

**Canadian Academy of Audiology** Academie Canadienne d'audiologie

# Music and Hearing Aids Speaker: Dr. Marshall Chasin, Au.D., reg. CASLPO Marshall Chasin and Associates

Moderator: Philippe Fournier, Assistant Professor of Audiology, Université Laval

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#### Moderator: Philippe Fournier, Assistant Professor of Audiology, Université Laval

Philippe Fournier is currently an Assistant Professor of Audiology for the faculty of Medicine of Université Laval in Québec city. He is a former postdoctoral fellow at the Centre national de la recherche scientifique (CNRS), Université d'Aix-Marseille, France. He is also the founder, and past CEO and president of the **Quebec Association of Speech-language** Pathologists and Audiologists (QASLPA) from 2011-2014. Philippe research has been dedicated to improving diagnostic measures and therapy options for tinnitus and hyperacusis.



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#### Speaker: Dr. Marshall Chasin, Head of Audiology, Musicians' Clinics of Canada, Adjunct Professor at the University of Toronto, and Western University

Dr. Marshall Chasin is Head of Audiology at the Musicians' Clinics of Canada, Adjunct Professor at the University of Toronto (in Linguistics), and Adjunct Professor at Western University. Marshall holds a B.Sc. in Mathematics and Linguistics from the University of Toronto, a M.Sc. in Audiology and Speech Sciences from the University of British Columbia and his AuD from the Arizona School of Health Sciences. He is the author of over 200 articles and 8 books including Music and Hearing Aids (Plural Publishing, 2022). Marshall writes a monthly column in Hearing Review called Back to Basics, and has been the recipient of many awards over the years.







# Music and Hearing Aids

#### Marshall Chasin, AuD

Musicians' Clinics of Canada <u>www.MusiciansClinics.com</u>

**Canadian Academy of Audiology** 

#### Conflict of Interest declaration...





# Three Differences ...

- Speech vs. Music Spectra
- Differing sound levels
- Crest factors





# Three Differences ...

(1) Speech vs. Music Spectra:

Speech has a relatively uniform spectrum

- Human vocal tract source
- Long-term speech spectrum "target"

Music has many sources

- Highly variable
- No "music target"









Moore, B. C. J. (2012). Effects of bandwidth, compression speed, and gain at high frequencies on preferences for amplified music. Trends in Amplification, 16(3), 159–172.

# Violin (soft and loud)



# French horn (soft and loud)



#### Spectral shapes differences (soft to loud)

	Low Frequency Region	High Frequency Region
Vocals	11-15 dB	0-10 dB
Stringed Instruments	11-15 dB	11-15 dB
Brass Instruments	< 10 dB	> 30 dB
Reeded Woodwinds	< 10 dB	> 30 dB

#### Three Differences ...

(2) Differing sound levels:

Speech is 65 dB SPL  $\pm$  12 dB

- (53 dB SPL to 77 dB SPL)
- Shouted speech can be 82 dB SPL

Music can reach 105 dBA; peaks of 120 dB SPL

Table 2-1. Average sound levels of a number of musical instruments (from over 300 musicians) measured from 3 meters on the horizontal plane. \*Also given is the sound level for the violin measured near the left ear of the player. (Chasin, 2006).

Musical Instrument	dB(A) ranges measured from 3 meters
Cello	80-104
Clarinet	68-82
Flute	92-105
Trombone	90-106
Violin	80-90
Violin (near left ear)*	85-105
Trumpet	88-108

#### Three Differences ...

(3) Crest factor: (instantaneous peak – long term RMS)

(Used in hearing aid testing... OSPL90 – 77 dB = Ref. Test Gain)

Speech has a crest factor of 12 dB- 16 dB

Music has a crest factor of 18 dB-22 dB

• Less damping.



#### Crest factor





# Speech

65 dB SPL RMS 12-16 dB crest factor -6 dB / octave Well defined SII and target Low frequency boost for louder speech

# Music

>100 dB SPL RMS
18-22 dB crest factor
Variable slopes
No "MII" and no target
Variable boosts for louder music

#### What about hard of hearing musicians ... ... or non-musicians who like to listen to music?





Sec. 1

the bring of beauties and



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# Peak input limiting level

Peak input limiting level of many hearing aids (up until very recently) limits sound above 90 dB SPL.

(...Only 1 analog aid of the 1980s had 115 dB) .... shouted [a] is about

82 dB SPL



# Peak input limiting level

This occurs just after the microphone, and is related to the A/D converter.

• Overloading the "front end".

