Listener fatigue

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Listener fatigue (also known as listening fatigue) is a phenomenon that occurs after prolonged exposure to an auditory stimulus. Symptoms include tiredness, discomfort, pain, and loss of sensitivity. Listener fatigue is not a clinically recognized state, but is a term used by many professionals. The cause for listener fatigue is still not yet fully understood. It is thought to be an extension of the quantifiable psychological perception of sound. Common groups at risk of becoming victim to this phenomenon include avid listeners of music and others who listen or work with loud noise on a constant basis, such as musicians, construction workers and military personnel.

Contents

Causes

The exact causes of listener fatigue and the associated pathways and mechanisms are still being studied. Some of the popular theories include:

Introduction of artifacts in audio material

Musicality, especially on the radio, contains musical aspects (timbre, emotional impact, melody), and artifacts that arise from non-musical aspects (soundstaging, dynamic range compression sonic balance). The introduction of these sonic artifacts affects the balance between these musical and non-musical aspects. When the volume of music is higher, these artifacts become more apparent, and because they are uncomfortable for the ear, cause listeners to "tune out" and lose focus or become tired. These listeners may then unconsciously avoid that type of music, or the radio station they may have heard it on.

Data-reduction systems

Digital equipment can generate distortions in audio signals that affect the way humans process sound. Many digital audio signals use the process of data-reduction to compress the amount of data needed to represent the signal. Such systems seek to optimize utility and achieve more with less. This sometimes leads to drop on the quality of the sound and creates an illusion that there is something missing from the audio. It has been observed that there is an intrinsic need, a compulsion, for greater loudness. Data-reduction systems may be a factor in this. This quest for greater loudness and pushing levels to the maximum may factor into listener fatigue.

Sensory overload

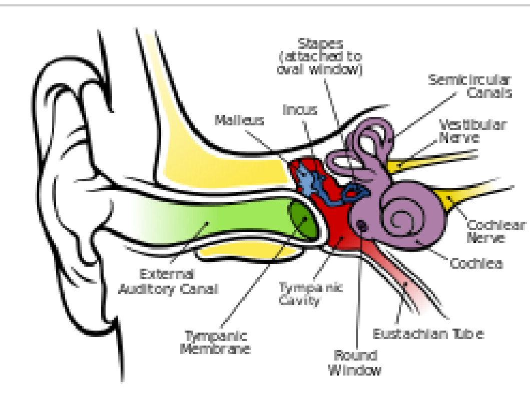
When exposed to a multitude of sounds from several different sources, sensory overload may occur. This overstimulation can result in general fatigue and loss of sensation in the ear. The associated mechanisms are explained in further detail down below. Sensory overload usually occurs with environmental stimuli[1] and not noise induced by listening to music.

Physiology

As with any type of hearing-related disorder, the related physiology is within the ear and central auditory system. With regards to listening fatigue, the relevant mechanical and biochemical mechanisms primarily deal with inner ear and cochlea.

Associated anatomy

The stereocilia (hair cells) of the inner ear can become subjected to bending from loud noises. Because they are not regeneratable in humans, any major damage or loss of these hair cells leads to permanent hearing impairment and other hearing-related diseases.[2] Outer hair cells serve as acoustic amplifiers for stimulation of the inner hair cells. Outer hair cells respond primarily to low-intensity sounds.[3]



Human Ear Anatomy

Relevant mechanisms

Vibration

Excessive vibrations that occur in the inner ear can result in structural damage that will affect hearing. These vibrations result in an increase in the metabolic demands of the auditory system. During exposure to sound, metabolic energy is needed to maintain the relevant electrochemical gradients used in the transduction of sounds. The extra demands on the metabolic activity of the system can result in damage that can propagate throughout the ear.

Temporary threshold shifts

When exposed to noise, the human ear's sensitivity to sound is decreased, corresponding to an increase in the threshold of hearing. This shift is usually temporary but may become permanent. A natural physiological reaction to these threshold shifts is vasoconstriction, which will reduce the amount of blood reaching the hair cells of the organ of Corti in the cochlea. With the resultant oxygen tension and diminished blood supply reaching the outer hair cells, their response to sound levels is lessened when exposed to loud sounds, rendering them less effective and putting more stress on the inner hair cells.[4] This can lead to fatigue and temporary hearing loss if the outer hair cells do not get the opportunity to recover through periods of silence.[5] If these cells do not get this chance to recover, they are vulnerable to death.

Temporary threshold shifts can result in different types of fatigue.

Short-term fatigue

Recovery from temporary threshold shifts take a matter of minutes and shifts are essentially independent of the length of exposure to the sounds.[6] Also, shifts are maximal during and at frequencies of exposure.

