# Preventing Hearing Loss

**By Staff Technical Writer**

Jan Voetmann, chair of the tutorial *Hearing Loss—Causes, Preventative Measures, and Effects on Sound Professionals and the Audience*, presented at the AES 120th Convention in Paris in May, introduced the event by explaining that the official limit for occupational noise is also used for evaluating the effects of listening to music. A sound level of 85 dBA for 8 hours of the day leads to an equivalent of around 100 dBA for a quarter of an hour, which is easily reached in leisure time by many people either in the home and yard, in clubs and discos, and at work. (For further information about equivalent noise levels see *Noise Exposure* on next page.) Short intervals with very high peak sound levels can still lie within the noise dose guidelines, even though they can be harmful. Voetmann said that it is difficult to find young people with normal hearing levels, based on informal data gathered at a university in Munich that showed common hearing losses consistent with listening to music at high levels. Gunshots, as experienced by hunters or soldiers, can reach 160 dB for a short period, and woodwind players in an orchestra can experience 128 dBC. If you go to a rock concert and stand in front of the loudspeakers you can experience 129 dBC. For an online sound demo, go to www.hei.org/education/soundpartners/guidelines.htm, where you can adjust a noise meter to hear the different sounds and sound intensities of everyday objects, courtesy the U.S. National Institute of Occupational Safety and Health.

