Phonak
Pediatric Focus 4.

Noise reduction in children's hearing aids: Evidence-based solutions

This expert consensus article reviews the basic principles and pediatric evidence on noise management for use in pediatric hearing aid fitting. Our recommendations include steps for clinical practice today and for future directions.

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In their daily lives, children live, learn, and play in noisy environments (Cooper et al., 2025; Crukley et al., 2011; Glista et al., 2021). In this review, we consider a wide range of hearing technologies, clinical protocols, and technical measurements that can help inform best practices (Roush & Jones, n.d.; Scollie et al., 2020.) for providing hearing aid interventions that are tailored for use in both quiet and noisy places. This Focus reviews recent evidence that supports child-centered, verification-informed decision-making. We aim to provide consensus on what is known now and offer recommendations for future directions.

Children's auditory ecology and the rationale for noise management

Several studies have evaluated children's auditory ecologies. Auditory ecology research considers the soundscapes of real-world environments using a variety of methodologies (Gatehouse et al., 2003). Crukley et al. (2011) used experimenter diaries and dosimetry to follow the daycare and school days of children in four age groups, compiling a sample of data for a continuous day. Across all age groups, children experienced sound levels greater than 75 dBA for periods of time exceeding 30 minutes. Characterization of these experiences indicated that the loudest portion of the children's days happened during active indoor play periods. The main source of high-level sound was produced by the children themselves, rather than noise from machinery or vehicles. Children and caregivers have reported experiencing a wide range of sound environments that vary in overall level, noisiness, and types of background noise (Cooper et al., 2025; Glista et al., 2021). Similarly, Easwar et al. (2016) found that children with cochlear implants were regularly exposed to environments with overall sound levels greater than 70 dBA. These studies illustrate that loud environments are part of children's daily auditory ecology.

Glista and colleagues (2021) examined children's hearing aid preferences using real-time assessment in real-world use and found that school-aged children and teens can and do choose among hearing aid programs based on their current listening environment. This agrees with past real world (Scollie et al., 2010) and in lab (Pittman & Hiipakka, 2013) studies showing that children can choose among hearing aid programs based on listening environment.

Noise Management is an umbrella term used to describe a set of related technologies that can be used separately or together with the aim of improving hearing experience in noise and device use. Noise management technologies fall into two broad categories: those that reduce noise, and those that facilitate the use of noise management. Both types will be considered in this article. A noise management strategy can include the option of multiple programs with automatic program switching, different prescriptions of gain or output levels for use in quiet versus noise, directional microphones, adaptive noise reduction, impulse (transient) signal reduction, and data logging with environment-specific classification. Caregiver and child partnership factors, as well as monitoring practices should be included (Bagatto et al., 2023). These strategies/practices have evolved over time as hearing aid technology has developed from analog, which provided no noise management, to digital devices that provide automatic activation in specific acoustic environments. Consensus has developed in professional resources (Audiology & Henry, 2020; McCreery et al., 2010), in critical and systematic reviews (Chong & Jenstad, 2018; McCreery et al., 2012b), and in evidence-based practice guidelines (AAA, 2013).

Rationales for providing any kind of noise management include alignment of the hearing aid fitting to the preferences of the child in noisy places, to promote comfort, and to prevent environment-specific needs to remove or mute the hearing device(s). Ultimately, the goal is to increase daily hours of use, and to improve perceptual outcomes such as speech recognition, comfort, and ease of listening without causing unwanted effects such as distortion, sound localization errors, or sound awareness limitations. Within this very broad set of rationales, the clinical programming of features within the hearing aids includes activation and tuning the strength of many signal processors, and the manual/automatic activation of programs across environments. Automatic activation is commonly used in children's hearing aids (Bagatto et al., 2023; Lundin, 2024a), and provides rapid, convenient switching between programs used for noisy versus non-noisy environments. Manual activation can be programmed to work with onboard hearing aid controls such as buttons or switches, or more recently via software applications on a smart device, which may provide enhanced levels of user control. In this review, we consider noise management from a processor-specific perspective, aligning with known principles and evidence for each. Current clinical protocols for the provision of noise management emphasize the role of the pediatric audiologist in understanding the supporting evidence for processor types and making wise use of hearing aid electroacoustic analysis (verification) to measure the effects of specific processors (AAA, 2013; Scollie et al., 2016).

