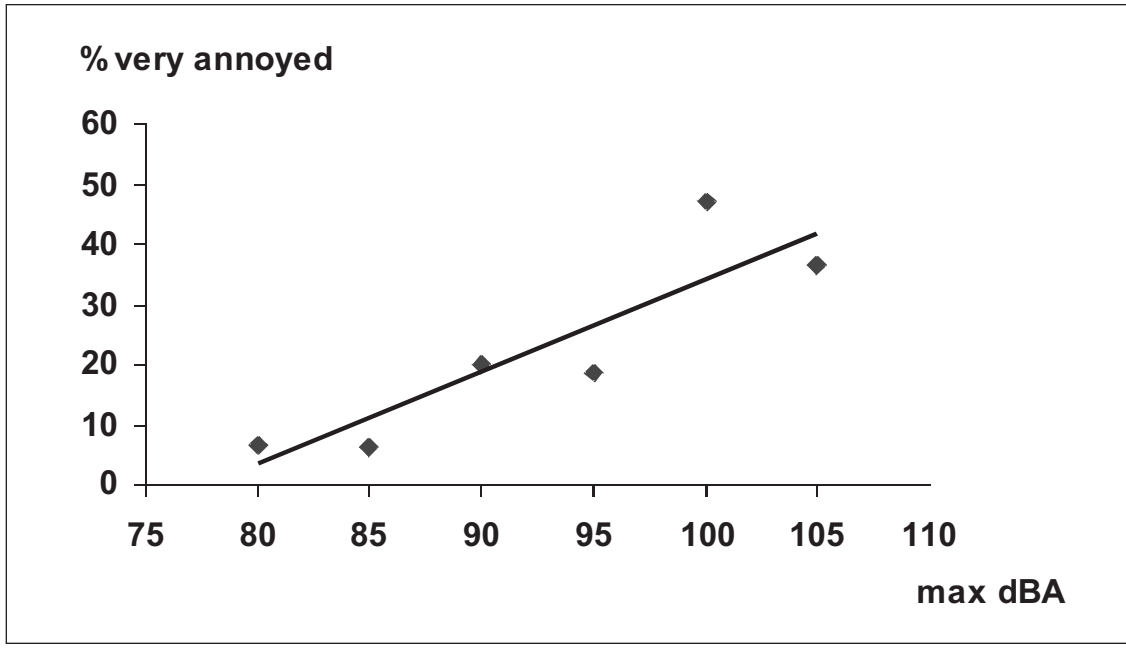

Figure 2. Relation between extent of annoyance and maximum noise level exposure from road traffic

only be achieved in long term programs where town planning, banning of vehicles with high noise levels and shielding of noise sources are the main tools. Restriction from building in areas where noise levels are high is another important preventive measure. Individual actions are also important to decrease the extent of annoyance due to noise. Lower levels on radios and TV-sets, lower voices when talking in mobile phones and less aggressive driving habits are examples of such actions.

6. Soundscapes

When dealing with sounds in the environment the emphasis has by tradition been on its negative effects. In a larger perspective it is necessary to consider the positive effects as well. Sound is an agent where the dose-response relationship is of a hormesis nature as illustrated in Figure 3.

The concept of the hormesis dose-response is that a small amount of the agent is beneficial and that negative effects develop at higher dose levels. This relationship is valid for a number of agents such as vitamin D, various stimuli such as alcohol and even substances generally considered as very toxic such as arsenic. It is very applicable to sounds in the environment. Staying for a longer time period in an environment where sounds are completely absent causes a feeling of isolation, insecurity and in some circumstances pathological reactions from the brain and the nervous system. Man requires a background of sounds for normal functioning and also for satisfaction. Examples of efforts to improve soundscapes are background music in public meeting places, the sound of birds singing in toilette facilities and modulation of sound characteristics at the workplace. So far the knowledge of such optimal soundscapes and criteria for their application has not been extensively studied but merits more attention in parallel to efforts to control unwanted sounds in the environment.

So in conclusion, sounds in the environment represent a multifaceted problem in terms of exposure, reactions and control. There is a need for a multidisciplinary approach to improve the present noisy environment and it is important that all such actions are be based on an understanding of the physiological reactions that occur in man after exposure to sounds.

Further reading

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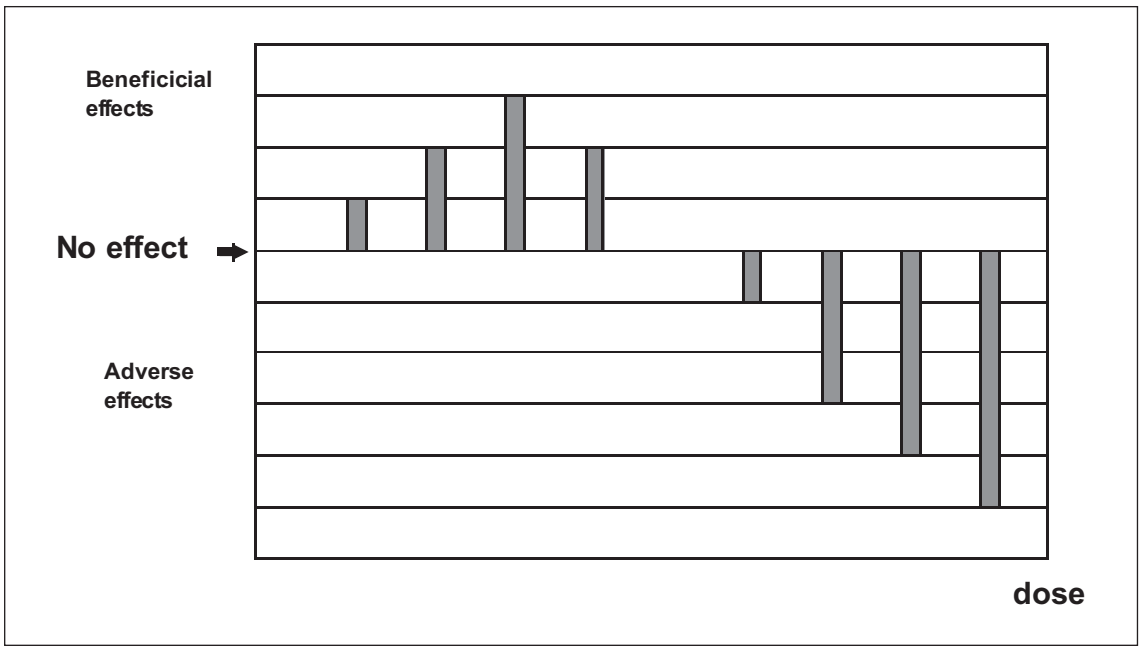

Figure 3. Hormesis dose-response relationship

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