The Weird Ear

AES Toronto Chapter Meeting
Date: Tuesday, October 26, 2004
Time: 7:30 pm
Where: Room 307, Image Arts Building
Ryerson University

Dr Marshall Chasin spoke about the physiology of the hearing system and its effects on altering the signal in sometimes weird and unexpected ways. This has ramifications for hearing aid fitting, hearing protection fitting, and earphone/ear monitor use facility. For those wishing to understand how their ears work, and how best to look after them, this is an ideal presentation.

Links to Dr. Chasin's Powerpoint presentation and other related information can be found at:

http://www.musiciansclinics.com/home.asp
and
www.randomizedtimer.net/music

distorted music samples from hearing aids (which come with built in limiters NOT optimal for listening to music):
www.randomizedtimer.net/musicandhearingaids/

The Weird Ear

Dr. Chasin began his seminar with an overview of the outer, middle and inner ear and went from there.

OUTER EAR

The ear automatically distorts everything coming its way, starting with:

The PINNA EFFECT
Cupping your "ear flaps" by hand results in an HF increase by 7-10dB. The main cup in your "ear flap" leading to your ear canal (the concea) serves to focus HF into the ear. It is also an approximately 500Hz Helmholz resonator, and has an "anti-resonance" on the vertical plane. This allows you to tell if something is over your head. The Pinnae also act as an obstruction to HF coming from the rear, of course, so you can tell when something is behind you. Extreme LF, as you can reckon, ignores all of this and goes right through your head.

No one is precisely sure what the other nooks and crannies in the ear do exactly, but speculation is the function is purely structural.

MIDDLE EAR

The “Ear Drum” is a Kleenex-thin membrane. The top doesn’t do much, rather it is the bottom that does all the vibrating, allowing for better transduction.

The “Ear Canal” is a _ wavelength resonant tube, generally 25-28mm long, resonating at around 3000 Hz. It behaves acoustically as if it’s slightly longer (30mm-ish), adding resonance at a frequency which is strictly length related. The circumference of the ear canal determines the amplitude of the resonance.

Most people have a 17dB bump at 3K-4K in their earhole, which is where the components of speech that affect intelligibility lie - plosive sounds like “ch” and “puh”. This bump will also affect the harmonics of these frequencies. Compare this to the high end of a piano, where the top note has a fundamental of about 4K.

When building a hearing aid or in-ear stage monitor, then, corresponding bumps at 3-4K and related harmonics must be built in to compensate for the amount of ear canal that gets plugged when you stick it in!

EAR WAX and EAR CANDLING

Ear wax differs greatly between Asians and Caucasians. In Asians the wax tends to be hard and flaky for whatever physiological reason, but in Caucasians the stuff is much more gooey. Ear candling is fantastic for Asians, melting the wax and creating suction with the rising heat to remove excess that just wouldn’t move on its own. For Caucasians, however, this only serves to remove a natural lubricant which should not be messed with. For this reason, Q-Tips really aren’t terrific either.

BOYLE’S LAW

Simply put, a smaller volume results in higher pressure, an inverse relationship. This practically means for an in-ear system the further you jam it in to the ear, the higher the loudness. Therefore, a system can be driven more quietly if it is closer to the ear drum without a loss in apparent level. This is frequency independent. Further in = louder and flatter in frequency response.

The OCCLUSION EFFECT

When you plug your ears, you’re no doubt familiar that some sound gets transmitted through the skull and jaw and so forth. Plug your ears (right now) and say “EEEE” than “AAAAH”. You’ll notice the “EEEE” sound appears much louder. This is because it’s first fundamental resonance is lower than “AAAH”, at around 125Hz, the lower frequency conducting better through your head.

In an in-ear system, this means some compensation must be added (a bore sitting against the canal, or an air hole which lets LF escape) to make up for the LF transmitting through the skull.

MIDDLE EAR

The "Ear Drum" or "Timpanic Membrane" is the first stage in the transducer which translates movement in air (sound waves) into movement in fluid, which the inner ear relies on to send impulses to the brain which we then "hear" as sound.

The mechanism in the middle ear is made up of tendons and muscles and three tiny bones, the Malleus, Incus, and Stapes (or Hammer, Anvil and Stirrup in perhaps more familiar terms). Fish have no middle ear… they're already in fluid and they don't need a transducer. If you yell at someone under the water in a pool, there's about 30dB lost in the change from air to water.