Signal processing for noise management

Hearing aid signal processing includes technologies that are aimed at processing sound for speech in quiet and in noise, for noise management, for music listening, and when listening through wireless technologies. Some topics are outside the scope of this article, including signal processing methods like noise floor reduction through expansion, and speech enhancement in quiet environments using channel-specific gain as these are not considered to be part of a noise management strategy. Although the use of remote microphones. are important for noise management, they have been reviewed elsewhere (AAA, 2011), and are not discussed further in this paper.

One important technology to review briefly is multiple microphones that focus the hearing aid's input sensitivity to a specific location. This is commonly referred to as directionality or beamforming. Many forms of beamforming exist, and vary in their location, number of beams, and type of adaptation. These have a range of settings to produce omnidirectional sound pickup, pinna-matched configurations, fixed frontal directionality, and adaptive directionality that finds speech from one or more than one direction. The developmental considerations and clinical use of directionality are reviewed in detail elsewhere. Outcomes (McCreery et al., 2012b) and clinical protocols (AAA, 2013; Bagatto et al., 2023) are described to guide the appropriate use of directionality for different ages and abilities. Briefly, these reviews make clear statements that pinna-matched directionality improves sound localization for behind-the-ear (BTE) hearing aid users, and that other forms of directionality provide well-understood benefits if the target speech is in the beam of sensitivity created by the hearing aid. For younger children and those with developmental differences, the ability and choice to move one's head to focus on the target talker may not be feasible or developmentally appropriate. Adaptive strategies may provide children with directional benefit across varying talker locations (Browning et al., 2019; Wolfe et al., 2022), with stable effects over time (Pinkl et al., 2021). For these reasons, the use of developmentally-appropriate directional strategies is encouraged (Bagatto et al., 2023), as summarized in this companion Pediatric Focus article (Lewis & Bagatto, 2017). In this paper, we incorporate consideration of directional signal processing but also refer the interested reader to these companion resources for more details.

Technologies that reduce noise

Prescription

Noise reduction signal processing can take many forms. Basic gain strategies that automatically reduce hearing aid gain as input level increases act as an automatic volume control, reducing the loudness of high-level sounds (McCreery et al., 2012a). This is typically called wide dynamic range compression, and when used in combination with hearing aid prescriptions that have been adapted for use in noise, further noise management may be possible. For example, the DSLv5 noise prescription was designed to provide lower gains for use in noise programs (Scollie et al., 2005). This noise-specific prescription reduces loudness discomfort for high-level sounds (Crukley & Scollie, 2012). The benefit of the noise program is greater if the noise prescription is combined with other noise management technologies (Crukley & Scollie, 2014), and appears to generalize to real-world hearing aid use (Glista et al., 2021). Providing program-specific gain reduction is a straightforward strategy that can be implemented by simply using a noise prescription as the basis for noise programs. An example of this target difference is shown in Figure 1, with the DSLv5 quiet and noise targets displayed on SPLograms for the same case. The noise target provides a small reduction in output in the low and high frequencies. A numerical display of these differences can be seen in Table 1.

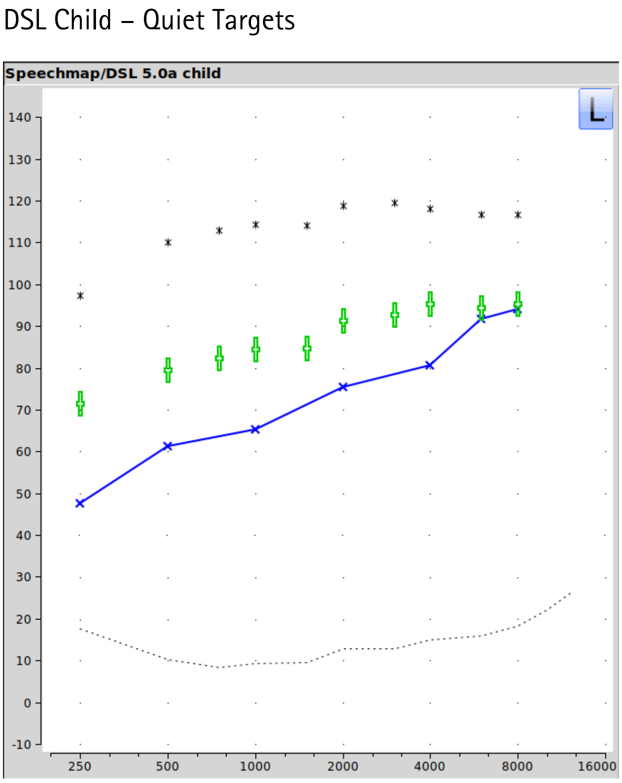

Figure 1. Hearing aid verification screens from the Audioscan Verifit2, displaying prescriptive targets for use in quiet and in noisy environments from the DSLv5 prescription.

