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# Hearing aids and the trouble with music

## Intensity and crest factors

As we will see, the words 'hearing aids' and 'music' imply a significant amount of difficulty when mentioned in the same sentence. Hearing aids are traditionally designed with speech in mind, and only with music as an afterthought. While there are so called 'music programmes' in modern hearing aids, for the most part these are merely marketing items and do not lend themselves to the differences between speech and music as inputs to a hearing aid.

Speech and music do have some similarities – they are both vibrations in the air and their bandwidths are constrained to a rather narrow region of our possible hearing range. Speech has its energy above middle C on the piano keyboard and extends another octave above the top of the piano keyboard. Music does have a broader range but not significantly so. Both speech and music have intense parts followed by quiet or even silences. They both have rapid changes from loud to soft, with speech being governed by the mechanics and neurology of the vocal tract, and music just being governed by the mechanical attributes of the musical instrument being played.

In short, music and speech can have similar, albeit not identical, spectra and time based waveforms. The differences lie in their intensities and crest factors. Instrumental music – even quiet music – can be in excess of anything produced by the human vocal tract. And crest factors can become quite significant as well. Table 1 shows the typical outputs in dBA of a

number of musical instruments. In most cases these values were obtained from a horizontal distance of 3 metres. In one case (violin), the values have also been measured near the musician's ear [1].

The crest factor is another difference between speech and music. This is the difference between the peak of a signal and its average value. For speech, the crest factor is about 12 decibels. For someone speaking loudly at 75 dB sound pressure level (SPL), then the peaks would be at 87 dB SPL; 12 decibels greater than the average. The most intense sound in any language of the world is the low back vowel [a] as in 'father' (please forgive my Canadian accent) and this has a typical level of about 82 dB SPL (with its peak therefore being at 94 dB SPL).

In contrast to speech, because music is generated by less damped structures than the human vocal tract, the crest factors tend to be higher – up to 20 dB. Music played at 90 dB SPL (which is relatively quiet) may have a peak around 110 dB SPL (90 + 20).

## Hearing aids and music

A major flaw with current digital hearing aids is that they have difficulty transducing inputs over about 95 dB SPL. This has everything to do with the hardware and nothing to do with the software. All digital hearing aids have an analogue-to-digital (A/D) converter and it is this converter that can only handle inputs below 95 dB SPL without a significant distortion of the signal.

Because even the most intense vowels in speech (plus their crest factors) are below 95 dB SPL, modern digital hearing aids have no difficulty transducing speech. This, however, is not the case for most forms of music [2,3].

Once music is distorted at the level of the A/D converter, which is very early in the hearing aid circuitry, no manipulation performed later on, such as software programming changes, can improve the fidelity.

This situation is similar to a low hanging bridge in London – single-decker buses can get through without any difficulty, but this may not always be the case with double-

**Table 1: Average sound levels of a number of musical instruments measured from 3 meters.** Also given is the sound level for the violin measured near the left ear of the players. Adapted from Chasin (2006) [1]. Used with permission.

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

**Table 2: Calculated amounts of gain required for a given hearing loss at 1000 Hz (column 1).**  
 For average levels of music (95 dB A) inputs, virtually no amplification may be required even for very significant hearing losses. Used with permission. Retrieved March 19, 2012, from [www.hearinghealthmatters.org/HearTheMusic](http://www.hearinghealthmatters.org/HearTheMusic).

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

decker buses. One must either lower the height of the bus or increase the height of the bridge. Solutions that are available in the hearing aid industry use both of these strategies.

**Some technologies and strategies to handle the more intense inputs of music**

There are a number of creative strategies and electro-acoustic techniques that are being used in the industry to resolve this 'high level input – front end' problem for music [4].

**Strategies**

- *Turn down the input (stereo) and turn up the aid volume (if necessary) – not the other way around:* This is analogous to ducking under the low hanging bridge. The result is a much clearer signal than if the stereo or car radio was turned up, and the hearing aid volume was reduced.
- *Removal of hearing aid for music:* Since music is inherently more intense than speech, this could be thought of as 'very, very loud speech'. As is shown in Table 2, very little gain may be required, even for those with rather significant hearing losses. Removal of the hearing aids for listening to music may improve the listening quality to a great extent [5].
- *Use Scotch tape over the hearing aid microphone(s):* This technology level is perhaps the easiest to implement clinically. Placing several layers of tape over the hearing aid microphones will temporarily decrease the sensitivity so the signal that is presented to the A/D converter may be more within its optimal

operating region. There is some experimentation needed with this approach and it does depend on the gauge of the tape but 3-5 layers that can be used prior to listening to music, or playing an instrument, and removed afterwards, will significantly improve the fidelity of the music.

**Technologies**

- *K-AMP analogue hearing aid:* 'Old style' analogue hearing aids do not have an A/D converter and some hearing aids of the 1980s and early 1990s were better equipped to handle the more intense elements of music than today's digital hearing aids. The K-AMP analogue hearing aid (manufactured by Etymotic Research) is still available today in many parts of the world. This 25 year old design can handle inputs up to the limit of modern hearing aid microphones (115 dB SPL) with virtually no distortion. It could be said that we are still playing 'catch up' with technology from 1988 and that digital technology has taken us back several decades, at least when it comes to music.
- *Head Room Expander (HRX):* This is a trade name of Sound Design (now owned by ON Semiconductors). They are a 'third party' manufacturer of hearing aid technology whose customers include many of the large hearing aid manufacturers. HRX functions by 'auto ranging' the input to the hearing aid such that whatever stimuli enters the hearing aid, it is automatically adjusted to be within the operating range of the A/D converter. This technology has been available for about a decade.

Similar approaches are also available now where an analogue compressor is used just before the A/D converter, and then re-expanded digitally after the A/D converter to be identical to the original signal.

- *95 dB SPL may not be the upper limit of modern digital hearing aids:* Contrary to my earlier comments, 95 dB SPL is not really the most intense input that can be transduced without distortion; rather it is a 95 dB dynamic range. The dynamic range is a difference measure between the quietest and the most intense signal and modern digital hearing aids are limited to about a 95 dB range. However, one can also have this 95 dB range from 15 dB SPL to 110 dB SPL. This is still a 95 dB range but one that is better suited to handle the more intense elements of music. This technology has been available for almost five years now [6].

**Conclusion**

Most of the strategies and technologies that have been discussed are related to many hearing aids not being able to handle the more intense inputs of music within their operating range.

Like most areas in the field of audiology, the realm of music as an input to hearing aids and the technologies that are available is a rapidly changing one. New technologies are on the horizon and many similar ones may well be implemented by various manufacturers under a score of different names.

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