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Science Matters

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In this installment of Science Matters we delve into the world of complex pitch and for this, we have a very interesting correction of some of my misperceptions and an overview of some of the elements of complex pitch.

I love being corrected – I learn something new! We all hold views and occasional misconceptions that we are sure are backed up by the data. And I especially love being corrected by someone as well-respected as Dr. William Yost. Who hasn't used one of his textbooks in our training? I keep having to buy another copy of *Fundamentals of Hearing: an introduction* by Yost and Nielsen (and the most recent versions are by Yost and not Yost and Nielsen) because I keep lending it out or it mysteriously goes missing from my office bookshelf.

I recently wrote a Back to Basics column, a monthly article in *Hearing Review* (www.HearingReview.com) and was talking about some things that our patients take for granted as "mother and apple pie." but actually were wrong. For musicians, the big one is that a wider frequency response (that goes down to 20 Hz if possible) is better than one that is restricted to the right-hand side of the piano keyboard. In that Back to Basics column I opined that one of the (many) reasons why a frequency response doesn't need to go down to 20 Hz is the missing fundamental – it is the harmonic spacing or DIFFERENCE between any two successive harmonics that define pitch and not the lowest frequency note name or fundamental (...musicians call this the "tonic"). One may not be able to hear 90 Hz, but one may be able to hear the difference between 900 Hz and 990 Hz- the difference is still 90 Hz but this frequency region is well-within the amplified region of many hearing aids.
...at least that is what I thought that I learned back in 1979 when I first learned about pitch and hearing.
Below are two items – my March 2017 Back to Basics (***with the erroneous part in italics and in bold***), reprinted courtesy of Hearing Review, and Dr. William Yost's reply. It seems that pitch is much more complicated that I thought, or remember that it was!

Back to Basics

March 2017 *Hearing Review*

By Marshall Chasin, AuD

Clinically we all need to walk the fine line between the "values" of our clientele and "facts." I ran into this problem recently where a well-meaning, but perhaps misinformed, musician wanted as much low-end in his hearing aid amplification as he could get. His personal "value" was that a broader bandwidth is always better—after all "half of the piano keys are below middle C" with middle C having its fundamental at 262 Hz. In fact, that's why we have the bass clef. Yet, clinicians know that, if we were to do this, the musician (and anyone fitted this way) would rip the hearing aids out of their ears.

The "fact" part of this balance is that in most hearing aid fittings, significant unamplified low frequency energy is heard which bypasses the hearing aid, entering directly through the hearing aid vent. Whether the sound has been amplified or merely allowed to enter the ear is irrelevant; it is still available to the hard-of-hearing person.

Of course, there are some minor technical differences, and indeed there may be occasional undesired resonances and anti-resonances caused by the interplay between the two sound paths. But, overall, these are of minimal importance, especially when listening to higher level inputs associated with music.

And in order to have significant amplified low frequency sound there needs to be significant occlusion, resulting in the occlusion effect and poor sound quality of a person's own voice (and/or woodwind or brass musical instrument).

The final element of the "fact" side of the equation is the psychophysical property called the "missing fundamental." In addition to perceiving the absolute value of the frequency, our auditory system also locks onto differences in sound energy. A 50 Hz difference between 50 Hz and 100 Hz, can also be perceived as that same 50 Hz difference between 2000 Hz and 2050 Hz. We don't need to hear low frequency sound information in order to perceive low frequency sound information.

Despite these "facts" it is never an easy task to re-educate a musician. And this fine line between "fact" and "value" is not always clear.

Another example of this is the move in the United States to allow over-the-counter (OTC) hearing aids to be dispensed, bypassing the hearing healthcare professional. The values of the consuming public are mother and apple pie: good value with easy and universal access. It is understandable that an OTC approach could fulfill these values, but the facts tell a different story.

In particular, there has been great confusion between "conductive" hearing losses and "sensory neural" hearing losses in the analogies of OTC proponents. Myopia, which may require eyeglasses to correct it, is a conductive problem—light is not properly conducted to the sensory organ of the eye. Changing where light impinges on the retina corrects the problem. Myopia requires merely a refocusing of the light to be resolved (ie, the lenses of glasses), often close to 20/20 vision.

I would agree that an OTC approach could also be used for conductive hearing loss where the sound volume just needs to be turned up. Practically, in cases of conductive visual or conductive hearing loss, there is no maximum light level or sound level that typically needs to be an issue.