	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
DSL Child	72	80	84	91	96	96
DSL Child - Noise	59	74	83	89	91	92

Table 2. Numerical representation (dB) of the prescriptive targets for use in quiet and in noisy environments from the DSLv5 prescription in the above image.

Adaptive noise reduction

More sophisticated forms of noise management signal processing include a range of adaptive processors that attenuate noise either quickly or slowly. Slow-acting adaptive noise reduction uses filtering and multichannel processing to reduce the gain in noisy channels. This well-established set of processors have been available in hearing aids for many years. They vary in their activation time and strength of noise reduction (Chong & Jenstad, 2018; McCreery et al., 2012b; Scollie et al., 2016). Adaptive noise reduction may provide a slight improvement for speech recognition when activated (Pittman & Hiipakka, 2013). More often, studies have shown no improvement or decrement for speech recognition (Crukley & Scollie, 2014) but instead report other benefits such as improved ease of listening, comfort, preference, or sound quality improvements (Chong & Jenstad, 2018; Scollie et al., 2016; Wolfe et al., 2017). Because adaptive noise reduction is most commonly implemented together with directionality, several studies have tested them together. Results of these studies show benefit for speech recognition in noise, as expected for directional systems, when the target talker is located within the directional beam (Crukley & Scollie, 2014; Pittman & Hiipakka, 2013; Wolfe et al., 2017, 2022). In summary, adaptive noise reduction is commonly-available, slow-acting, and is most often shown to improve the acceptability of noise.

Faster-acting processors provide impulse (or transient) noise reduction and are widely available with a range of trade names. These processors detect the onset of rapid, brief, loud sounds such as a door slamming or object dropping, and assign a fast-acting suppressor to quickly but briefly attenuate the impulse sound. The goal of these processors is to attenuate the impulse quickly, but also to recover quickly to avoid reducing ongoing sounds in the listener's environment. One recent evaluation of several brands of impulse noise reduction schemes revealed that the peak sound pressure level during impulses was reduced significantly across most brands, without changes to the aided speech signal (Husstedt et al., 2023). Importantly, the decrease provided by impulse noise reduction was greater than that provided by output limiting, non-impulse noise reduction, or amplitude compression. This indicates that the unique characteristics of impulse noises require a dedicated form of signal processing. Adult hearing aid wearers had reduced loudness discomfort when using the processor, and the improvements in listening comfort were correlated with the strength of the impulse noise reduction. Although these processors have not been evaluated in children, their effectiveness at reducing impulse sounds, for example from dropped items, would align with the acoustic ecology of children and may be expected to decrease situational loudness discomfort.

Clinical strategies for noise management

Our understanding of auditory ecology helps us to see that most children spend time in loud environments and can be considered candidates for noise management. This is consistent with the common default strategy of providing automatically-activated noise programs in hearing aids (Nelson et al., 2024; Wolfe et al., 2017). Technology and clinical practices have changed over time and the provision of noise management is now considered routine. That said, providing effective noise management, having an informed clinician, partnering effectively with families, and meeting individual needs may require verification and tailoring of noise management settings and strengths. Children and families report situational loudness issues that can be highly individualized, so adjustment of settings to meet individual needs is a component of noise management. The following section addresses several different strategies that can be used in clinical practice.

Data logging uses the hearing aids or cochlear implants to measure the total hours of use per day (Easwar et al., 2016; Walker et al., 2013). Pediatric studies have compared this feature against reported use from parents and from teachers, with some studies finding that children may overestimate use time (Flynn et al., 2022), and others finding good agreement (Gustafson et al., 2017). Diving deeper into datalogging, we can also use this function to understand how and when hearing aid users wear their devices in various sound environments, because data logs are now often displayed per environment, as well as across the use period (Humes et al., 2018). Pediatric protocols suggest that environment-specific data logs may provide insight about children's real-world usage, and that lower hearing aid use in noisy environments may indicate candidacy for a more robust noise management plan (Bagatto et al., 2023; Scollie et al., 2016).