If distortion occurs this early in the circuitry, then nothing later (e.g. software adjustments) can improve things.

Chasin, M., & Russo, F. (2004). Hearing aids and music. Trends in Amplification, 8(2), 35–48.

Oeding, K., & Valente, M. (2015). The effect of a high upper input limiting level on word recognition in noise, sound quality preferences, and subjective ratings of real-world performance. Journal of the American Academy of Audiology, 26(6), 547–562.

*Plyler, P., Easterday, M., & Behrens, T. (2019). The effect of extended input dynamic range on laboratory and field-trial evaluations in adult hearing aid users. Journal of the American Academy of Audiology, 30(7), 634–648.* 

#### Its not the microphone...





# The overpass analogy



80 dB dynamic range

# High level music and low "ceiling"



# An Experiment:

A hearing aid was constructed where the peak input limiting level can be successively reduced from 115 dB SPL, to 105 dB SPL, to 95 dB SPL ... and back to 115 dB SPL.

Acknowledgments: Mead Killion, Russ Tomas, Norm Matzen, Mark Schmidt, Steve Aiken.

Speech

Music





#### Therefore ....

Peak Input Limiting Level should be at least 115 dB SPL .... Or maybe even up to the limit of modern hearing aid microphones ?

... And it's not just for music. What about the level of a hard of hearing person's own voice at their hearing aid?

Chasin M. The "best hearing aid" for listening to music: Clinical tricks, major technologies, and software tips. Hearing Review. 2014;21(8):26-28.

# Benefit even for high level speech...





# What the crest factor can tell us about speech...

A hard of hearing person's own voice can overdrive their own hearing aid!

84 dB input + 16 dB crest factor = 100 dB ish

#### Four clinical strategies...

\* Lower volume on stereo or other input and increase gain on aid.

\* You can use an ALD (WITH A VOLUME) as input.

\* Use (creative) microphone attenuators such as Scotch tape. (3-4 layers of tape will provide 10-12 dB of flat attenuation up to 4000 Hz).

\* Take off the hearing aids

Use microphone attenuators such as Scotch tape.

3-4 layers of Scotch tape will attenuate the input by 10-12 decibels...




### Take off the hearing aids

dB HL at 1000 Hz	65 dB input	80 dB input	95 dB input
15	0	0	0
25	2	1	0
35	8	4	0
45	14	7	0
55	20	10	1
65	28	15	2
75	36	20	3
85	44	24	4

### Higher inputs require lower gains...





### Low gain/high output test

Set an aid for 5-10 dB of gain, but maximum OSPL90 with a 105 dB SPL input and if distortion (>20%) then cannot handle loud (live) music.

## Input + gain << Output

Chasin, M. "Can your hearing aid handle loud music? A quick test will tell you", The Hearing Journal Dec. 2006, 59 (12), 22-24.

### Four technical innovations...

- 1. -6 dB/octave low cut microphone
- 2. Shifting the dynamic range upwards
- 3. Front end compression prior to the A/D converter
- 4. Post 16 bit architecture

### 1. -6 dB/octave low cut microphone

We can use a desensitized microphone.

Use a high frequency emphasis (-6 dB low frequency roll-off) microphone.

## Same frequency response but less front end distortion.

Chasin, M., & Schmidt, M. (2009). The use of a high frequency emphasis microphone for musicians, Hearing Review, 16(2), 32–37.

Schmidt, M. (2012). Musicians and hearing-aid design—Is your hearing instrument being overworked? Trends in Amplification, 16(3), 140–145.

## Microphone noise... you will need expansion...



#### Expansion comes to the rescue



# THD Results with Broad Band Mic for 95, 100, 105 & 110 dB SPL inputs



# THD Results with High Frequency Mic for 95, 100, 105 & 110 dB SPL inputs



### 2. Shifting the dynamic range upwards

Transformer effect by doubling the voltage

Increases the high end of the dynamic range by up to 6 dB (can be accomplished off-IC chip)

### 2. Shifting the dynamic range upwards

And other approaches ...

Auto-ranging of the A/D converter that detects the input and ensures that the input is within the optimal operating range. (e.g. HRX)

"Stacked A/D converters", while still commercially available, aren't widely used.

# 3. Front end compression prior to the A/D converter

Some hearing aid manufacturers are now using an analog compressor prior to the A/D converter ... ... and then digitally re-establish gain after...



### 4. Post 16 bit architecture

20 and 24 bit architecture A/D converters that have > 96 dB dynamic range.