Goldfish only hear between 1K and 3K anyhow, so talk amongst yourselves while fishing. They won't clue in.

The ear is 66% efficient, meaning all frequencies are not transmitted equally inside the ear. We have seen this depicted in the familiar "Phon" curves, or "Fletcher-Munson" curves of equal apparent loudness. If 1K is 0dB SPL, LF might need an additional 40dB of gain to seem equally loud.

People generally hear in a range of 20Hz to 20kHz. Other animals hear sounds in surprisingly (or maybe not) different ranges, such as:

Monkey – 100Hz to 20kHz (pretty close)
Dog – 50Hz to 46kHz
Dolphin – 1kHz to 130kHz
Bat -3kHz to 140kHz

Needless to say you've been wasting time talking to the bat.

The 3 bones in your ear are the three hardest bones in your body. The **stipedial muscle** is connected between the Incus and Stapes or thereabouts. It contracts when loud sounds are present, damping the system, and acting as a -20dB peak limiting system.

If you want to make this muscle contract, try humming right now. If you know a loud sound is coming, hum before and after the sound hits you and you will get added protection from having the "limiter" already somewhat activated. This muscle is quite hardy and still provides almost undiminished protection for the inner ear well into old age.

BELL'S PALSY

Bell's Palsy is a temporary paralysis of one side of the face, usually lasting up to 6 weeks. It *temporarily* disables the function of the stipedial so in this condition the ear totally lacks any kind of protection from loud noise. The condition does not affect hearing, rather increased vulnerability that can quickly lead to permanent hearing loss.

Scientist Eric Borg cut the stipedial muscle on a rabbit and discovered a 30dB hearing

loss on the cut side compared to the side he left alone, after a relatively short amount of time.

It is hard to determine whether 2 people on the same assembly line in the same noisy environment will have equal hearing loss because of the difference in the action of their stipedial muscle, among other factors.

The hearing-loss relationship between the duration of exposure to loud sounds and the SPL of the sound is inversely proportional. For example a sound that is "half as loud" you can listen to "twice as long" and suffer equal damage. Loud music may occur in short bursts with time for recovery (temporary threshold shift or TTS) which leaves the hearing system more or less unscathed. Prolonged exposure is much more dangerous.

The maximum dB SPL before a sound becomes damaging is commonly accepted as 85dB, but practically damage occurs at quieter levels, closer to 80dB.

Chris Stokes-Rees of Etymonic Design in Dorchester, ON demonstrated the "Audioscan," the newest incarnation of a system Dr. Chasin invented 20 years ago for testing the resonance of the ear canal and an advanced kind of hearing test, based on the workings of the inner ear.

http://www.audioscan.com/

INNER EAR

The inner ear is made up of a solution similar in consistency to salt water, and 15,000 nerve endings attached to tiny hairs known as "cilia," all contained in the "Cochlea." The hairs are mounted on the "Basilar Membrane" which is coiled up inside the cochlea in a manner somewhat reminiscent of a snail shell. Kind of.

Of the hair/nerve cells, _ go TO the brain, _ return FROM the brain, like a feedback loop. The 75% of returning cells cause **Otoacoustic emissions**. This is best understood as similar to the microphone/speaker relationship. In short, the whole system also works in reverse - the tympanic membrane or ear drum acts as a both a microphone *and* loudspeaker at the end of the chain.

All mammals have this feature.

(related website: www.otoemissions.org)

The hearing test performed by the "Audioscan" uses a small probe to pick up the sound generated by the ear drum. It is useful for determining if newborn babies have proper hearing, and predicting future hearing loss as losses will show up in the Otoacoustic emissions *first*.

Otoacoustic emissions have been somewhat understood for about 15 years, some theories

as to what they accomplish exactly include; alerting your ears when your name is called and you have to start paying attention, and signaling your ears to filter out some LF and amplify speech frequencies using positive feedback so you can tune in someone whispering to you. “Perk up your ears” indeed!

TINNITUS

Tinnitus, or persistent ringing of the ears, has turned out to be an entirely brain-related and not ear-related problem at all. With hearing loss, caused by the death of cilia in the inner ear due to prolonged exposure to loud sound (not from over exercise of the stipedial muscle), the brain suddenly finds it is not receiving sound information from the ears it has come to expect and compensates by generating its own sound.

A hearing aid will block out or mask tinnitus at first, but over time if the brain “hears” constant sound, it gradually (over the period of a couple years) stops feeling the need to create the ringing.