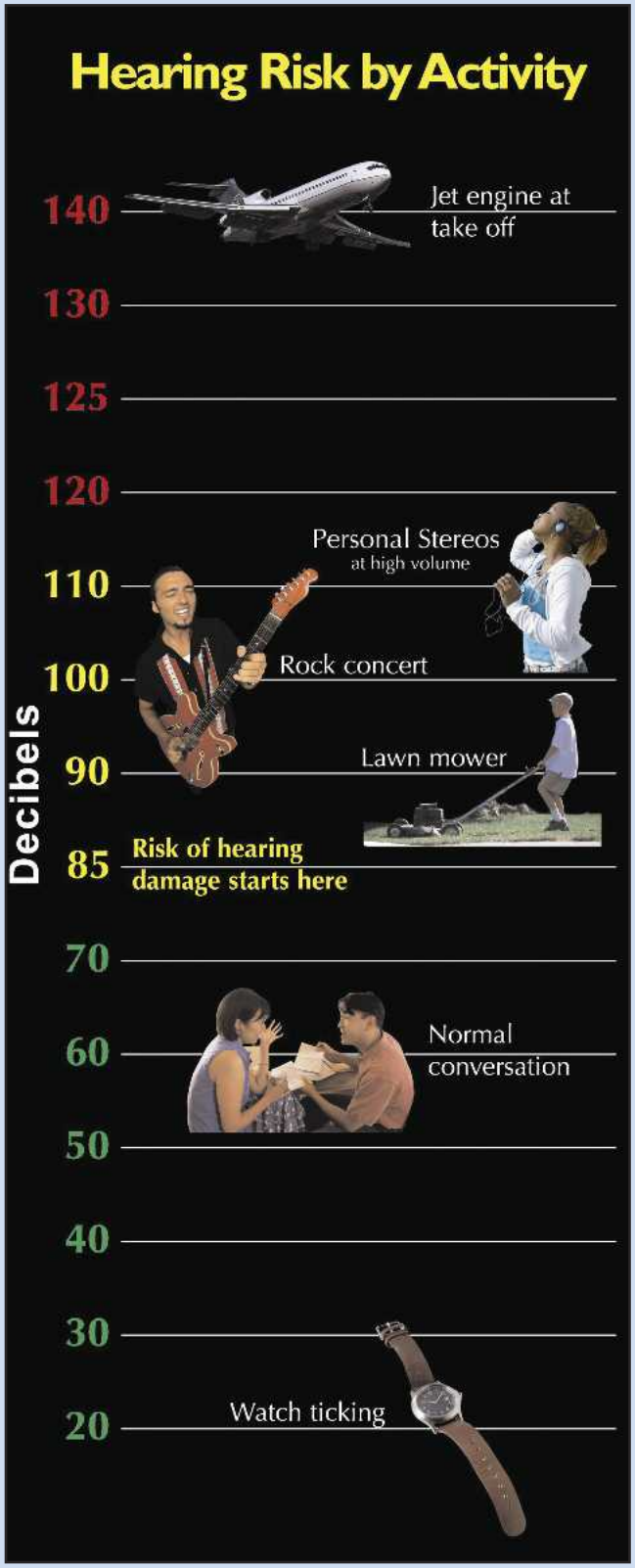


Fig. 1. The intensity of common sounds measured in decibels (Figs. 1–3 courtesy House Ear Institute)

## THE RISK FROM PERSONAL STEREO DEVICES

Dorte Hammershoi of Aalborg University in Denmark dealt specifically with hearing damage resulting from listening to personal stereo devices. The time averaging that is used in standard noise-dose measurements is supposed to integrate the different levels experienced over the period concerned, and it is weighted approximately according to equal loudness filtering. However, equal loudness is not necessarily related directly to the potential for hearing damage. Even so, the standard exposure guidelines are based on many years of experience of what causes hearing damage and are a good place to start.

When listening on headphones these standards are more difficult to apply because noise dose standards are based on external soundfield measurements rather than measurements of levels inside the ear. The head-related transfer function (HRTF) can be used to convert between a free propagating external soundfield and that in the ear. In the mid-frequency range a difference of some 18 dB can be noticed, for example. If you measure at the ear drum you get a different result from a measurement made at the entrance to the ear canal, and similarly if a blocked ear canal measurement is used you also get a different result. So it is important to use the correct HRTF. An ISO standard (ISO 11904) deals with this issue in some detail. The gain ranges of many personal stereo ➥

### NOISE EXPOSURE

Noise exposure is usually measured in the form of an integrated measurement (LEQ) taken over a fixed period of time. An increase of 3 dB in the noise level corresponds to a halving of the time taken to reach a certain noise dose, so, for example, 80 dBA for 8 hours is deemed equivalent to 83 dBA for 4 hours, 86 dBA for 2 hours, and so on. However, there is a debate in the community surrounding possible differences between occupational noise and music. Some claim that listening to music does not have the same effects on hearing as industrial noise.

In Europe the first action level for noise at work used to be 85 dBA (over an 8 hour day), as it still is in the U.S., but it was recently lowered to 80 dBA. At this level certain precautions should be taken, warning notices displayed, and hearing protection made available. This new standard has also been adopted throughout most of Canada. The second action level is now 85 dBA, when hearing protection must be worn and corrective action taken to reduce the noise level. Workers also have a right to hearing checks where assessments indicate a possibility of hearing damage. The new regulations have the additional measure of a maximum exposure of 87 dBA for any worker, factoring in the effect of hearing protection. Where noise exposure varies widely over the working week, a weekly average may be taken. There is also now a first action level for peak sound levels, which is 135 dBC, with the second action level at 140 dBC.