For each bit (n) add 6 dB to dynamic range
(20n)log2 = 20n x 0.3 = 6n



### One way that manufacturers determine this...



### 4. Post 16 bit architecture

Some "19 or 20 bit" systems .... As reported by manufacturers, 116-119 dB SPL:

Unitron Blu/Vivante™ Phonak Paradise™ Oticon Intent™ (auto-range)\* Widex Moment™ Bernafon Alpha™ (auto-range) Resound Nexia Starkey Genesis Al™

### Frequency response... the two ends...



### Frequency response... the low end

Low frequency end (down to 55 Hz):

- affected by earmold/eartip venting

-Hirsch and Bowman (1953)

- distortion occurred for low frequency inputs >80 dB SPL

- High level, low frequency sounds rarely would be seen by speech but commonly seen even by unamplified music.

Moore, B. C. J., & Tan, C-T. (2003). Perceived naturalness of spectrally distorted speech and music. Journal of the Acoustical Society of America, 114(1), 408–419

*Hirsch, I. J., & Bowman, W. D. (1953). Masking of speech by bands of noise. Journal of the Acoustical Association of America, 25, 1175–1180.* 

## Frequency response... the high end

- Hallowell Davis et. al (1950):
  - American servicemen (and Davis himself) volunteered to have TTS created unilaterally.
  - They were given two unmarked knobs; one controlled frequency and the other, sound level. Asked to match the sound in the good ear with that of the TTS affected ear.
  - Low frequencies = good correspondence
  - High frequencies = heard as louder, but not higher pitched
    - .... Subjects heard the sound as flat relative to good ear.
      - Diagnostic clue = if a client hears sounds as flat...

(opposite study has yet to be done...)

Davis, H., Morgan, C. T., Hawkins, J. E., Galambos, R., & Smith, F. W. (1950). Temporary deafness following exposure to loud tones and noise. Acta Otolaryngologica, 88(Suppl.), 1–57.

### Frequency response... the high end

In the early 1990s Brian Moore and his colleagues noted that sometimes if the hearing loss was very severe, then cochlear dead regions may exist.

TEN test which takes around 10 minutes for 4 frequencies

- 1. Reduce the amplification in this region
- 2. Frequency shift to a lower frequency (healthier) region

Moore, B. C. J. (2004). Dead regions in the cochlea: Conceptual foundations, diagnosis, and clinical applications. Ear and Hearing, 25(2), 98–116. 3.

Moore, B. C. J., Glasberg, B. R., & Stone, M. A. (2004). New version of the TEN Test with calibrations in dB HL. Ear and Hearing, 25, 478–487.



## A clinical trick to assess dead regions...



Chasin M. "Testing for cochlear dead regions using a piano". Hearing Review. 2019;26(9):12.

# Summary of limitations of the high frequencies... (based on speech, but...)

Mild hearing loss	>55 dB hearing loss	Steeply sloping audiogram
Broad bandwidth	Narrow bandwidth	Narrow bandwidth

Aazh, H., & Moore, B. C. (2007). Dead regions in the cochlea at 4kHz in elderly adults: Relation to absolute threshold, steepness of audiogram, and pure-tone average. Journal of the American Academy of Audiology, 18(2), 97–106.

*Ricketts, T. A., Dittberner, A. B., & Johnson, E. E. (2008). High frequency amplification and sound quality in listeners with normal through moderate hearing loss. Journal of Speech-Language-Hearing Research, 51, 160–172.* 

#### Sometimes we can just change the input...

A client came in with a high frequency hearing loss as a result of chemotherapy as a child. Great mezzo soprano but was having difficulty passing an ear training class (intervals, chords,...)

Was able to convince the administration to perform the test one octave lower...

.... She passed!

## No frequency lowering for music



### No Frequency Lowering

- **1. FREQUENCY TRANSPOSITION**: linear decrease up to 2 octaves (e.g., Widex Audibility Extender)
- 2. FREQUENCY TRANSLATION: spectral envelope warping. A "copy and paste" approach where high frequencies are pasted right onto a lower frequency region (e.g., Starkey Spectral IQ)
- **3. SOUND RECOVERY**: non-linear compressing by as much as 2:1, but typically not more than 1.5:1 (e.g., Phonak and Unitron)

### No Frequency Lowering

Music: line spectrum (except percussion).

## Speech: line spectrum for low frequencies continuous spectrum for high frequencies



# Frequency lowering is for speech; not for music

Speech:

- 1. Low frequency line spectra Sonorants
- 2. High frequency continuous spectra Obstruents (e.g., 's, sh, th, f,...')

