Music is noise

BY MARSHALL CHASIN

Marshall Chasin recaps what we know acoustically about music and noise, and discusses the potentially damaging levels of music, how temporary threshold shift (TTS) is not necessarily temporary and gives us some considerations for protective devices for musicians.

Most of what is known about the effects of music on hearing loss derives from six studies from the five year period between 1968 and 1973. These were large scale studies performed on industrial workers and these were later used to develop the policies for a number of national and international regulations, such as that of the Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH) and later contributed to the ISO 1990 Standard R-1999 model. The ISO model is considered accurate enough for use by regulators and administrators to make policy suggestions for workers but group results should not be used when an individual is considered [1]. Table 1 shows the predicted permanent hearing loss for several levels of noise exposure for a number of studies.

Exchange rates

In 1966 the Committee on Hearing and Bioacoustics (CHABA) attempted to develop a model that would relate exposure level to duration of exposure in an attempt to develop damage risk contours (DRC). For example, can we relate an exposure of 85 dBA for 20 hours a week to the potential risk for someone who is exposed to 90 dBA for 18 hours a week? Such a relationship is called an "exchange rate" or "trading relationship".

The 3 dB exchange rate is based on the "equal energy hypothesis" that the effects of noise (or music) exposure that is summed over time adds up to a well-defined exposure energy that is independent of being steady state or intermittent. In this scenario, an exposure to 90 dBA for 40 hours a week is identical to 93 dBA for 20 hours a week, and so on. This "3 dB exchange rate" is the policy of NIOSH in the United States and most other jurisdictions around the world [1]. The 5 dB exchange rate is predicated on the assumption that equal amounts of temporary threshold shift (TTS) are equally damaging. In this scenario, an exposure of 90 dBA for 40 hours a week is identical to 95 dBA for 20 hours a week, and so on. There is very little theoretical research to support this view since PTS is not correlated to TTS. Subsequently this "5 dB exchange rate" is not found commonly in policies around the world, but the Occupational Safety and Health Administration in the United States and a few jurisdictions in Canada do subscribe to this view.

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Acoustically, music has a similar structure as noise. Both music and noise have significant low frequency fundamental energy which musicians call the tonic (or note name), and higher frequency harmonic or broadband energy. Music, like noise, can have sound levels in the 60-70 dBA region and also sound levels in excess of 110 dBA. One difference is that many sources of industrial noise exposure are steady state, in that the sound levels have minimal variation over time, whereas music is characterised by highly fluctuating levels. This intermittency over time has been studied for decades beginning with the 1966 CHABA report that defined the on/off fraction rule which essentially weighted the exposure by the time varying levels of the noise source – the quieter periods are balanced against the louder periods. This is one reason why music exposure for any given gross measure, such as dBA or Leq, tends to result in less hearing loss for musicians and those who listen to music, than their industrial colleagues.

The audiometric configuration of long-term noise exposure is even similar to that of long-term music exposure. It is frequently difficult to differentiate a noise induced hearing loss from a music induced hearing loss purely on audiometric data. A thorough case history is required as the differentiating element. It is therefore not surprising that many of the research results using noise as a stimulus can apply (or have been applied) to music in many national and international regulations and policies.

Temporary threshold shift (TTS)

As the name suggests, TTS is a temporary loss in sensitivity to certain sounds for a period following an exposure to noise or music. The pathophysiology is not well understood but appears to be in part related to the temporary disarticulation between the outer hair cells and the tectorial membrane in the cochlea (which re-establishes itself after 16-18 hours) and glutamate levels that become ototoxic, where the levels return to a normal (lower) level after 16-18 hours. TTS is considered to be a cochlear sensory (rather than neural) dysfunction. TTS has to be discussed in two time periods.

Prior to the year 2000 TTS was considered to be a benign feature of exposure to noise or music resolving in 16-18 hours – a temporary cochlear phenomenon. Because TTS was "temporary" it was a paradigm commonly used to assess whether a person was subjected to an overly high level of noise or music. Much of the research revolved around whether

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a measure of TTS could be used to predict future permanent threshold shift (PTS), however no research has shown that TTS (or the pattern of recovery from TTS) can be used as a predictor of future PTS [2]. This is one of the main arguments against the 5 dB exchange rate.

After the year 2000, a number of studies have demonstrated that despite hearing thresholds returning to the pre-exposure level (i.e. no measureable TTS), there can be some permanent neural deficits that may not be immediately detectable. That is, despite a return to normal cochlear function (with a normal audiogram), there can be neural deficits that remain. Specifically, the synapse from the cochlear inner hair cells to the VIII auditory nerve can be permanently altered with a reduced amplitude on the Wave I on a traditional ABR evoked audiometry paradigm. This has been referred to as "cochlear synaptopathy" [3-5]. There are currently no accurate measures of cochlear synaptopathy and its prevalence is not well defined.

While prevalence estimates of cochlear synaptopathy in animal models are found in the literature, it would be erroneous to relate this to humans. There is very little data but there has been some research on human temporal bones. Viana and colleagues [6] counted the number of synapses in five temporal bones. As a function of age, there were fewer synaptic connections at the time of death. Another study by Makary and colleagues [7] showed that again, as a function of age in 100 human temporal bones, there was a marked decrease in cochlear spiral ganglion cells, despite having intact cochlear sensory cell populations at the time of death.

Cochlear synaptopathy has colloquially been referred to in the media as "hidden hearing loss" and while that can grab headlines, at this point in time, little is known about how this can manifest itself in humans, how this can be reliably measured, and what the prevalence actually is.

Hearing protection

Because of the laws of physics where high frequency sounds acoustically 'see' any obstruction better than lower frequencies, conventional industrial hearing protection tends to provide only about 20-25 dB of protection for the lower frequency sounds but up to 35-40 dB for the higher frequency sounds. Because sound energy can enter the skull directly to the cochlea (in the 2000 Hz region), the maximum limit of attenuation on any hearing protector is 40 dB. [8].

The musician's earplug utilises an acoustic network (either Helmholtz or wavelength based) to re-establish much of the mid and high frequency sound energy; the result being a flat or uniform hearing protector. Having a uniform attenuation hearing protector allows the musician to hear the proper balance between the lower frequency fundamental (or tonic) energy and the higher frequency harmonic energy. All acoustic energy in the music is reduced identically from a potentially damaging to a non-damaging sound level. Various manufacturers of musicians' earplugs have different strategies to accomplish this but most provide approximately 15 dB of sound attenuation. While 15 dB does not sound like a lot, every 3 dB reduction effectively cuts the dose of exposure in half. A musician wearing a 15 dB uniform hearing protector can then be in a musical environment for 32 times as long as without hearing protection – more is not necessarily better.

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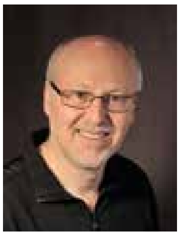

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Table 1. Predicted PTS for a range of exposure levels (in dBA) for a number of studies and models. Adapted from [1].

Sound Level dBA	Passchier-Vermeer (1968, 1971)	Robinson (1968, 1971)	Baugh (1973)	NIOSH (1973)	ISO R-1999 (1990)
85 dBA	8	6	9	5	6
90 dBA	15	12	14	11	11
95 dBA	23	18	17	20	21