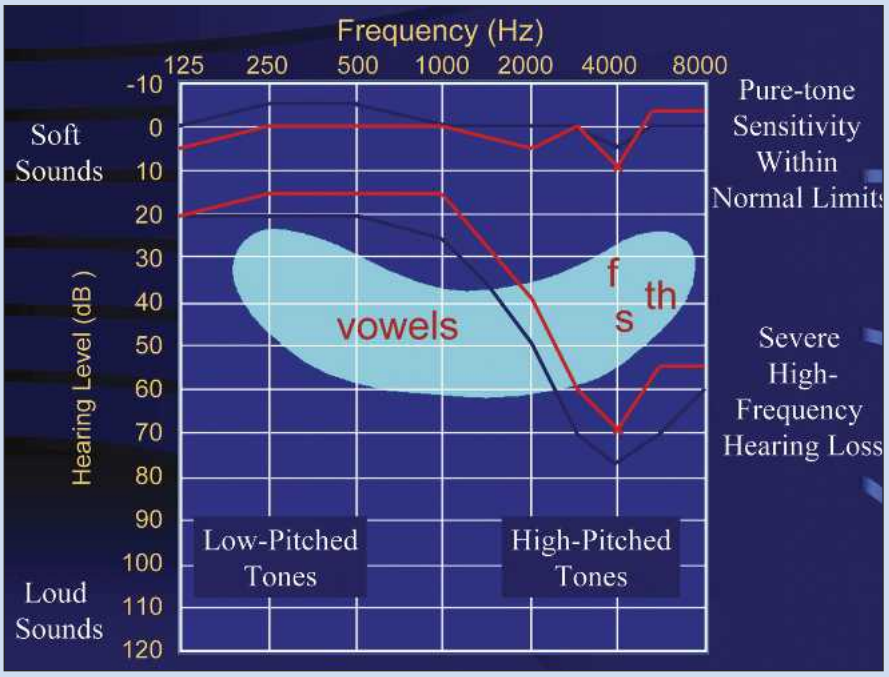


Fig. 2. People with sensori-neural (noise-induced) hearing loss have difficulty hearing vowels and consonant sounds in the light-blue, banana-shape area of the graph.

systems make it possible to exceed the recommended daily limits for sound exposure by quite a large amount. The high sound levels that result in "secondhand" sound exposure, what we hear blasting from the earbuds of our fellow passengers on the metro or elevator, may not endanger our own hearing, but it certainly can't be good for those primary listeners.

Of the few studies that have measured the typical listening levels that people use with such devices, one early survey that evaluated 750 listeners using personal cassette players concluded that an equivalent level of 90 dBA was exceeded by about 5 percent of that population, which put them at risk of hearing damage. About 20 percent of those listeners reported symptoms of tinnitus, and they were likely to have exceeded the 85-dBA limit. A later study from 1996 concluded that the exposure in 50 percent of the subjects listening to personal stereos exceeded 85 dB. If the background noise level is higher than about 72 dB, the evidence showed that people tend to turn up the level beyond the safe limit. Hammershoi's own experience with young students suggests substantial hearing loss in a number of cases. Bozena Kostek, from the audience, confirmed a similar experience with young students at her university, and even in younger people, who displayed a hearing notch at 6 kHz.

One of the effects of such damage is the reduction in level of the otoacoustic emissions (for more information see *Otoacoustic Emissions*). In a healthy ear this echo is relatively strong, and there is some evidence of a decline as age increases. A prediction made by an Australian research team suggests that, whereas the natural decline in inner ear health would normally lead to a likelihood of someone needing a hearing aid by the age of 75, if the current levels of sound exposure of young listeners is extrapolated using the Australian data, those young people could need hearing aids by the age of 30. In the study those exposed to industrial noise did not show the effects of hearing damage until about the age of 29, whereas with personal stereo exposure such effects were noticed earlier.

When there is poor coupling to the ear, as there is with many earphones that do not provide a good seal to the ear canal, there is a substantial loss of low frequencies, which makes listeners think that the volume is not high enough. The tendency, then, is to turn

### OTOACOUSTIC EMISSIONS

In addition to receiving sounds, the ear also emits them (but very quietly). These so-called otoacoustic emissions (OAEs) are understood to be the result of the expansion and contraction of the outer hair cells in the cochlea. Some of these emissions are spontaneous in that they occur without any external auditory stimulation, whereas others occur in response to external sounds. These can be transient or sustained. They are used quite commonly in the diagnosis of inner ear health, as only weak OAEs are generated from ears in a bad state of health.

up the volume, thereby boosting the middle range of frequencies that causes the most damage. The music that is listened to on such devices often has a sustained high energy level, and the user group is typically quite young and unmonitored. A further problem is that the recovery time allowed for the hearing mechanism is not always long enough to avoid hearing damage. Because personal stereos are used regularly without much in the way of breaks, the opportunity for harm to occur is greater than it would be if the breaks between listening sessions were longer.

