Music, Musicians, Audiology & Neuroscience

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How much time does it take to become an expert?

10,000 hours = 4 hours daily for 2,500 days

7 years to become an expert.

After 10,000 hours developing listening skills, brains undergo "involuntary auditory (re)habilitation" and develop listening skills that "carry over" to the real world.

Speech in Noise Skills?

Musicians attend to the “sound of interest” among a cacophony of noise, picking out their instrument… “involuntary AR”
One major difference between musicians and non-musicians is the difference between HEARING and LISTENING.
Humans are not very good at hearing.
Cute? Perhaps... Dogs hear to 40 kHz, cats to 50 kHz. Good at Listening? Not so much!!!
<table>
<thead>
<tr>
<th>Animal</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>20,000</td>
</tr>
<tr>
<td>Canines</td>
<td>45,000</td>
</tr>
<tr>
<td>Felines</td>
<td>64,000</td>
</tr>
<tr>
<td>Rats</td>
<td>76,000</td>
</tr>
<tr>
<td>Bats</td>
<td>110,000</td>
</tr>
<tr>
<td>Beluga Whales</td>
<td>123,000</td>
</tr>
<tr>
<td>Porpoises</td>
<td>150,000</td>
</tr>
</tbody>
</table>
Humans are extraordinary at listening....

Listening is where hearing meets brain!
Assigning meaning to sound!
Speech and music are two very different sounds, each pulling in their own direction…
Count The Dots, 2010
Mueller and Killion, Hearing Journal
For Speech…71 dots (%) at or above 1000 Hz
88 Keys on a piano. Middle C = 256 Hz, 63/88 keys <1000 Hz, For music 72% of fundamental frequencies < 1000 Hz

Therefore….

SPEECH is essentially a HIGH FREQUENCY event, MUSIC is essentially a LOW FREQUENCY event.
WHAT HAPPENS WHEN YOU ADD MUSIC to the HUMAN BRAIN?

&

= ?

oticon

PEOPLE FIRST
PET & fMRI scans confirm
MUSIC triggers the release of DOPAMINE
(same thing occurs w/pleasurable stimuli).
Musician....on dopamine!
Behavioral Evidence
Musicians, Hearing Care Professionals, and Neuroscientists.

Zendel: 74 musicians (ages 19 to 91 years),
89 non-musicians (ages 18 to 86 years)
All with normal hearing.

Musicians demonstrated "clear advantages" in listening skills.
The average 70-year-old musician understood speech-in-noise as well as the average 50-year-old non-musician.

Zendel … a lifetime of musical expertise may help mitigate age-related listening problems.
Behavioral Evidence
Musicians, Hearing Care Professionals, and Neuroscientists.

Moreno et al: 6 months of musical training improved the reading ability and perception of speech pitch across a group of 8-year-old children.

Thompson et al: Music training improved perception of emotion in speech.


Schellenberg: Positive correlation between music lessons and IQ/academic ability.
Behavioral Evidence
Musicians, Hearing Care Professionals, and Neuroscientists.

Chandrasekaran and Kraus:
Music training improves many skills that underlie the ability to communicate despite background noise, including auditory working memory, sound source segregation, auditory attention...

Tallal and Gaab:
Music training improves rapid spectro-temporal processing (necessary for processing speech sounds).

Overy:
Music training caused improvements in rapid auditory processing and phonological and spelling abilities in children with dyslexia.

Hannon and Trainor:
Music training improves attentional and executive functioning skills.
Parbery-Clark suggested musical training may "reduce the impact of age-related auditory decline." They reported musicians are better at making sense of speech in challenging acoustic environments relative to non-musicians.

Compared 16 musicians to 15 non-musicians with regard to the Hearing-in-Noise Test (HINT) and the Quick Speech-in-Noise Test (QuickSIN).

