Investing in new hearing aids or maybe even your first pair can be overwhelming. Today, some advanced technology features, which were formerly only available in expensive, high-end hearing aids, are now available in economy-level hearing aids. This article discusses several new hearing aid technologies and suggests questions that you may want to ask your hearing health providers when you select your next set of hearing aids.

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#### Access to High-Frequency Information

Audibility of high-frequency sounds is essential for developing speech and language. The ability to hear high-frequency speech sounds is crucial for understanding speech as well as the rules underlying language and grammar, such as plurality, possessives and subject-verb agreement. Furthermore, research has shown that when children with hearing loss cannot adequately hear sounds above 4,000 Hz, they will have to be exposed to three times as many words as children with typical hearing to learn new vocabulary and concepts due to the reduced acoustic bandwidth caused by the hearing loss (Pittman, 2008). The “Familiar Sounds Audiogram” shown in Figure 1 illustrates the large number of consonants that reside in the high frequencies. Unfortunately, hearing aids have typically been limited in their ability to provide sufficient audibility for high-frequency sounds.

Figure 1. Familiar Sounds Audiogram (high-frequency sounds are circled in red)

Hearing loss is frequently poorer in the high frequencies relative to the low frequencies. In response to the aforementioned difficulties, hearing aid manufacturers have developed several approaches to improve audibility and understanding of high-frequency speech and environmental sounds.

Traditionally, hearing aids have been unable to provide sufficient amplification for sounds beyond 4,000 to 6,000 Hz. This constraint was primarily attributed to a limitation of the hearing aid receiver (the term used to refer to the miniature speaker of the hearing aid), which simply could not provide adequate amplification of high-frequency sounds. Additionally, the hearing aid would often produce acoustic feedback (i.e., whistling, squealing) with attempts to amplify high-frequency sounds.

Recently, several manufacturers have introduced “extended bandwidth” hearing aids, which promote improved receivers that...
sufficiently amplify sounds to 8,000 Hz and beyond. Although this technology is promising, there is a paucity of studies showing significant improvements in speech recognition with the use of extended bandwidth amplification. Research studies addressing technologies designed to enhance access to high-frequencies will be discussed following the proceeding discussion on frequency-lowering technology.

Rather than attempting to extend the limits of the hearing aid’s frequency response, some manufacturers have developed hearing aids with frequency-lowering technology. Frequency lowering can be achieved by linear frequency transposition (LFT), non-linear frequency compression (NLFC), or spectral envelope warping (SEW). A brief explanation of each follows.

Figure 2.

Linear frequency transposition (LFT) (Figure 2B) takes high-frequency sounds, transfers them down into a lower frequency range, filters the transposed sound and then mixes it in with the amplified low-frequency sounds, where the patient has better hearing, so that the high-frequency and low-frequency sounds are overlaid on one another.

Non-linear frequency compression (NLFC) (Figure 2C) takes high-frequency information above a designated frequency range, referred to as the crossover frequency, and compresses it into a lower range as determined by a pre-set frequency compression ratio. Sounds below the crossover frequency are not compressed, and low-frequency and high-frequency sounds are not mixed with one another.

Spectral envelope warping (SEW) (Figure 2D) is designed to capture a high-frequency sound information and replicate it at a lower frequency. Similar to LFT, the bandwidth of the high-frequency sound information is not altered, SEW moves the high-frequency of sound to a lower frequency range, where the low-frequency and high-frequency sounds are overlaid on one another. However, in contrast to LFT, SEW also amplifies the high-frequency sound and presents it at its original frequencies as well (Rodemerk et al., n.d.; Simpson, 2009).

All of the aforementioned frequency-lowering strategies possess potential advantages and limitations, and there are no published research studies showing one approach to be superior to another. However, published studies have shown that each of these different frequency-lowering technologies can improve audibility and speech understanding of high-frequency speech sounds for children and adults with severe to profound hearing loss (Auriemmo et al., 2008; Glista et al., 2009; Kuk et al., 2010; Simpson et al., 2005; Galster et al. 2011). Additionally, Wolfe and colleagues (2010; 2011) determined that NLFC improves audibility and recognition of high-frequency speech sounds for children with moderate high-frequency hearing loss, and they showed that performance with NLFC improved with experience (i.e., acclimatization) with the frequency-lowering technology. As such, several weeks of NLFC use may be necessary before benefit is fully realized. More recently, Wolfe and colleagues (submitted, 2013) compared aided thresholds and speech recognition for a group of children who had mild hearing loss and used hearing aids with NLFC and extended bandwidth. NLFC provided better access to low-level high-frequency sounds as well as better recognition of high-frequency speech sounds when compared to hearing aids with extended bandwidth.