The cilia in the basilar membrane detects HF on the outside, and LF deeper inside. The “HF cilia” reside on much less stable and wavy flexible tissue than the “LF cilia” which are securely mounted on a bony structure. Consequently, HF hearing loss always occurs first.
Inner ear hearing loss is not treatable, though mechanical loss in the middle ear, and even nerve damage, is.

NERVES and the BRAIN

The nerve which emanates from the ear, the 8th cranial nerve, is about 1” long, just over the ear, feeding a very tiny chunk of brain. This is duplicated on both sides. The individual nerves have a 1:1 relationship with the brain, each 1/3 octave critical band in the ear has corresponding nerves and brain cells. The mapping is “nice and clear.”

Hearing will be more or less uniform at all frequencies within each individual critical band. Dips in sensitivity, then, happen at all frequencies within a critical band that ain’t working so great!

The nerves are surrounded by Myelin Sheathes which accelerate the transmission of impulses by 30x-40x from the cochlea. When folks get older and these sheathes start to die away, the neurological conduction is slower, which is why you have to talk slower to grandma.

No hearing aid can fix that!

HEARING LOSS

Well, things aren’t quite as dire as we’ve been lead to believe, but at the same time there is reason to be cautious. Sony Walkmans are still very dangerous, but music related hearing loss isn’t exactly epidemic among our youth to the degree we think. On the whole North Americans are bigger and deafer though, compared to some 3rd world

unindustrialized tribal folk. This could be due to multiple factors however. Oddly, in Russia you can be 30dB deafer than Europeans and Americans and still be considered to have “perfect hearing” by their standards! Deafness in Europe is measurable by a standard, in North America we pretty much take it that if you use sign language, you’re deaf. You may be unwilling to use sign language and be deaf-er.

Smoking (get this) actually improves your hearing situation, because it decreases your blood flow to the REST of your body first. Your main components get left alone, therefore your ears get a bit of preferential treatment there.

Certain chemicals such as heavy metals used in radiation or chemo are known to kill or knock out some hair cells in the ear. Way, way too much Asprin will accomplish the same thing.

Cochlear Implants can help “kickstart” the inner ear *if* accompanied by rehabilitation which teaches the brain what to do with the new information. Without retraining, the implants are useless.

Next on the horizon is a “Morning After Pill” for the after-effects of exposure to loud sounds. The FDA is testing such a thing right now, invented by Don Henderson at the University of Buffalo, and spurred on by the US Military. That’s right, get it on unprotected at the ACC with SUM 41 or the Hip, then pop one of these babies in the next 6 hours and – WOW - no permanent damage will result. NOTE: this will not fix hearing problems, only prevent them.

The deaf-est jobs include Punch Press (loud, impulse-type noise) and Military work where guns and mortars are going off. Also stay away from pneumatic drills and aircraft carriers if you can help it.

Motorcycle helmets; cruising helmetless on your hog results in about 85dB of sound, but adding a helmet will amplify that noise to 115dB, so it is well advised to protect your ears as well as your noggin.

There is barely a difference in resulting hearing loss from various frequencies, what really matters here is sound pressure level or amplitude. Decibels and duration, folks. Decibels and duration.

It is recommended, if you are an audio professional, to get your ears checked once a year.

Thank you Dr. Chasin!

==========

Dr. Marshall Chasin
AuD, M.Sc.,Reg CALSPO,

Aud(C), Audiologist
Director of Auditory Research
Musicians' Clinics of Canada

Dr. Marshall Chasin, AuD, M.Sc., Reg. CASLPO, Aud(C) is an Audiologist and the **Director of Auditory Research** at the **Musicians' Clinics of Canada** in Toronto, Ontario.

He is also the Co-ordinator of Research at the Canadian Hearing Society, **Adjunct Professor** at the **University of Toronto** (in Linguistics) and an **Associate Professor** at the **University of Western Ontario** (School of Communication Sciences & Disorders).

Marshall has been involved with hearing and hearing aid assessment since 1981 and is the author of over 150 clinically based articles. He has lectured extensively, and is frequently on TV and radio (he's the good looking balding guy sometimes on Much Music).

Marshall is the author of several books, including "Musicians and the Prevention of Hearing Loss" (1996), the "CIC Handbook" (1998) and "Noise Control- a primer" (1999) (all through Singular Publishing Group.) Marshall also wrote "Hear the Music" (2001).

==========