Music and hearing aids

Sound quality is important to enjoy music
Optimized speech intelligibility, currently major focus of hearing devices

Interest on topic Hearing aids & music increases (not complete):
- “Hearing Aids and Music” (Chasin & Russo 2004)
- “Music as an Input to a Hearing Aid” (Chasin 2007)
- “Six ways to improve the listening of music through hearing aids” (Chasin, 2010)
- “Hearing instruments to enjoy live music” (Hockley et al. 2010)
- “Hearing Matters: Aided Mapping for Music Lovers: Addressing the Basic Issues” (Colucci 2013)
- “The Influence of Non-Linear Frequency Compression on the Perception of Timbre and Melody by Adults with a Moderate to Severe Hearing Loss” (Uys et al. 2013)
- “Music Preferences With Hearing Aids: Effects of Signal Properties, Compression Settings and Listener Characteristics” (Croghan et al. 2014)

Frequency range and dynamic range of music

20 Hz – 20 kHz
Very large dynamic range: 40 up to >110 dB SPL

Important factors:
- Rhythm
- Harmonic structures
- Timbre
- Modulations

Music in the view of a hearing aid manufacturer

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Consequences of sensorineural hearing loss

- reduced dynamic range -> soft sounds become inaudible
- reduced frequency bandwidth -> loss of high frequencies
- reduced frequency resolution -> poorer pitch detection
- Degraded binaural processing -> poorer spatial resolution

- Difficulties to resolve complex music with a damaged auditory system
- Perceived distortions may result from altered auditory function

- Key for a good music experience:
  - present the relevant cues of music appropriate to the residual hearing capabilities
  - But: what are the most important cues?

Important perceptual properties for music are affected

Main factors influencing music perception with hearing aids – technical view

- Dynamic range
  - possible distortions at very high input levels
- Limitations of the Loudspeaker (Receiver)
- Gain control: AGC, WDRC, MPO
- Impact of sound processing algorithms like
  - Directional microphones, Feedback cancellation, noise reduction etc.

What is «natural sound quality»?

It depends on
- the hearing loss:
  - Mild to moderate Hearing loss vs. Severe to profound loss
- Familiarity:
  - For inexperienced hearing aid users:
    - acoustic transparency – ie a flat frequency response, no compression
  - For experienced users:
    - Familiarity to the used devices -> switch from Analog to Digital devices
- Needs and expectations:
  - Active musicians vs non-musician

- Do we have a common vocabulary to describe attributes / factors contributing to sound quality?
  - Musicians vs. naive listeners vs clinicians? -> find a common language

There is not one solution for all

A modern hearing system

- An overview over features and possible impact on music perception
Hearing aids - electroacoustic of the Input stage

- Dynamic range of current HI microphones + AD-converter: 25 dBA - 115 dBSPL
- Covers most inputs without distortions
- Omni-directional vs directional:
  - ITE/ CIC: omni for most natural spatial perception
  - RIC/ BTE: RealEarSound -> restauration of the Pinna effect, omni gives more «room» and reverberations

Typical input distortions for 4 current digital HI

The Loudspeaker / Receiver

Amplifier outputstage:
typically > 100dB dynamic range

- Receiver technology:
  - Balanced armature receiver is optimized for high efficiency
  - limited frequency response at high frequencies
  - smoothness of frequency response?
    - can be compensated with DSP filtering to some extent
  - High level distortions of the receiver
    - relevant for very high output levels

Gain processing

Music sample: 107 dB SPL, 118 dB Peak level
Consequences of cochlear hearing loss

- Normal hearing (Sound level dB SPL)
  - Extremely loud
  - Not audible

- Frequency kHz

Hearing aid compression

- Input Level [dB SPL]
- Output Level [dB SPL]
- Gmax
- UCL
- HTL

- Loudness limit: very loud sounds
- Compression: range of speech sounds
- Expansion: noise floor

Fast or slow Gain processing?