Musicians' performance was superior on both speech-in-noise tests and musicians demonstrated better working memory as well as superior frequency discrimination ability.
Musicians have stronger and earlier ABR to speech and music.

Musicians demonstrate superior pre-attentive auditory processing as shown by mismatch negativity (MMNs) recordings obtained in response to mistuned chords.

Musicians also show enhanced responses in the hippocampus to new and unusual music.
Three years of childhood-based musical training changes the auditory nervous system...these changes persist into adulthood.

Regular physical activity in childhood is associated with better cognitive function later in life and musical experience is predictive of enhanced cognitive performance in older adults.
When you spend time actively working on making “sound-to-meaning” connections (via musical or auditory training) you create a nervous system able to respond consistently and to recognize meaningful sound patterns and efficiently represent meaningful elements of sound.
Musicians demonstrate structural differences in the brain.....increased gray matter in both auditory cortex, Broca's area, left primary sensorimotor cortex, right cerebellum, visuo-spatial areas and the hippocampus.

NATURE vs NURTURE?

Some people argue musicians have a predisposition for music. Longitudinal study of children receiving weekly keyboard lessons over 15 months showed increases in the size of their motor and auditory areas of the cortex, and no apparent changes in the control group.

Exceptions happen:

Beethoven, 1st performance at age 7.5 yrs.
Mozart started composing at age 5 yrs.
Cognitive Evidence
BRAIN TRAINING ACROSS the LIFESPAN
Changing...Musicians, Hearing Care Professionals, and Neuroscientists.

Gordon-Salant and Friedman (2011):
Group One = young adults 18 through 30 years with normal vision
Group Two = adults 60 through 80 years who had normal vision.
Group Three = adults ages 60 through 80, all blind 20 years +.

Challenge...Time-compressed speech-in-noise tests.

Group Three performed best. That is, as their need for additional sensory input increased, they learned to listen more attentively to the sounds they heard.
Our aim was to study the specific effects of musical training vs. the effects of other leisure activities in elderly people.

Reading music and playing a musical instrument is a complex activity that comprises motor and multisensory (auditory, visual, and somatosensory) integration in a unique way.

A group of participants that received piano lessons and did daily training for 4-month (n = 13) was compared to an age-matched control group (n = 16) that participated in other types of leisure activities (physical exercise, computer lessons, painting lessons, among other).

We found a significant improvement on the piano training group on the Stroop test that measures executive function, inhibitory control and divided attention.

Furthermore, a trend indicating an enhancement of visual scanning and motor ability was also found. Further, piano lessons decreased depression, induced positive mood states, and improved the psychological and physical QOL of the elderly.

Our results suggest that playing piano and learning to read music can be a useful intervention in older adults to promote cognitive reserve (CR) and improve subjective well-being.
Musicians are the consummate multi-taskers.

Music performance requires facility in sensory and cognitive domains, combining skills in auditory perception, kinesthetic control, visual perception, pattern recognition, and memory.

Because of its cognitive demands and the coupling required across sensory systems, musical training has provided a fruitful model for studying plastic changes in the brain and behavior that occur through short- and long-term training.
Adult musicians have more gray matter in somatosensory, premotor, superior parietal, and inferior temporal areas and these enlargements correlate with their levels of expertise.

Musicians also have larger cerebellar volume, with the extent of this greater volume correlating with the lifelong intensity of musical practice, which has been proposed to be due to the role of the cerebellum in motor and cognitive skill learning.
Support for training-related plasticity leading to neuroanatomical differences and improved neural encoding of sound.

Among professional musicians, individual distinctions lead to differences in performance capabilities. Still, one need not be a musical prodigy to gain benefits from musical training.

Non-musicians, amateur musicians, and expert musicians, increased musical expertise correlated with gray matter density in areas involved with higher order cognitive processing and auditory processing.
Older adults benefit from music training early in life: biological evidence for long-term training-driven plasticity. White-Schwoch T, Carr KW, Anderson S, Strait DL, Kraus N.