Music:

#### All frequencies have line spectra

Chasin M. Back to Basics: "Frequency Compression Is for Speech, Not Music". Hearing Review. 2016;23(6):12.

#### 1/2 of one semi-tone decrease above 1500 Hz



### No Frequency Lowering

½ of one semi-tone decrease above 1500 Hz with one note (1.059/2)



Same thing with full music score



But OK for speech

### -6 dB/oct roll-off above 1500 Hz



### -6 dB/oct roll-off above 1500 Hz



Do not change the frequencies of the harmonics, but instead gradually reduce the amplitudes slightly

### Music is the same as speech

Compression

Frequency response

### Music is different than speech

- No advanced features such as noise reduction, feedback management
- No frequency lowering

# Less is more when it comes to music!

## Whoever said "less is more" clearly wasn't a coffee drinker.



# #1
### Music Program #1- Live Music

- 1. The "front end" has been taken care of
- 2. The frequency bandwidth has been optimized for that client
- 3. Frequency lowering has been disabled
- 4. Similar compression characteristics to a speech-in-quiet program
- 5. Advanced features such as feedback management has been "managed"

## #2

### What about streamed music?

Thank you to:

Crogan, N., Arehart, K, and Kates, J. (2012). Quality and loudness judgments for music subjected to compression limiting. JASA, 132(2), 1177-1188.

Music has been compression limited once already during the creation of the MP3/MP4 process. This is a relatively benign form of compression but does reduce the volume. (Some radio stations tend to use this as well).

Should not "doubly" compress this streamed music, so the music program should be close to linear.

### Music Program #2- Streamed Music

- 1. The "front end" has been taken care of
- 2. The frequency bandwidth has been optimized for that client
- 3. Frequency lowering has been disabled
- 4. Linear, or only slight WDRC compression for this program
- 5. Advanced features such as feedback management has been "managed"

# #3

### What about "instrumental only" music?

..... An island of refuge...

### An island of refuge... .... The one octave counter-example

If all frequencies (e.g. above 1500 Hz) are decreased <u>linearly by exactly one octave</u>, the odd numbered harmonics will line up perfectly with already existing harmonics.

Depending on the acoustics of the musical instrument, either a perfect fifth will be created (for ½ wavelength resonator instruments) or a third will be created (for ¼ wavelength resonator instruments).

### An island of refuge... .... The one octave counter-example

Can use either Frequency Lowering (e.g. Widex) which is a linear decrease

or

## Frequency Translation (e.g. Starkey) which is a "cut and paste" linear approach.

Chasin, M. Fabry, D., and Kuk, F. (2024). The benefits of linear frequency lowering for music. Hearing Review (January 2024).

### Perfect Fifth (violin, guitar, flute,...)



### Third - clarinet, trumpet, French horn ...





## But.... the one-octave "island of refuge" is not useful for speech/vocals





Marina Salorio-Corbetto, Thomas Baer & Brian C. J. Moore (2016): Quality ratings of frequencycompressed speech by participants with extensive high-frequency dead regions in the cochlea, International Journal of Audiology, DOI: 10.1080/14992027.2016.1234071

### Music Program #3- Instrumental Only Music

- 1. The "front end" has been taken care of
- 2. The frequency bandwidth has been optimized for that client
- 3. One octave linear frequency lowering
- 4. Similar compression characteristics to a speech-in-quiet program
- 5. Advanced features such as feedback management has been "managed"



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### All audio files can be found at: MusiciansClinics.com/Demos



#### Links to Marshall's audio files

<u>The Problem with Frequency Transposition and Music 1.pdf (musiciansclinics.com)</u> https://musiciansclinics.com/publications/The%20Problem%20with%20Frequency%20Transposition%20and%20M usic%201.pdf

<u>The Problem with Frequency Transposition and Music 2.pdf (musiciansclinics.com)</u> <u>https://musiciansclinics.com/publications/The%20Problem%20with%20Frequency%20Transposition%20and%20M</u> usic%202.pdf

https://musiciansclinics.com/publications/OVERDRIVING%20A%20HEARING%20AID%20WITH%20MUSIC.pdf https://musiciansclinics.com/publications/OVERDRIVING%20A%20HEARING%20AID%20WITH%20MUSIC.pdf

### Questions?

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UPCOMING WEBINAR: MUSIC AND HEARING AIDS WITH MARSHALL CHASIN – APRIL 17, 2024 AT 1PM ET

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