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Noise Management in Pediatric Hearing Aid Fitting

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The provision of hearing aids for infants and young children is just one of those professional services for which audiologists feel a high level of accountability, so it receives a lot of effort and attention when we develop evidence-based practice guidelines and protocols. Decision-making for the developers of these protocols is usually made more complicated by the fact that trials with hearing aid signal processing are rarely done with young children, and rarely done with young infants. We are often therefore in the position to make practice recommendations in the absence of direct evidence, so instead, we integrate what we know about auditory development and learning with what we know about signal processing and outcomes from studies that use either electroacoustic measures or trials with older children or adults. It's the best we can do. In recent years, this has never been more true than with recommendations for noise management for children who use hearing aids.

Hearing aid signal processing for noise management employs three main strategies: (1) directional processing; (2) automatic noise reduction; and (3) multiple programs in hearing aids, often with automated switching between these programs. Our current view of each of these, through a pediatric lens, is summarized below. These general concepts are included in the Ontario Infant Hearing Program Protocol for the Provision of

Amplification,[1] which we co-developed with colleagues in the OIHP. A full copy of this protocol is available for download (https://tinyurl.com/w7v44e2). Our core rationales for the use of noise management for children include the frequent exposure of infants, children, and teens to high levels of noise,[2] the high perception of loudness that some children experience for high-level sounds[3–7] and the knowledge that excessive loudness can sometimes limit the duration of hearing aid use[3,4] We know that full-time hearing aid use is an important predictor of long-term benefit from hearing aids, so management of louder environments may help to facilitate daily full-time use.[8]

Several technologies exist for providing noise management within hearing aids for children of all ages.

Directionality: It's very common for hearing aids, especially behind-the-ear hearing aids, to offer beamforming options that use multiple microphone arrays to focus the sound pickup more in one direction, suppressing some sound from other directions. This directional beam is often pointed to the front of the listener but may also be adaptive or user-controlled to point in other directions. **Directional systems are proven to support easier and more successful speech recognition in noisy situations** when there is some spatial separation between the target talker and the surrounding noise.[9] Directional systems vary. They can be strong, pointing only in the front and providing fixed and significant suppression of sounds from the sides and back. They can also be mild, using a wide or multimodal beam with less suppression of sounds from the sides and back, and may adapt to find speech-laden sources around the listener. Some use bilateral wireless links to help the two hearing aids work as a team, supporting a different range of beamforming than is possible with one aid alone. Finally, they can be pinna-matched, by applying a slight amount of directionality that is designed to mimic that of an open external ear. Pediatric studies confirm that children derive benefits for speech understanding in noise, and may prefer noise reduction from directionality at least in lab conditions.[2,10] For younger children, we consider how the use of directionality might interact with sound awareness, overhearing, and localization for young children. We know that **overhearing** is an important learning strategy for young children and that **children don't orient their heads to the talker** of interest most of the time, which can create a directional disadvantage for non-frontal sounds (see AAA, 2013 for a review of this issue).[11] We know that localization of sound

emerges early but continues to develop through childhood,[12] so from a pediatric perspective it may be important to understand how a directional system impacts localization. Horizontal localization is mainly driven by the low-frequency components of sounds,[13] which may explain why children, like adults, localize better with **open fittings**.[14] **Pinna-matched directionality** provides better localization in adult hearing aid users compared to omnidirectional microphones in behind-the-ear hearing aids.[15,16] **Binaurally-linked microphones** have mixed results, but some studies indicate that they may improve localization and/or speech recognition in noise over omnidirectional processing, and that linked systems may preserve binaural cues and be preferred in blind testing, at least for adults and school-aged children.[17–19] Putting all of this together, it's not about whether to use "directional" for kids or not because the reality is more refined than that – it's not an “off versus on” discussion anymore. Current practice guidelines recommend against full-time use of fixed/strong directional hearing aid programs and encourage the facilitation of overhearing in younger children.[1,11] However, **some directional systems may be acceptable** for use especially with children who can monitor their environments. For example, if a hearing aid is fitted with significant venting, pinna-matched directionality, or other proven technologies, it may support accurate localization of sound while maintaining speech in noise benefits.

Noise reduction processors reduce gain and output in frequency regions that are dominated by noise. They reduce the physical level of noise and noisy speech, providing a lower overall listening level to the hearing aid user.[6] Early concerns about the developmental impact of noise reduction included the unknowns of how it might affect access to speech sounds or awareness of environmental noises. Recent studies show that **noise reduction doesn’t degrade speech recognition** for children who are hearing aid users and may provide **easier listening** and **loudness relief**.[10,20,21] As with directional systems, noise reduction systems **vary in strength** and maybe either fast-acting or slow-acting, and it’s possible to test strength and speed with hearing aid analyzers.[6] Some strong-acting systems may degrade sound quality. However, most studies of noise reduction with children have examined mild to moderate systems. One recent study found that many adults may prefer a stronger setting, but the preferred strength for noise reduction by children remains unknown. Current pediatric protocols

recommend **routine use of noise reduction**, as well as **routine verification** of the processor so that the clinician is aware of the strength level that has been applied.[1,11] It is also possible to combine noise reduction with reduced gain in a noise program, with the overall effect of reducing loudness.[2]

Multiple programs in hearing aids allow control over the allocation of gain levels, directionality, and noise reduction as well as how these will be applied in different environments. Most hearing aids can automatically select programs in real-time. **Automatic activation** of an age-appropriate noise management program is recommended for most children.[1,11] **A targeted program for use in loud or noisy places** can use lower gain levels,[4,5] activate noise reduction and may apply directionality. Particularly when combined with data logging, this strategy can provide insights into how much noise is in a child's life, which programs are used the most, and help with discussions on whether certain situations are still needing more support to promote comfortable listening. In particular, if hearing aids are taken off because of noise tolerance issues, that means that they then need to be put back on. One goal for young children is to work towards 10 hours or more of daily hearing aid use, especially once they no longer take naps.[7] To achieve this goal, we need to prevent disruptions in use, and disruptions due to loudness intolerance can sometimes be ameliorated with an effective noise management strategy. **Monitoring daily use** to **ask about noisy times** of day may provide insight into barriers and their solutions.

In summary, times and technology and knowledge have changed. Certainly, **recommendations for the use of noise management for children has varied across protocols and time**.[22–24] Some variability was linked to a lack of evidence when early generations of noise management technologies became available, particularly evidence that could inform how we use these for children. However, this changes as evidence evolves. Particularly for noise programs, some types of directionality, and medium-strength noise reduction systems, we have direct evidence from older children to indicate that the benefits include improved comfort, preferred usage, and improved speech recognition in for signals from the front. Newer verification and usage logging options allow us to test processors objectively, and to document the use and impact of interventions we have provided. These objective indicators can, in turn, help us to evaluate and change intervention strategies. **Kids spend a lot of time in noise.** It’s ok

to harness today’s technologies to help them out, and an ever-growing body of research that can inform the decisions.

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