Aging results in pervasive declines in nervous system function. In the auditory system, these declines include neural timing delays in response to fast-changing speech elements; this causes older adults to experience difficulty understanding speech, especially in challenging listening environments.

These age-related declines are not inevitable! Older adults with a lifetime of music training do not exhibit (the typical) neural timing delays.

We examined neural timing in a group of human older adults who had nominal amounts of music training early in life, but who had not played an instrument for decades. We found that moderate amount (4-14 years) of music training early in life is associated with faster neural timing in response to speech later in life, long after training stopped (>40 years).

We suggest that early music training sets the stage for subsequent interactions with sound. These experiences may interact over time to sustain sharpened neural processing in central auditory nuclei well into older age.
What to do for the musician with hearing loss?
Counseling....

MOST musician’s should not wear amplification while performing because most performances are above (way above) 85 dB.

Hearing aids amplify speech sounds, the majority of which are high frequencies. Music is essentially a low frequency event.
While performing…. 
Musicians should consider ER-15s (or similar HPDs).
Fans attending concerts/performances should wear HPDs.
http://www.musiciansclinics.com/home.asp

Toronto
340 College Street, Suite 340
Toronto, Ontario
CANADA M5T 3A9

Phone: (416)966-8742
Quiet speech ~ 55 dBSPL,
medium speech ~ 65 dBSPL and
loud speech ~ 75 or 80 dB SPL.

Quiet music ~ 80 to 85 dBSPL,
medium music ~ 95 dBSPL and
loud music ~ > 100 dB.

Remove hearing aids...Insert hearing protection devices (HPDDs)
## Time vs Loudness

<table>
<thead>
<tr>
<th>Exposure</th>
<th>NIOSH</th>
<th>OSHA</th>
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<tbody>
<tr>
<td>8 hrs</td>
<td>85 dB SPLA</td>
<td>90</td>
</tr>
<tr>
<td>4 hrs</td>
<td>88</td>
<td>95</td>
</tr>
<tr>
<td>2 hrs</td>
<td>91</td>
<td>100</td>
</tr>
<tr>
<td>1 hr</td>
<td>94</td>
<td>105</td>
</tr>
<tr>
<td>30 min</td>
<td>97</td>
<td>110</td>
</tr>
<tr>
<td>15 min</td>
<td>100</td>
<td>115</td>
</tr>
<tr>
<td>7.5 min</td>
<td>103</td>
<td>120</td>
</tr>
</tbody>
</table>
When sounds louder than 90 to 95 dB are amplified the hearing aids distort like crazy, they saturate the analog to digital converter, causing the hearing aids to sound awful!
1- Turn the volume of the sound source and then crank up the volume of the hearing aid, so the input to the hearing aid is lower, allowing the hearing aid circuit to do what it was designed to do.

2- Place three or four layers of scotch tape (cellophane tape) over the hearing aid microphone to reduce the sound pressure before it enters the hearing aid, this works very well.

3- Typical hearing aids use a broad-band/flat mic response to amplify sounds maximally. If we use “minus 6 dB per octave” microphones we decrease the input to the analog to digital converter in the lows, by 6 dB at 500 Hz and 12 dB at 250 Hz….less SPL at the analog to digital convertor and less likely to saturate.

4- Place an analog compressor at the front end of the circuit, before the analog to digital convertor, to compress sounds so as to not allow the analog to digital convertor to ever saturate, and then the sound can be digitally expanded inside the digital circuit.

5- “Auto-range” solution. Hearing Aids have a 96 dB limited range of the analog to digital convertor, it doesn’t mean it has to start at 0 dB SPL as the bottom and use 96 dB SPL as the top. What if you were to shift it to start at 10 dB SPL or 20 dB SPL, then you could use a 96 dB dynamic range and you might be able to go up to 106 dB SPL or 116 dB SPL before saturating the front end.