## LIVING WITH TINNITUS

Anne-Mette Mohr of the Interdisciplinary Health Clinic in Copenhagen, a psychologist who has worked with tinnitus (for more information see *Tinnitus*) for some 15 years, introduced ways of dealing with this affliction. Most of us, she said, will experience some form of tinnitus in our lives, but probably only occasionally. Seventy percent of us have experienced tinnitus for periods of at least five minutes. Most people who have it actually cope very well, while one percent of the population becomes seriously disabled by it.

The application of a low-level noise source is one method for treating tinnitus, but Mohr feels that the success of this method is probably more a result of myth than anything else. It has, however, been known to help some people. Many people simply learn to live with the condition, a process that can take from 18 months to 2 years. However, some form of counselling has been found to be particularly important to help sufferers adjust to the affliction. The best tools for those who are treating patients with tinnitus seem to be understanding what it is like to have the condition and properly trying to appreciate the root of the problem. Unfortunately, very few hearing therapists actually listen to what sufferers say about their experience. When therapists try to listen and understand, the evidence suggests that the care they give is much more effective.

Psychological factors play a large part in the progression of tinnitus, and misbeliefs about the condition are rife. For example, the misbelief that a sufferer won't be able to listen to music any longer is very unhelpful. The brain needs sound, and tinnitus sufferers should not isolate themselves from it. However, care should be taken to protect the hearing of tinnitus sufferers from loud music environments. Trauma and grief are particularly significant triggers for the condition and can make it worse if it already exists. Similarly, it is well known that depression is linked strongly to tinnitus, so much so that it has recently been suggested that tinnitus should be one of the diagnostic indicators for depression. Stress awareness and coping techniques for stress and anxiety are also particularly important because people with tinnitus are often found also to be highly stressed or anxious people. Relaxation practice, physical activity, and positive role models can be useful for treating people suffering from anxiety and stress.

It may be that it is not possible to completely cure tinnitus. There is still no conclusive explanation for its cause. Conventional science has tried for many years to come up with appropriate therapies, some of which have been strongly criticized in recent years. Mohr concluded that there is, in fact, a great deal of hope for tinnitus sufferers since it can be effectively treated.

### TINNITUS

Tinnitus is an involuntary perception of sound originating somewhere in the head. This may involve tones and other noises. It is sometimes linked with another complaint known as hyperacusis, in which the sufferer is particularly sensitive to sounds in the environment. The sounds may appear in one or both ears or somewhere in the middle of the head, or they may be hard to localize. It is often related to hearing loss and is more common in older people who suffer from age-related hearing loss. While there are many possible explanations of its causes, one says that it is result of abnormal activity in the neural pathways that gives rise to the perception of sound in the auditory cortex. Especially in quiet conditions or when there is hearing damage, when the auditory nerve does not have enough normal activity, one explanation suggests that the hearing mechanism generates its own involuntary output. Hearing injuries that may have involved exposure to sudden loud sounds can give rise to tinnitus. Otosclerosis, abnormal bone growth of the middle ear such as suffered by Beethoven, can give rise to tinnitus, although today otosclerosis can be corrected with surgery. Furthermore, there are middle-ear diseases and tumors that can damage the hearing mechanism in such a way that the person can be left with a form of tinnitus. High doses of some drugs, anemia, and high blood pressure have also been suggested as causes of tinnitus.

Treatments such as the herbal remedy ginkgo biloba have been marketed as possible cures, but controlled studies have shown these to be no more effective than a placebo. Current thinking on possible treatment seems to center more on the development of a positive attitude, relaxation, and other forms of psychological therapy.