The role of *verification* in the provision of noise management for children who use hearing aids is based on two main considerations: (1) ensuring that the noise management strategy does not negatively affect speech sound access, and (2) ensuring that the clinician can characterize the effects of the activated processors (AAA, 2013). Specific clinical protocols have been developed to be used with clinically-available hearing aid analyzers (Scollie et al., 2016). Well-established processors such as adaptive noise reduction and impulse noise reduction have been shown to avoid negative impacts on speech, as reviewed above. However, we also know that the strength of noise reduction varies significantly across hearing aids and settings. Routine verification of adaptive noise reduction is possible with most hearing aid analyzers, and can help the clinician set an appropriate strength of noise reduction. Settings that reduce high-level pink noise test signals by 7- 10 dB have been tested in pediatric studies (Crukley & Scollie, 2014; Scollie et al., 2016; Wolfe et al., 2017), including some that have tuned the adaptive noise reduction to moderate and strong settings.

Tests of adaptive noise reduction allow the measurement of whether various devices or device settings differ and also allow the tester to see the speed with which the activation takes place. Because adaptive noise reduction activation times vary widely, testing to see whether the hearing aids need ten seconds or 40 seconds to adapt fully may help in guiding expectations during informational counselling. Pairing this with verification of speech audibility in quiet and evaluation of directionality can provide a clearer picture of device performance across a range of sound types.

Examples of verification for strength of noise management signal processing across programs are shown in the figures below. The degree and type of adaptive noise reduction and directionality have each been tested in programs 1 and 2 of a multiprogram hearing aid with adaptive program switching. Program 1 is intended for use in speech in quiet environments, while Program 2 is intended for use when speech is mixed with noise. Figure 2 compares the two programs for attenuation of a pink noise test signal. The two programs differ in their noise attenuation strength, with the noise programming providing 7 dB of reduction. Results with different test signals will vary, but this indicates that the noise reduction system in the hearing aid is active, and the strength can be compared to evidence-based recommendations. The verification results in Figure 3 indicate that the hearing aid offers pinna-matched directionality in Program 1, and speech-directed adaptive directionality in Program 2. This type of strategy is typically recommended for use with school-aged children, and is automatically activated for convenience. Putting the noise reduction and directional testing together, it is clear that Program 2 provides distinct signal processing that is tailored for use in noise. The noise reduction in this program can be adjusted to be stronger or weaker, depending on the child's preferences.