Ask your audiologist

As previously mentioned, there can be disadvantages associated with frequency-lowering technology. In particular, if the frequency-lowering is too aggressive, then speech and environmental sounds may become distorted resulting in poor sound quality and a reduction in speech understanding. Audiologists should properly select good candidates for frequency-lowering technologies, program this technology appropriately for the individual’s needs, and verify the benefit the wearer receives through the use of probe microphone measures (ask your audiologist about probe microphone measures if you are unaware of this important hearing aid assessment tool). Further, the benefits of frequency-lowering technology should be validated with behavioral testing and feedback from parents, speech therapists, and teachers. Researchers have suggested several different practices to effectively fit and verify frequency-lowering technology as well as to determine candidacy for these technologies (Glista & Scollie, 2009; Kuk, 2013; Simpson, 2009; Wolfe et al., 2010, 2011).
Hearing Aid Noise Reduction Technologies

One of the most pressing difficulties of persons with hearing loss is an inability to effectively understand speech in the presence of noise. Studies have shown that around 40% of adult wearers continue to be unsatisfied with their ability to hear in noise after being fitted with hearing aids (Kochkin, 2010). Numerous research studies have shown that children with hearing loss experience even more difficulty understanding speech in noise when compared to their peers with typical hearing or adults with hearing loss (McCreery et al., 2010; Stelmachowicz et al., 2001). Hearing aid manufacturers have developed numerous technologies to improve performance in noise, including directional microphones, digital noise reduction (DNR), wind noise reduction, and dereverberation algorithms.

Directional microphone technology typically employs two or more microphones to amplify sounds coming in from the front as prescribed, while limiting or reducing amplification for sounds coming from the sides and back. This approach assumes that the wearer will face the signal of interest in a noisy environment, and consequently, the speech will be enhanced and the surrounding noise will be reduced. Numerous research studies have shown that directional microphones improve speech understanding in noise more than any other technology currently built into hearing aids (although directional microphones do not provide as much improvement in speech understanding in noise as remote microphone radio frequency systems—also commonly known as FM systems—which are an assistive technology that may be used with hearing aids to provide the most improvement in speech recognition in noise (Schafer & Thibodeau, 2004)). As a result, directional technology is routinely recommended for adult hearing aid wearers.

In contrast, there are conflicting recommendations regarding the use of directional microphones in children (Bagatto et al., 2010; King, 2010; McCreery et al., 2012; Ricketts et al., 2010). For instance, the Ontario guideline for fitting hearing aids for children discourages the use of directional microphones for children, while the Australian guideline recommends the use of directional hearing aids for children (Bagatto et al., 2010; King, 2010). The hesitation associated with directional microphone use in infants centers around the concern that directional amplification may limit a child’s access to important sounds that arrive from behind him/her. We know that incidental listening, the term used to describe a child’s tendency to listen to speech that is not directed specifically to him or her, is responsible for a great deal of a child’s vocabulary and social development. In fact, Dr. Carol Flexer has estimated that as much as 90% of what a child learns during the first few years of life comes from incidental listening (Cole & Flexer, 2010). Could directional microphones, which inherently limit access to sounds arriving from behind a child, interfere with incidental listening? There has not been enough research examining directional hearing aid use in young children to fully answer that question yet.

Digital noise reduction (DNR) is another hearing aid noise technology designed to improve performance in noisy environments. DNR analyzes the sound arriving to the hearing aid, determines whether it is speech or noise, and reduces the aided gain when background noise is the dominant input. Research conducted with adult hearing aid users has shown that DNR significantly improves listening comfort in noise,
and wearers consider DNR to be one of the most important features in their hearing aids (Powers et al., 2006; Kochkin, 2010). Other studies have indicated that DNR provides at most a modest improvement, and in many cases, no change in speech understanding in noise (Bentler, 2005; Peeters 2009). Most studies have shown no degradation in speech recognition in noise for adults using DNR. Like directional technology, DNR is routinely recommended for adult hearing aid wearers.

As with directional hearing aids, we are still examining the appropriateness of DNR for young children. Research with pediatric hearing aid users has essentially shown that DNR does not degrade or improve speech recognition in noise (Bentler et al., 2010; McCreery et al., 2010). Bentler and colleagues (2010) did show that DNR may improve listening comfort for children in noisy situations. They also showed that children’s novel word learning abilities were improved with the use of DNR, a fact they attributed to a decrease in the cognitive processing load afforded by improved listening comfort associated with DNR. Taken collectively, these findings suggest that DNR may be quite beneficial for children and should be considered for use with pediatric hearing aid wearers (McCreery et al., 2010; Stelmachowicz et al., 2010).

However, it is important to remember that not all hearing aids work alike, and it is possible that some DNR algorithms may reduce gain for speech. It is imperative that the audiologist verify that gain is not reduced when speech is present. Contemporary hearing aid testing equipment typically allows for this type of verification. The interested audiologist is referred to an excellent review by McCreery and colleagues on electroacoustic assessment of hearing aids with DNR (McCreery, Gustafson, & Stelmachowicz, 2010). Once the audiologist does determine that DNR does not reduce gain when speech is present, DNR should be considered for pediatric hearing aid wearers.

**Binaural Processing**

There is a reason we have two ears. In people with typical hearing, the ears work together to better understand speech in noisy environments as well as to determine the direction from which a sound originates. For instance, we can tell that a sound originates from our right side, because it is a little louder and arrives a little earlier at the right ear than the left. Hearing aids are now capable of sharing information with one another in an attempt to preserve the natural differences that exist between sounds arriving at the two ears and mimic the way the natural auditory system works.