## SAFE AND FUN CLUBBING

Kim Kahari of the National Institute for Working Life in Gothenburg, Sweden started a project in 2003 because of a meeting with an angry event organizer who had been fined for excessive sound levels in his rock club. She set up meetings between the various parties, who previously had been unable to find any common ground, including the musicians' union, sound technicians, university staff, event organizers, and health professionals. Her project was designed to create a healthy live-music environment with high-quality sound at reduced levels without reducing the audience's enjoyment of the live event. Kahari and her colleagues also wanted to validate the sound-level measurement method used in Sweden at the time. Typically, health and safety officials would measure only five minutes of ➥

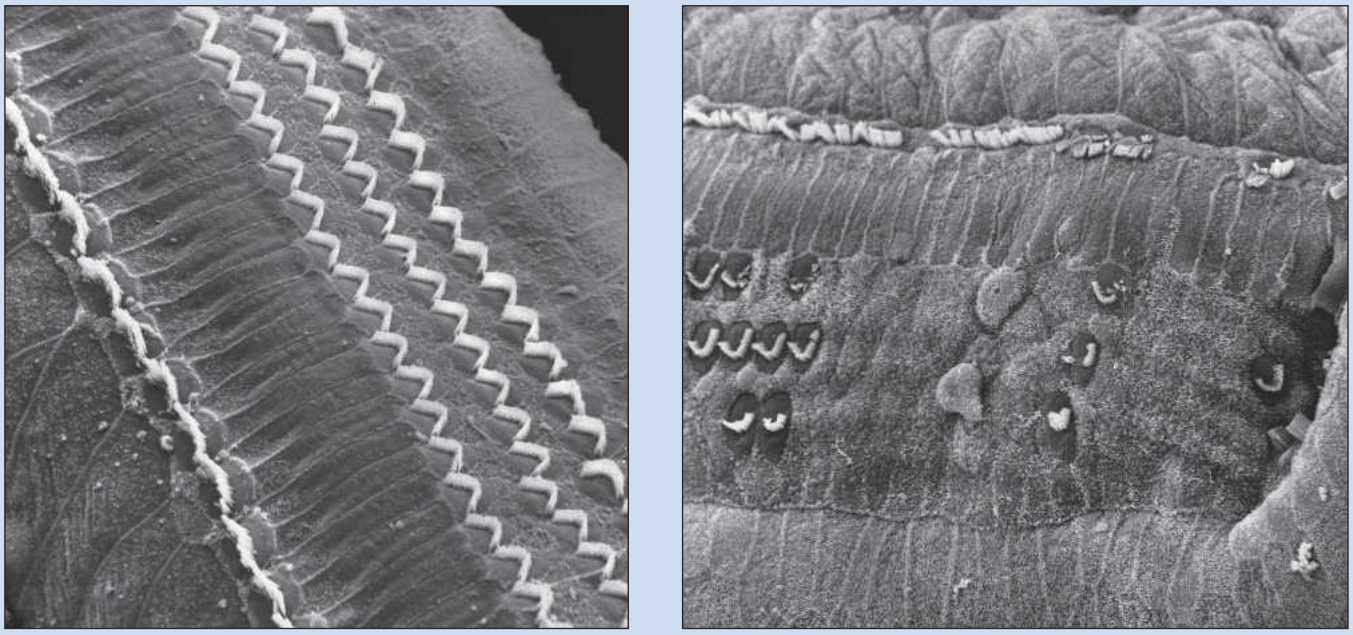

Fig. 3. The photo on the left is a magnified microscope image of undamaged hair cells in the inner ear. The photo on the right shows hair cells that have been permanently damaged.

a concert, often at the loudest point in the event, which gave a misleading impression of the loudness throughout the event.

The researchers found that the stages at such events were often rather small and crowded, with loudspeakers facing in the wrong direction and yet close to the musicians. The direct sound levels presented to the audience close to the stage were very high and the ceilings were typically very low and reflective. Walls were hard, leading to very high reflected sound levels. Their planned intervention in a trial venue involved treating the floor and walls to make them more absorbent and raising the loudspeakers above ear height. This intervention took 3 dB off the level of the drum kit, and an 80-cm screen around the drum kit reduced the level still further. The direct sound from the stage was reduced by half by the various methods involved. The bar was moved off the event floor so that the bar staff was not exposed to such high levels of sound. However, Kahari also pointed out that no amount of absorption and screening will compensate for a poorly educated sound technician who does not know what he's doing. Education is therefore particularly important. The club's sound technicians were given two days of training, which was only the beginning of the educational process.

