Aided Mapping for Music Lovers: Addressing the Basic Issues

By Dennis A. Colucci, AuD

Retired musicians who use hearing instruments frequently stop performing, practicing, going to the concert hall, or even listening to music at home. Discriminating music lovers do the same, avoiding live performances and finding music unpleasant.

This pattern happens not only as a result of detuning of the auditory system, but also because amplified processing can cause music to sound unnatural and uncomfortable, with distortion of pitch and tone.

Frequency (Hz)	125	250	500	1000	1500	2000	3000	4000	6000
PTA	50	50	60	60	65	60	60	60	55
Mod	75	75	80	80	80	80	85	85	85
UCL	85	90	90	90	90	90	90	95	95
NAL-NL1 Modified	NA	7	17	28	30	28	22	22	22
Speech Output	NA	82	85	93	93	90	90	95	95
Music 1	10	15	22	18	15	15	13	13	13
M1 Output	85	90	90	85	80	80	80	80	80
Music 2	15	20	24	15	13	13	10	10	10
M2 Output	85	90	90	85	80	80	80	80	80

This is an actual prescription for a patient who has a flat, moderate hearing loss, with gain and output for the NAL-NL1 real-ear probe response for speech and alterations for the music maps (M1, M2). PTA: pure-tone audiogram; UCL: uncomfortable loudness level.

Long-term music training tunes how the brain temporally binds signals from multiple senses, resulting in specific and unique neuroplastic changes (***Proc Natl Acad Sci U S A* 2011;108[51]:E1441-E1450**). As a result, audiovisual-tactile processing is different in musicians than in nonmusicians, with music memory and actuality more at odds.

As an amateur musician since childhood, I have learned to play some instruments, and, as an audiologist and specialist in acoustics, I understand why amplified music can sound so unnatural when listening to an orchestra with hearing aids.

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Since music and environmental noise can actually train the brain for speech processing and listening in noise, music appreciation is an integral part of hearing rehabilitation for my patients. Frequently, a music program is a must.

Without proper processing in the hearing instruments, too much treble, increased pitch and loudness distortion, and a lack in the sensations of boom, projection, warmth, and fullness damage music acuity and make listening unpleasant.

Music soothes the limbic system, supports neuroplasticity and memory, and is paramount in the treatment of hearing loss, tinnitus, and stress. Therefore, prescriptive methods that enable and enhance feelings of musicality and listening pleasure are crucial in audiological care.

UNDERSTANDING THE BASICS

In order to correlate music with the prescriptive tuning of hearing aids, the audiologist should understand musical and environmental acoustics, auditory system distortion issues, and hearing aid limitations. I will briefly discuss these areas and how they pertain to creating a basic music map.

- Musical acoustics take into account the physics and psychoacoustics of music, the interactions of instruments, and the creation of the desired musical message. Primary tones, beats, and harmonics are coordinated within and between instruments to create ambiance, emotion, and performance. An understanding of how instruments produce sound and how the sounds are perceived by the brain is critical in designing hearing aid prescriptions.

Most music and vocals share their emotional message from signals that are biased by time to frequencies below 2,093 Hz (C7) down to 40 Hz, with emphasis about 440 Hz (A4), which is the tuning standard for music pitch and instrument design.

With only some instruments having primary tones above 2,093 Hz, such as the piccolo, harp, organ, and piano, the harmonics that signify the character of the individual instrument families are low in tone and rarely reach above C7. The loudness of musical instruments falls between very soft

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(pianissimo) at 50 dB and very loud (fortissimo) at 90 dB (**aamhl.org/dBchart.htm**).

In contrast, speech understanding is biased to frequencies of 1,000 Hz or greater, with emphasis in the crunchy and sibilant high tones (2,000 Hz or greater), and loudness varies between very soft at 20 dB and too loud at 75 dB. Thus, music and speech processing require different and opposite performing prescriptions.

- Environmental acoustics pertain to the characteristics of the venue itself, including volume, dimensions, audience size and preferred seating, structure and furnishing, surfaces (reflection, diffraction, and absorption), reverberation time, acoustic and amplified gain characteristics, and a host of other parameters.

Ideal venues balance these characteristics to enhance the musicality within a genre. For example, a concert hall is acoustically tuned differently than an open air venue or studio, which must be taken into consideration as tones, direction, emphasis, and loudness shift.

- A prescription for a live performance may not work well for home listening because electronics and recording devices come between the listener and the instruments. In many cases, electronic equipment, especially car radios and portables, cannot reproduce the low tone signals to adequate levels.

A radio sounds better when it can reproduce lower tones not only from the speaker system, but also from the acoustic amplifier. My preference is that all sound systems include a subwoofer covering the 40 Hz to 200 Hz range to insure that the rhythm or beat of the music is not just audible but at performance levels.

- The auditory system is subject to both peripheral and central changes and distortion, especially from inputs in the high frequencies. In fact, second-order beats are not heard above 1,500 Hz in normal hearing subjects (**Sound vibrations, pure tones, and the perception of pitch. In: *The Physics and Psychophysics of Music*; New York: Springer, 2008**).

Fortunately, the lower tones that have better gap detection and pitch discrimination are fundamental to music perception. Controlling the contribution of the higher frequencies is crucial in reducing discomfort and pitch distortion.