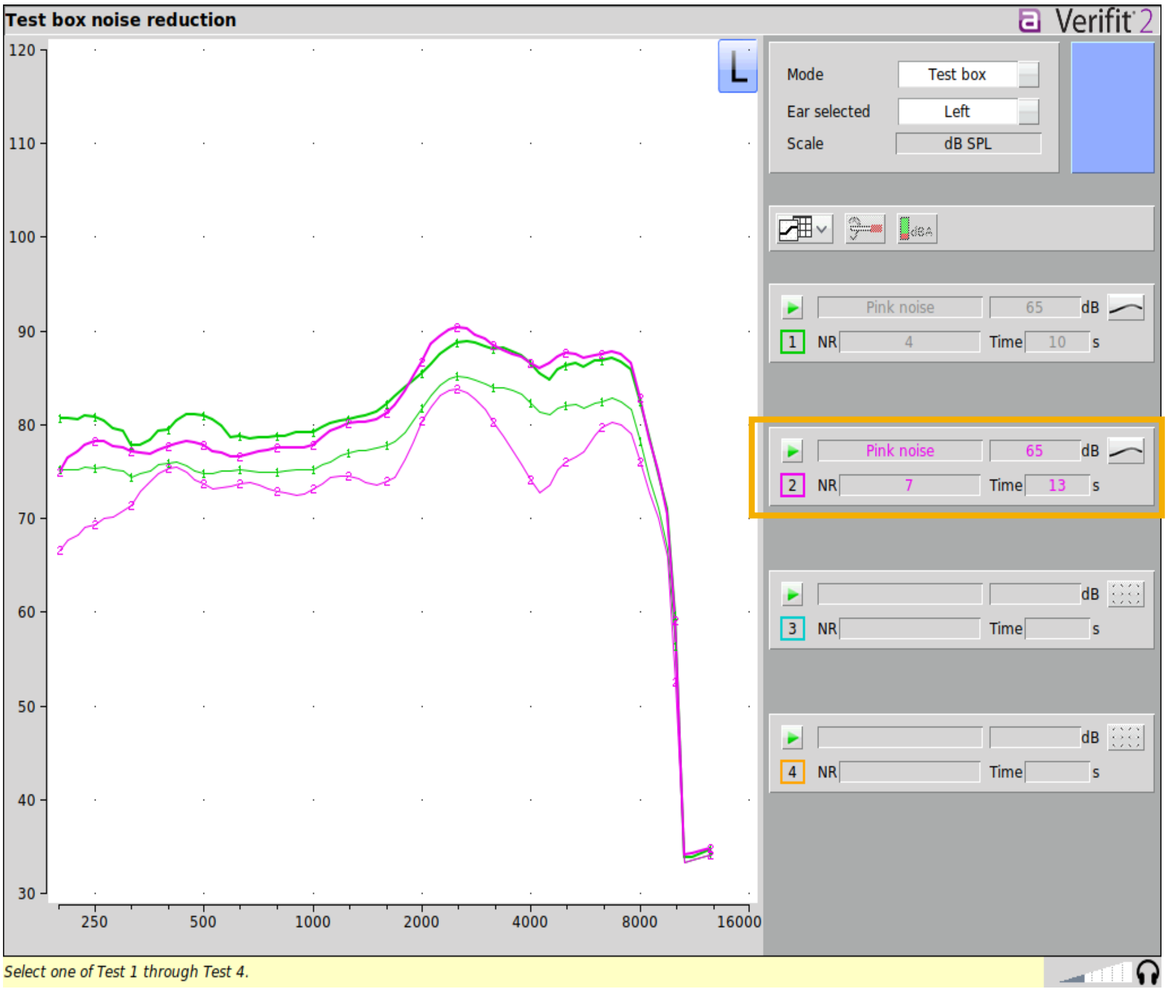

Figure 2. Tests of program-specific signal processing for adaptive noise reduction.

