Research on the effects of frequency-lowering signal processing has proliferated rapidly over the past few years, leaving audiologists who fit hearing aids for children with many questions about whether or not this processing should be activated. As former pediatric audiologists who became researchers, we have been interested in research questions that would help audiologists know which children who are hard of hearing should have frequency lowering activated in their hearing aids. Although there are still many questions about frequency lowering left to be answered, research from our laboratory and data from other researchers have helped to enhance our understanding of how this processing might benefit children who are hard of hearing.

Audible Bandwidth
Frequency lowering is designed to enhance access to high-frequency speech sounds by moving them to lower frequencies where the hearing aid can provide more gain, or where hearing loss is less severe. Lowering speech sounds has the potential to increase audibility of high-frequency speech sounds, but also carries the risk of distorting speech cues. This trade-off between audibility and distortion is a key factor in determining whether or not frequency lowering should be activated. In terms of candidacy, children who have limited access to high-frequency sounds with conventional amplification should be considered candidates for frequency lowering. The audible bandwidth represents the range of frequencies audible to the listener with conventional processing. The upper limit of the audible bandwidth is the frequency range between where the average and peak of the long-term average speech spectrum intersect the audiometric thresholds in the high frequencies (FIGURE 1). The upper limit of the audible bandwidth can be estimated from the SPL-O-GRAM during hearing aid verification.

To optimize the audible bandwidth with frequency lowering, a setting should be selected that lowers the maximum input frequency with frequency lowering to within the upper limit of the audible bandwidth. For example, if a patient has an upper audible frequency limit of 3500 to 4000 Hz, and if the maximum input frequency for the hearing aid is 11,500 Hz, then you would want to lower 11,500 Hz to somewhere between 3,500 and 4,000 Hz. Doing this will maximize the bandwidth that is audible to the patient. To minimize distortion, you want to avoid selecting settings that lower the maximum input frequency to a frequency lower than the upper limit of the audible bandwidth. Our research has shown that using this procedure improves speech understanding when compared to conventional amplification or to other fitting methods for frequency lowering (McCreery et al, 2013; McCreery et
al, 2014). If the upper limit of the audible bandwidth with conventional amplification is greater than 6000 Hz, the potential for increased audibility with frequency lowering is marginal and, therefore, might not have a benefit.

### Acclimatization

Several previous studies have suggested that some of the speech recognition benefits that occur with frequency lowering may require listening experience with the processor before they can be observed (Glista et al, 2012; Wolfe et al, 2011; Ellis and Munro, 2015). In other cases, some improvements in speech recognition are immediately apparent, even without previous experience listening to the frequency lowering (McCreery et al, 2014). These results suggest that the benefits of frequency lowering may not be immediately apparent when assessed as part of clinical validation, such as an aided speech recognition assessment. Audiologists should document aided speech recognition in children at the initial fitting when frequency lowering is activated and then again after at least 6–8 weeks of consistent hearing aid use. Clinicians should consider using speech recognition materials that contain a sufficient amount of high-frequency exemplars to ensure that differences in high-frequency audibility related to the processing can be detected.

### Sound Quality

Although the primary purpose of frequency lowering is to increase the audibility of high-frequency speech sounds, children may be less likely to use frequency lowering if the processing reduces perceived sound quality. Our research assessing multiple dimensions of sound quality for children compared conventional amplification with limited high-frequency bandwidth to conventional processing with extended high-frequency bandwidth and frequency lowering (Brennan et al, 2014). Preference was assessed for children with mild to severe hearing loss for speech and different types of music. The preferred type of processing varied widely across the children, and most children did not have a preference. While few children expressed a preference for restricted bandwidth, most of the children in the study preferred either extended bandwidth conventional processing or frequency lowering, or did not show a consistent preference. The variability in listener preference for the three different types of processing suggests that we should ask children about sound quality when they are old enough to report a preference. Assessing the child’s perceptions about sound quality can allow audiologists to achieve frequency-lowering settings that enhance audibility without sacrificing sound quality.

### FIGURE 1

The aided long-term average speech spectrum (LTASS) in dB SPL as a function of frequency (Hz). Connected circles represent the right ear thresholds. The solid green line represents the average of the aided LTASS and the blue lines represent the peak (upper) and minimum (lower) of the LTASS. The shaded blue area of the LTASS is audible. The black arrows represent the points where the LTASS intersects the audiogram for the average (right-facing arrow) and peak (left-facing arrow). The solid black lines demonstrate the frequencies where those intersections occur. The range between the two arrows represents the maximum audible frequency range for this patient (approximately 3000–3800 Hz).
Future Directions for Research

Although significant progress has been made to advance our understanding of how frequency lowering affects speech recognition and sound quality for children who wear hearing aids, many questions remain unanswered. Much of the research conducted with frequency lowering has focused on a single approach to frequency lowering, nonlinear frequency compression. Comparisons of the benefits and limitations of different types of frequency lowering may help audiologists to better identify which types of processing to use with children or with different audiometric configurations.

Methods of optimizing frequency lowering for individual patients would also benefit from further research. Specifically, there is limited evidence to support whether or not frequency-lowering settings should be symmetrical between ears or allowed to vary in cases of asymmetrical hearing loss. Maximizing the audible bandwidth is a simple way to assess the potential benefits of frequency lowering, but different combinations of frequency lowering parameters may result in similar enhancements to audibility. More research is needed to help clinicians optimize the parameters of frequency lowering to provide the best outcome.

References