- Different manufacturers have different philosophies for hearing loss compensation
- Fast actings syllabic compression (WDRC):
  - Optimized for speech intelligibility
  - Aims at making all sounds audible again
  - Compensates for cochlear compression loss
- Drawback:
  - Reduces temporal and spectral contrast -> «blurred»
  - Reduces binaural cues -> «narrow» sound image, less spatial separation

Fast or slow Gain processing?

- Slow compression (Automatic Volume Control):
  - Tries to restore average loudness perception
  - Can preserve dynamics of the signal (speech)
  - Can preserve spatial cues
- Drawback:
  - Sudden loud sounds may be perceived too loud
  - Soft sounds following loud input may get inaudible

- For music slow or combined fast/ slow systems seem to be preferred
MPO – maximum power output limiting

—An important function in hearing aids to avoid excessive SPL and discomfort for very loud inputs
—Helps to avoid distortions of the output stage or the loudspeaker/ receiver
—Drawback:
  — Too low MPO settings reduce the signal dynamic range
  — Multi band limiters also may reduce spectral contrast of the signal
—Ideally the MPO is only rarely activated for music

Gain expansion – «soft squelch»

—Is used to reduce system noise (microphones, preamplifier) or low level background noise
—It is optimized for speech input
—Drawback:
  — The device may be perceived as «dead» in quiet environments or for very soft music passages
  — It may create unwanted fluctuations when activated and deactivated
—For Music:
  — If possible deactivate the expansion or set the expansion TK very low
  — With improved technology soft squelch is less important

Frequency response

— Typically hearing aid amplification emphasise the main speech region (500-3000 Hz) and reduce low frequencies
— This results in improved speech intelligibility at same loudness perception compared to a flat frequency response
— Impact on music perception:
  — Reduced low frequencies: Music is not perceived as full
  — Increase low frequencies (below 1 kHz) to achieve fuller sound

Frequency response - example

— Flat 50 dB hearing loss, NAL NL2 target

Program manager

Not connected

default program

Phonak music program
**Frequency lowering**

Idea:
- Make high frequency fricatives eg «s» «sh» «th» «f» audible again for severe to Profound hearing impaired
- Depending on the algorithm it can affect the harmonic structure of sounds
- Is designed mainly for speech

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**Frequency lowering**

- Adaptive Frequency lowering (SR2) better preserves music sounds than static frequency lowering
- For Music: either disable or set high Cutoff frequency (> 2kHz)

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**Feedback cancelling**

- Maintains acoustic stability with high gain
- Up to 20 dB over critical gain is possible with phase cancellation algorithms and frequency shifting (eg 10 Hz)
- Works great for speech input

But:
- Frequency shift can be perceived as mistuned pitch (out of tune)
- Adaptive FB-canceler modulates tonal periodic signals

For music:
- disable Feedback canceller if possible or use a less aggressive settings
- Reduce gain if needed
If a fully automatic hearing device is desired
- For music the device should behave consistent and predictable:
- No fading between different sound processing schemes
- Reaction time is rather slow – 10-15 sec

Finally: my hints for improving music experience with Hearing aids
- Turn off fancy adaptive features like:
  - Noise reduction, reverberation reduction, Adaptive beamforming, feedback cancellation
- Try to achieve a smooth and flat frequency response
- Choose the largest acceptable receiver for RIC devices to have more bass and dynamics. Eg. xP instead of xS receiver with Phonak products
- A more linear setting is preferred in most cases (slow or dual compression) + (increased MPO)
- Increase the low frequencies, but avoid clipping/ saturation
- Use either a manual music program or a dedicated program in the automatic mode

Accessibility - streaming music
- Bluetooth technology enables direct streaming from smartphone / TV/ MP3 player to the hearing aids.
- No direct sound available
  - It has to be delivered from the Hi- receiver
  - If possible choose a larger Receiver for RIC devices
  - Results in more headroom in the lows -> fuller sound