In contrast, the vast majority of hearing loss is sensorineural, which is akin to macular degeneration. Resolution of this problem requires significant prescription, counseling, and fine-tuning. In addition, assistive visual and listening devices may be required.
Unlike a conductive hearing loss, the maximum input for a sensorineural loss needs to be carefully controlled and limited. Too high a level and the device may not be worn, and there is a significant chance of over-amplification with associated further hearing deterioration.
Since the vast majority of hearing loss that is seen in the clinic is sensorineural, care must be taken to ensure that maximum levels are not exceeded, and this must be verified by the hearing healthcare professionals.

Eyeglasses are for conductive losses. Hearing aids are for sensorineural losses. The two are quite different pathologies that require quite different levels and models of intervention.

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COMMENT FROM DR. WILLIAM (BILL) YOST, PHD

Dear Dr. Chasin,

I enjoy many of your articles in *Hearing Review* and I read them regularly. However, I would like to encourage you to more thoroughly review the literature on complex pitch processing, so you can better inform the readers of *Hearing Review* on this topic. In the March 2017, Vol. 34, No. 2 issue of *Hearing Review* you repeat a claim that you have made before that the explanation of the pitch of the missing fundamental stimulus is: while the fundamental may be missing from such a stimulus the remaining spectral components are spaced at a frequency difference equal to the fundamental. While this is a true description of the missing fundamental stimulus of an otherwise harmonic series, there is a relatively extensive literature that shows that an equal frequency spacing among the harmonics of an otherwise harmonic series cannot explain the pitch of such stimuli. Without providing an extensive description of that literature, I refer you to the studies published by Roy Patterson (see below) based on his PhD dissertation; works that I believe are the most exhaustive data on the topic. Not only does the literature on what Shouten (see below) called the "residue" or sometimes the "pitch shift of the residue" refute the argument that the pitch of a harmonic-like sequence of spectral components is due to the constant frequency spacing, such "pitch-shifted" stimuli pose a significant challenge for the role of amplitude envelope as an explanation for the pitch of such stimuli. A harmonic series of tones (i.e., F0, 2F0, 3F0,…,nF0, n=an integer) has the same envelope, but a different pitch, than a series of tones consisting of F0+?f, 2F0+?f, 3F0+?f,…,nF0+?f, n=an integer and ?f<=.5F0). For instance, a 200+300+400+500+600 Hz complex has a 100-Hz pitch, but a 240+340+440+540+640 Hz complex has an approximately 106-108 Hz pitch (depending on the listener); its fundamental is 40 Hz and the frequency spacing is 100 Hz, but its pitch is neither the fundamental nor the frequency spacing. And both stimuli have analytically the same envelope. You also stated in this same article: "A 50 Hz difference between 50 Hz and 100 Hz, can also be perceived as that same 50 Hz difference between 2000 Hz and 2050 Hz." Assuming that you mean this in the context of a harmonic series of tones in the study of pitch (not two tones presented in sequence), this claim is not supported by the literature. 2000 Hz and 2050 Hz are the 40th and 41st harmonics of 50 Hz. A large literature (see some examples below) has consistently shown that only harmonics up to about the 10th (certainly not the 40th) can be resolved by the auditory periphery and, as a consequence, be perceived as separate spectral components by human listeners. The pitch of unresolved harmonics can be perceived, but such pitches are very weak, have difficulty in supporting music perception, and fade to obscurity well before the 40th harmonic.

I have also listed some older and some more recent reviews of the pitch of complex stimuli that I highly recommend. I believe that among those in the psychoacoustics field who study pitch processing you will find two agreements: (1) After more than 150 years of trying there is still not an agreed-upon unified theory (model) of complex pitch perception, and (2) At the present time the best one can do given this limitation is to base pitch perception on the temporal fine-structure of the resolved spectral components of a complex sound, especially if one wants to account for musical pitch (i.e., neither spectral explanations nor temporal envelope explanations can account for anywhere as much of the data as explanations based on the temporal fine-structure of resolved components). Pattern matching and autocorrelation-like models are about the best one can do in “modeling” pitch these days, but these two modeling approaches are often transforms of each other and there are several pitch phenomena they cannot account for.

Sincerely yours,

William (Bill) A. Yost, PhD

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