Deriving an Audibility Index for Frequency-Lowered Hearing Aids

Ruth A. Bentler, Bill Cole[1], and Yu-Hsiang Wu
Department of Communication Sciences & Disorders, The University of Iowa
[1]Etymonic Design Inc.

Introduction

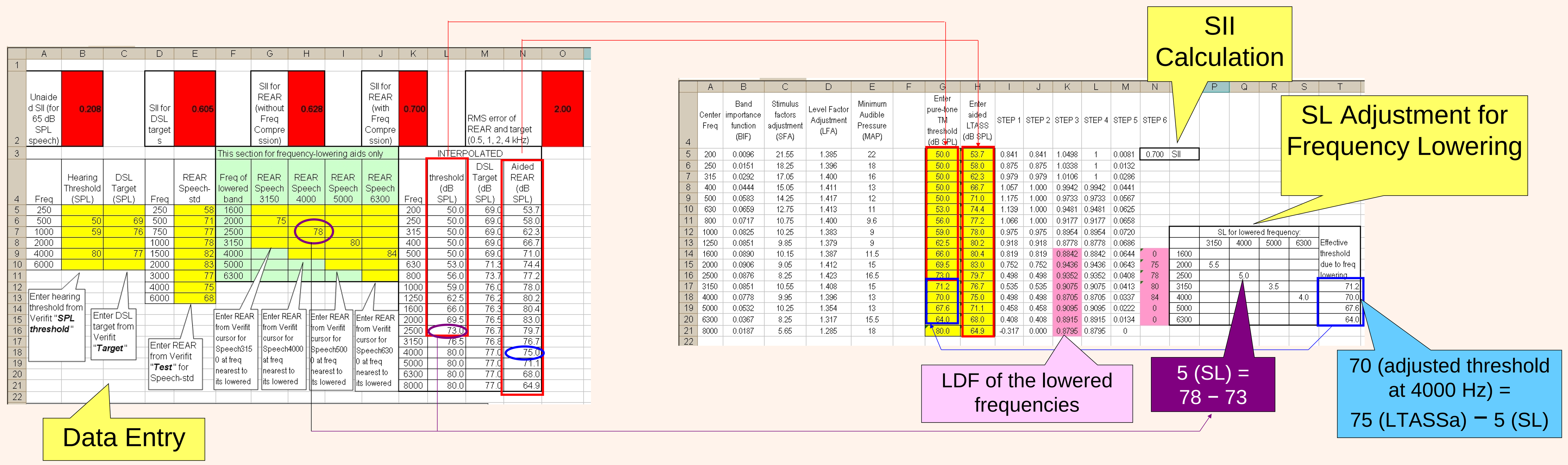
As part of a large NIH-funded longitudinal study of outcomes of children with mild to severe hearing loss*, we were interested in the contribution of aided audibility to speech and language outcomes. Since most of our subjects are using hearing aids, we have been able to capture some evidence of that audibility utilizing aided probe microphone measures, with derived Speech Intelligibility Index (SII) values for different input levels. However, it became apparent that a significant percentage of our children are utilizing frequency compression hearing aids, thus invalidating the SII obtained with our previous Verifit measures.

Methods

We have developed an algorithm that calculates a weighted audibility provided by frequency compression hearing aids, using the band-passed speech stimuli of the Verifit (Audioscan). We do so by adjusting the SPL thresholds at 3150, 4000, 5000 and 6300 Hz (interpolated) to produce the same Sensation Level (SL) at those frequencies for the amplified standard speech signal as is produced by the band-passed speech stimuli after they have been lowered. We then multiply the audibility at 3150, 4000, 5000 and 6300 Hz by the band-importance functions (BIFs) for those frequencies and the level distortion factor (LDF) for the level of those band-passed speech stimuli after they have been lowered.

Example

After frequency lowering, let's assume the SL of the Speech4000 band is 5 dB at its lowered frequency of 2500 Hz. We adjusted the SPL threshold at 4000 Hz to give an SL of 5 dB for the standard speech signal. This ensured that the correct band-weighting value is applied. We then multiplied by the level distortion factor for the 2500 Hz level of the lowered Speech4000 band. Consequently, in this modified SII model, the band importance factors remain those of the unshifted frequency components while the level distortion factors are those of the shifted frequency components. The usefulness and limitations of this derived algorithm will be discussed.



Steps in the calculation: IN EACH 1/3 OCTAVE BAND where LTASSa = aided LTASS and TSPL = SPL threshold:
STEP 1:Calculate the audibility (A) as: A = (LTASSa - TSPL + SFA)/30
STEP 2: Clip A at 0 and 1
STEP 3: Calculate the Level Distortion Factor (L) as L= LFA - .00625*LTASSa
STEP 4: Clip L at 0 and 1
STEP 5: Calculate SII band contribution as A*BIF*L
STEP 6: Add the band contributions to get the SII

Notes:
The SII 1/3 octave band importance function has been multiplied by 1.0088 to account for the loss of the 160 Hz band.
The Minimum Audible Pressure is from Speechmap/DSL 4.1.
The average free-field-to-eardrum function is from S3.5-1997.
SFA = 15 + MAP – Bandwidth adjustment – Avg REUG – Ref internal spectrum noise level (x)
LFA = 1 + (Bandwidth Adjustment = Ave REUG + SII standard normal speech + 10)/60

Limitations

There are a number of potential limitations to this method of estimating audibility, including:

1. None of the masking effects of SII (e.g., spread of masking) have been implemented; their effect is small, however, for most applications and we are looking for relative SII values, rather than absolute accuracy.
2. The band-importance functions (BIFs) used are from the average speech in ANSI S3.5, compensated for removal of 160 Hz. These BIFs may not be appropriate for this pediatric population.
3. Calculation of this audibility factor may not be consistent with the original intent of the SII; that is the goal is to quantify the sensation level of accessible speech cues. The original SII was used as a prediction of speech recognition performance. Recent data (Grant & Braida, 1991; Gustafson & Pittman, 2011) remind us that equivalent SII values do not result in equivalent performance for adult or children, even when the stimulus type (short passages, singles words, etc) is considered. That is, our calculation assumes that the contribution to speech intelligibility of any frequency band is independent of other non-overlapping bands. The contribution of each band adds linearly. However, other researchers (Grant & Braida, 1991; Gustafson & Pittman, 2011) have shown that it may not be the case.
4. A single calculation of audibility of a standard speech signal for this type of processing does not address the issue of removal of spectral fine structure, known to impact format transitions, among other effects. As a result, the validity (for purposes of predicting speech perception) must be studied.

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Outcomes of Children with Hearing Loss
a study of children ages birth to six

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