**Figure 3. Directionality with Binaural Processing.**

Furthermore, some hearing aids work together so that a wearer may adjust the volume or a program on one hearing aid and the change automatically happens at the other hearing aid. Some hearing aids also have the capability of allowing the user to hear the sound from a telephone in both ears simultaneously when the phone is placed next to one of the hearing aids. Finally, some advanced hearing aids share information between their microphones in order to allow for “super directionality.” As shown in Figures 3B and 3C, beamforming achieved by two hearing aids working together can be much more precise than either hearing aid working alone.

**Figure 3A. Omni-Directional Microphones without Binaural Processing.** The circle represents the fact that the hearing aids are amplifying sounds from all directions equally, which may result in the wearer experiencing difficulty hearing the signal of interest (i.e., “How are you?”) over the surrounding noise.

**Figure 3B. Directional Microphones without Binaural Processing.** Here, a directional hearing aid provides amplification for sounds arriving from directly in front of the wearer, while reducing the volume for sounds arriving from other directions. As shown, much, but not all of the noise is attenuated by the directional amplification.

**Figure 3C. Directional Microphones with Binaural Processing.** Here, a listener is using hearing aids with directional microphones enhanced by binaural processing. Note how the binaural directional response is more focused on the sounds arriving from the front than the directional response achieved by the hearing aids in Figure 3B. There is the potential to provide better speech recognition in noise than conventional directional hearing aids without binaural processing.
Streaming Accessories

Almost every major hearing aid manufacturer now has a way to wirelessly link your hearing aids with your personal technology (from phones to computers to TVs). Some companies use “streamers” (a device you wear around your neck to allow you to interface between the hearing aids and the accessory) to wirelessly connect to your personal products, while other manufacturers have developed hearing aids that allow you to wirelessly connect without an interface device. Some manufacturers also offer a wireless microphone accessory, which can pick up an important voice and wirelessly send it to the hearing aids directly or via the streamer. This type of technology is great for noisy environments such as a restaurant, because the voice of a parent (or spouse) can be captured by the microphone and sent directly to the hearing aids of the child (or significant other).

Smartphone technology is also paving the way to allow you to use an app to control your hearing aids. This is an ever-evolving technology, so ask your hearing professional about the best option for your lifestyle.

Digital Modulation (DM) Radio Frequency (RF) Systems

Personal remote microphone radio frequency (RF) systems have been around for a long time, and have long been recognized as the most effective means to improve speech recognition in noisy places. In short, these systems possess a microphone/transmitting unit that captures the signal of interest and sends it by way of a radio signal to small receivers that are coupled to the user’s hearing aids or cochlear implant sound processors. Because the microphone is positioned closely to the mouth of a parent or teacher, the speech signal captured by the system’s microphone is typically much higher in volume level than the surrounding background noise. The transmitting device may also be plugged into a computer, MP3 player, classroom smart board, etc., to directly capture and send that audio signal of interest to the receivers.

Historically, these types of systems have used an analog frequency modulated (FM) RF signal to transmit the signal of interest. Recently, manufacturers have started introducing digitally-modulated RF systems, which are similar to Bluetooth® technology used in several recreational and business applications. Digital RF systems are able to provide a higher level of analysis and control over the signal that is captured by the microphone and eventually delivered to the receiver. Furthermore, these systems typically use a carrier frequency that “hops” from frequency to frequency many hundred times per second, a characteristic that makes digital RF systems less susceptible to interference from nearby RF devices (Wolfe et al., in press). Studies have shown that hearing aid and cochlear implant users receive great benefit from dynamic digital RF systems when compared to traditional/classic and dynamic FM systems (Thibodeau, 2013; Wolfe et al., in press).
Waterproof/Water Resistant

Perhaps it’s just icing on the cake, but besides all of the great technology that allows individuals to hear better in a variety of settings, several hearing aid companies have now made some of their products water-resistant. Some even claim you can swim with them. It is important to consider how the warranty works if you do choose to participate in water activities with the hearing aids on. Some are not “water-resistant” per se, but have a special coating inside the electronics that helps repel moisture—especially good if you (or your child) are susceptible to excessive sweating or have wax problems. If you know that you have this specific concern, let your provider know so they can request that special coating is applied to your hearing aid as it may not be standard in all cases.

Ask your audiologist

In summary, hearing aid technology has improved significantly over the past few years. Although it is not perfect, contemporary technology can improve the communication abilities of most everyone with hearing difficulties. If you are struggling with your hearing, you should consult your audiologist to determine whether new technology may alleviate your communication difficulties. Your hearing is too important to struggle through life with inferior technology. Additionally, make certain you see a licensed audiologist who is experienced with providing new technology for patients in your age range (or the range of your child). The best technology in the world can be worthless if it is not selected and fitted appropriately to meet the wearer’s needs. Remember, we should work together to use new technology so that each person with hearing loss reaches his/her full potential. Your hearing is worth it!

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