Although fine pitch discrimination can be difficult in more severe cases, where diplacusis is inevitable, enjoying music can be accomplished if the prescription is musically and tonally satisfying.

- Hearing aids can finally be programmed to meet the needs of most patients. Custom programming has never been more available.

However, nonlinear processing used for speech understanding is unnecessary for music because it can sacrifice natural sounds to improve speech reception. Too much compression, low knee points, insufficient control over the output, preselected phase and tone enhancements, directionality, expansion, transposition, and noise-cleaning techniques damage music perception.

Therefore, the ability to control these options is important when fitting hearing aids, especially to a musician or discriminating music lover. For music mapping, I prefer eight bands or more (≤ 125 Hz to 6,000 Hz), with adjustments for 40 dB, 65 dB, and 80 dB gain, and output.

It is also important to measure front-end distortion in the hearing instruments to insure that they are capable of handling higher inputs created by music (***Trends Amplif* 2012;16[3]:136-139**).

I do not fit hearing aids that have black box processing predetermined by the factory because it is impossible to determine individual needs and necessary changes without the patient's interactions.

MAPPING IT OUT

Before trying to program a music map, I obtain uncomfortable loudness level (UCL) and loudness growth curves from 125 Hz to 6,000 Hz, in addition to standard audiological testing. These measures come in handy for maximum power output (MPO) and output compression settings. The goal is to deliver fullness and the right amount of projection, boom, and warmth while providing the higher end treble with crunch and presence without discomfort or distortion.

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I start by using the patient's primary program in the omnidirectional setting with noise reduction and other processing turned off. I use real-ear probe microphone testing to insure that the target gains are matched to a protocol for speech that is successfully used by the patient.

I copy this prescription to an alternate memory and start the process. First, the instruments are set to linear so that the 40-dB gain equals the 65-dB gain and the 80-dB gain would accommodate the UCL and output compression settings.

My initial prescription for a flat, moderate sensorineural hearing loss is loaded in the low tones, with emphasis from 110 Hz (A2, boomy) to the peak at 523 Hz (C5, fullness). Gain and output for the 110 Hz to 523 Hz range may need to be increased by 5 dB to 10 dB above the speech program settings to accomplish the sensation of greater fullness and warmth.

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From 523 Hz, the response is tapered at 3 dB to 5 dB per octave as the pitch decreases to 65 Hz (C2, feel) or increases to 7,040 Hz (A8, brilliance). This creates a 9 dB to 15 dB difference between 523 Hz and 4,186 Hz (C8, presence). Too much gain in the low tones can make the sound boomy or muddy, and too much gain in the high tones will cause distortion and sound tinny and crunchy.

Loudness is controlled so that the output and loud gain using 85 dB HL of white noise produces the perception of "loud, but OK," and the very soft sound is equivalent to 50 dB HL.

I discuss with the listener that seating is very important and advise not to be too close to the orchestra or an amplified speaker system, as high inputs are not necessary for listening pleasure. Furthermore, the patient should have volume control and two programs with different loudness balancing between low and high tones—pivoted at 523 Hz—as venues and genres produce different characteristics.

Regardless of the precision in fitting the starter music map, I always find myself customizing the final prescription. For example, if professional vocals are of special interest to the musician, an increase in the 2,800 Hz to 3,400 Hz range can be added to reach the formants of higher resonances found in the vocal tract of trained singers, allowing the listener to hear the vocals over the orchestra (***J Acoust Soc Am* 1974;55[4]:838-844**). For some patients, based on the degree and slope of hearing loss, the decreases and increases are not as dramatic as those seen in the starter map.

REDISCOVERING MUSIC

With minor alterations in the basic program for fullness and reductions for tinny, presence, and crunch distortions, as seen in the table, I was able to help a retired concert clarinetist with a flat moderate hearing loss "re-enjoy listening to rehearsals and concerts at various venues and orchestras, including the New York Philharmonic at Lincoln Center, with programs ranging from 18th- to "20th-century music."

The degree of electrical activity in the brain that is created by music is dense and diverse, as it shares insight and emotion. Over time, it supports learning, memory, and auditory processing for both speech and noise.

Regardless of the genre, music is a mode of communication in sound and in language. For musicians and music lovers, hearing music satisfactorily maintains or heightens their sense of musicality.

Given the effects of music on processing and its application to hearing loss, it is important that hearing aid programs meet the acoustical and neural challenges necessary to enhance music pleasure and appreciation.

ACKNOWLEDGEMENTS

Special recognition for helping me rediscover my love for playing music and realize the importance of properly programming hearing instruments for musicians and discerning music lovers must be given to Judy Kalin-Freeman—musician, clarinetist, and teacher. Her relentless pursuit and help in establishing the concept of a basic music map for musicians and championing, along with me, the importance of music in the rehabilitation of people with hearing loss is exemplary.

LINK TO MORE INFORMATION

To learn more about music and instruments, see the following charts and explanations that I used in creating this presentation.

- Frequency Chart of Instruments: **bit.ly/FreqChart**.
- Musical Dynamics and Decibel Chart: **bit.ly/dBChart**.
- EQ Sound Frequencies: **bit.ly/EQ-Sound**.
- Orchestral Acoustics 101—Avery Fisher Hall: **bit.ly/AveryFisher**.