When people at the club were questioned, 40 percent complained of existing hearing disorders and many of them said they wore ear plugs during the performances. Over 50 percent of the musicians were experiencing some form of tinnitus, and most of them wore ear plugs during performances. After the intervention by Kahari and her colleagues, the quality of sound experienced by the clubbers rose dramatically: 96 percent said that the sound quality was good at the venue, up from 45 percent who had said it was good before the intervention.

Further work is required to understand better when and how to measure sound levels at live events, and it seems clear that sound levels have to be logged so that they can be studied for legislative and research purposes.

## ANY QUESTIONS?

An audience member at the tutorial asked about the effects of different frequency ranges on hearing damage. Hammershoi explained that research suggests that low frequencies have little effect on temporary hearing threshold shift, middle frequencies have more, but high frequencies have an even greater effect. This implies that the commonly applied A-weighting filter is not necessarily appropriate as a means of measuring high musical sound levels for risk purposes. The C- and D-weighting curves are flatter at low frequencies, but still not particularly appropriate (the D curve has a middle-frequency peak). Annoyance does not necessarily correlate to risk. People tend to be more annoyed by low frequencies but more at risk from high frequencies, so different filters are probably required to measure sound for these different purposes.

## FOR MORE INFORMATION

**Internet-based hearing evaluation**: www.telewelfare.com/

**ISO 11904**:
www.iso.org/iso/en/CatalogueDetailPage.CatalogueDetail?CSNUMBER=33944

**Personal stereos and sound exposure (Canada)**:
www.hc-sc.gc.ca/iyh-vsv/life-vie/stereo-baladeur_e.html

**Tinnitus**: www.tinnitus.org.uk

**House Ear Institute**: www.hei.org


Fig. 4. Headphones and electronic calibrator used by listeners to set the gain of the computer sound card used for an Internet-based hearing assessment.

The idea of "one size fits all" does not seem to be very helpful here.

Voetmann added that the measurement of equivalent sound level is not necessarily the best way of evaluating music listening levels, because short peaks can have an important effect on hearing damage. Choosing the right weighting curve for integrated equivalent levels is not the only problem to be solved, he suggested. Some means is also required for evaluating absolute peak levels. The 85-dBA limit averaged over an 8-hour day, used in Europe, is only based on a statistical likelihood of hearing damage. (New European regulations address this point to some extent, see *Noise Exposure* on page 1110.) Still, some people will have their hearing damaged at lower levels than this, as there is a small but important fraction of the population that has more sensitive hearing than normal and whose hearing is more easily damaged. Some members of the audience also commented on the situation of people who work wearing headphones all day, such as call-center workers. These workers have been found to often increase the volume in their headphones, eventually reaching unsafe listening levels during their shift. Headsets with built-in limiters could be one possible solution to this problem.

## INTERNET-BASED HEARING ASSESSMENT

Prior to this tutorial at the AES 120th Convention, Andrzej Czyzewski of the Technical University of Gdansk presented a paper at the 119th Convention in New York that describes an Internet-based system for the automatic testing of hearing impairments. This system enables the mass screening of large numbers of people using a relatively simple interface and a pair of calibrated headphones. The process involves speech audiometry rather than tone auditometry. Whereas the latter is only capable of detecting the pure tone "conduction" threshold of the peripheral auditory system, speech audiometry also tests higher level parts of the hearing process associated with recognition.

The system uses a "speech-in-noise" approach whereby speech is presented at the same time as a masking noise, which makes detection of the speech syllables more difficult but also reduces the influence of the background noise in the environment, as it sets an artificial background noise that is usually higher than that of the surroundings. Typically this is around 60 dBA or higher. A closed-set test is employed, which involves a fixed set of words, and the listener is required to select the identified one from a set of possibilities. Although the audiometer at the server end of the system requires careful calibration using an artificial ear, the user end requires a relatively simple electronic calibrator to set the gain of the sound card in the computer for the headphones to be used (see Fig. 4). This Internet-based system and a further resource relating to tinnitus can be found at www.telewelfare.com/.