Long-term fatigue

Long-term fatigue is defined as full recovery from temporary threshold shifts taking at least several minutes to occur. Recovery can take up to several days. Threshold shifts that result in long-term fatigue are dependent on level of sound and length of exposure.[7]

Potential risk factors

Temperature and heat exposure

The temperature and heat levels of the body are directly correlated with the temporary threshold shifts of the ear.[8] When the levels of blood temperature increase, these threshold shifts increase as well. The transduction of sounds requires an oxygen supply that will be readily depleted due to the prolonged threshold shifts.

Physical activity

When combining exercise with exposure to loud noises, humans have been observed to experience a long temporary threshold shift as well.[9] Physical activity also results in an increase in metabolic activity, which has already been increased as a result of the vibrations of loud sounds. This factor is particularly interesting due to the fact that a large population of people listen to music while exercising.

Experimental studies

Human

A study conducted in Japan reports fatigue sensation shown in subjects who listened to a metronome for six minutes.[10] A metronome was used as part of a technique to test the effects of musical and rhythmic stimulation in physical rehabilitation programs. After a series of tests involving physical therapy exercises while songs with different tempos played, subjects were asked to evaluate their own levels of fatigue. The results showed no statistically significant difference between fatigue levels with and without listening to various music. However, many patients that did respond with fatigue after music recorded the highest level of fatigue possible on the evaluation scale. This experiment paves the way for further study in distinction of the perception of listening fatigue between individuals.

Lin et al., conducted an experiment in Taiwan that tested the effect of generation of reactive oxygen species on temporary threshold shift and noise-induced hearing loss.[11] [12] Subjects were employees at a steel manufacturing company and each one was assessed for personal noise exposure during work shifts. Statistical analysis yielded a correlation between exposure of higher-frequency sounds to lower temporary threshold shifts and greater levels of tiredness and hearing loss.

Animal

A multitude of animal studies have been conducted to help understand hearing loss and fatigue. However, it is difficult to quantify levels of fatigue in animals as opposed to humans. In the experiment done by Ishii et al., subjects were asked to "rate" their levels of fatigue. Without an analogue for animals, it is difficult to measure fatigue in a useful way. However, techniques used by Ishii et al., are not perfect, as the recorded fatigue levels were self-perceived and prone to bias. Studies have been done on a variety of animal species, including guinea pigs[13] and dolphins.,[14] rats,[15] fish,[16] and chinchillas.[17]

However, these studies do, in their conclusions, associate levels of fatigue with prolonged exposure to high levels of sound.

Treatment and prevention

At first glance, it would seem that reducing the noise and volume would be sufficient to reduce or prevent listening fatigue altogether. However, it is evident that the issue is at least partly physiological in nature. In cases of sensory overload not related to purposeful listening of hazardous noises, common ear protection such as earplugs and earmuffs can help alleviate the issue. Discomfort and social embarrassment are some of the main concerns when using tools such as this.

Many musicians and audio engineers and scientists that work in industry are exploring ways to mitigate the effects of listening fatigue.

Audio technology

Synthetic membrane earphone

Modern technology seeks to minimize or prevent listener fatigue entirely. Blockage of the ear canal, common in headphones, is thought to be a main contributing factor in listener fatigue. When cut off from outside sound with the earphone, an oscillating pressure chamber is created in the eardrum. This effectively provides a boost in sound pressure levels. When this boost occurs, an acoustic reflex mechanism triggers and acts as a defense against this sounds. This mechanism seeks to reduce the sound energy in the ear by dampening its transfer from eardrum to cochlea. It has been seen that this process can reduce sound waves by up to 50 decibels. Although this mechanism can decrease the sound energy, it does not negate the oscillatory pressure. Due to this defense mechanism, sounds do not seem as loud as they are, and ironically, listeners will want to increase the volume. As a result, the reflex mechanism is activated again, and the cycle continues on. This ultimately leads to fatigue.

Researchers at Asius Technologies have designed a synthetic membrane to take the brunt of the pounding in earphones away from the ear drum by disrupting the pressure waves.[18] This new membrane technology can be retrofitted and applied to existing headphones. A film of medical-grade polymer (ePTFE) is stretched over a hole, essentially acting as a membrane to help absorb pressure buildup in the ear drum.[19]

Another alternative developed by Asius is a seal called the Ambrose Diaphonic Ear Lens (ADEL). The seal attaches to headphones or hearing aids and is inflated like a balloon and acts as an additional makeshift eardrum. The earpieces are able to utilize the pressure from the headphone itself to inflate itself. The inflated earpiece emulates the feeling in the ear of slight pressure relief, akin to riding in an elevator. This seal blocks outside noise while also absorbing some sound pressure and redirects away from the more sensitive regions of the ear. The inflation of the seal provides it with its utility as well as helping it stay snugly within the ear canal.

These technologies are still in development and are soon scheduled for commercial sale in the near future (2014) in conjunction with Apple's iPhone device.

See also

- Auditory fatigue

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External links

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