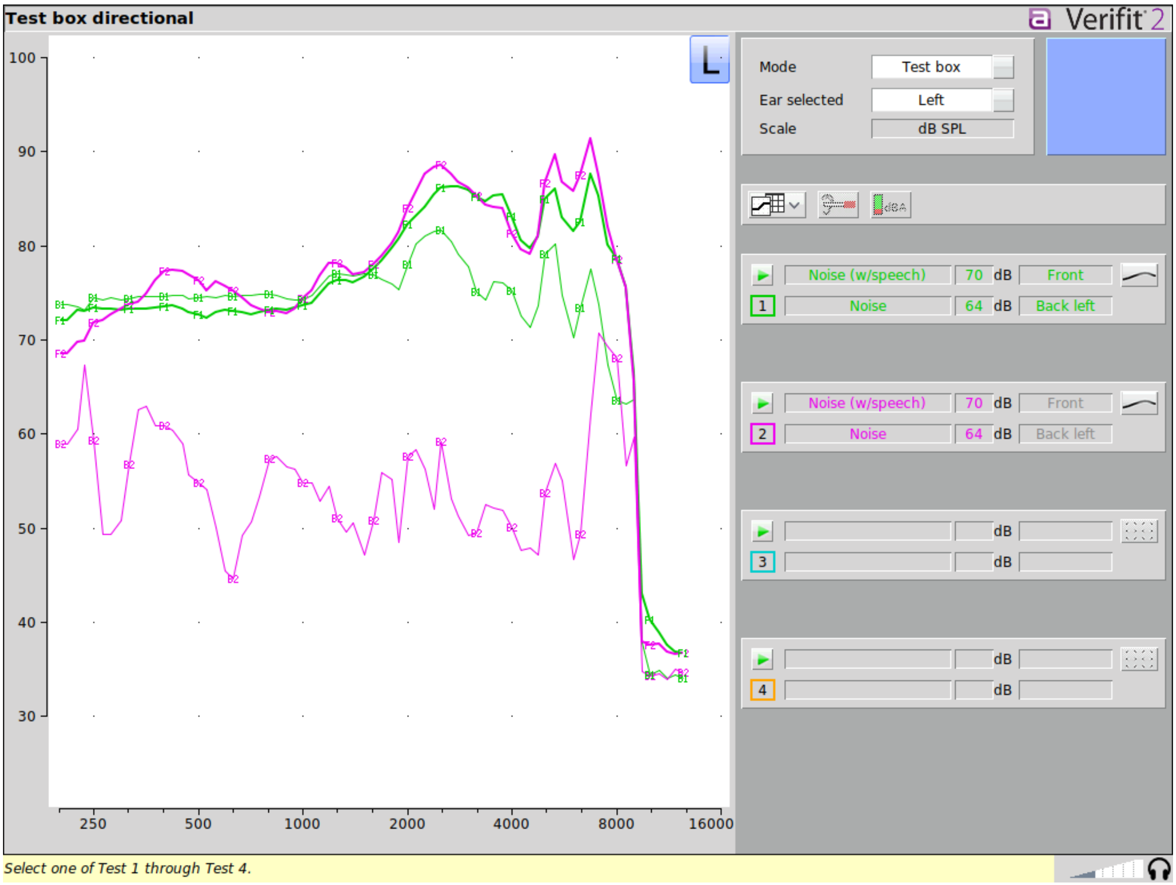

Figure 3. Tests of program-specific signal processing for directionality.

Verification limitations

Unfortunately, not all aspects of noise management have clinically available tests in hearing aid analyzers. Areas for future test innovation in verification include tests for wind noise, impulse noise, and the audibility of speech mixed with noise.

Partnering with caregivers

Assessing how well a child's hearing aids are working in real-world environments includes consideration of the child's activities and outcomes, so effective partnership with children and caregivers is an important aspect of noise management over the longer term. This can take the form of making access to noise management easier by using automatic activation of multiple hearing aid programs. It may include informational counselling to parents about technology options, current settings, and potential alternatives. Data logging can provide a clear bridge between clinical appointments and real-world use by linking sound environment types to overall use, helping to trigger important discussions about situations that may need a different noise management strategy. Similarly, questionnaires that query hearing aid outcomes in quiet and in noise, lend insight into real-world function and whether different settings may be necessary (Ching & Hill, 2007; Hornsby, et al., 2022).

The role of parents in noise management considerations

From the time a child is diagnosed with hearing loss and fitted with amplification, parents evolve their understanding of the benefits and challenges of device usage. Parents don't always understand the impact of noise on their child's life particularly when hearing aid fitting happens in an audiology booth at an early age. As their child ages, grows, and moves out into the real world, they begin to have firsthand experience of communicating with their child in noise and its effect on communication. The first step toward noise management considerations is to ensure that parents actually understand the implications of device use in noisy situations.

As one parent stated:
"My hard of hearing child is 'like a hearing person' when we are in quiet situations and communicating one on one, close up. I have to admit I thought that is how she also heard when we were in noisy situations. It took me some time to realize that my child is not a 'static' listener. Their access to communication is highly dependent on the environment they are in. Our child's audiologist was actually the first person that helped us understand the impact of noise. It was a life-changer. We particularly became stronger advocates in the educational setting, as our child began to move through the changing listening environments throughout the day. As parents, we must be aware of how our kids are using their residual hearing in the real world and use all the tools available within our reach to give our kids access to communication in their world."

From the parent perspective, effective noise management is about more than just the device. It's about partnership. Families depend on clinicians to help explain what technology can and can't do, such as how long it may take for adaptive noise reduction features to fully adjust. As technology and clinical practices in noise management evolve, there is a clear correlation between managing the aspects of the technology, and ensuring settings reflect the highly individualized situations and preferences of the child's day-to-day listening environments. Parents contribute valuable feedback about their child's real-world experiences, whether that's struggling in a noisy lunchroom, thriving in a quiet classroom, or feeling overwhelmed in social situations. These insights help guide meaningful decisions about tailoring settings, whether manual or automatic, child-driven, or parent-directed. When parents have a clear understanding about the decisions being made for the use of effective noise management, they can also support their child in the day-to-day usage of the settings. Children may have the ability to manage their usage throughout the day, and to report what is and isn't working, yet parents are often the ones hearing from their child about situational issues with loudness or clarity, and these observations are essential in guiding clinicians toward adjustments that better meet a child's needs.

The collaboration between caregiver and clinician helps to bridge the gap between clinical verification and everyday use, supporting individualized strategies that optimize a child's access to communication. When parents are recognized as active contributors to the process, noise management becomes not only a technical intervention but a shared effort that enhances child directed usage and device performance.

Conclusions and future directions

What can we do now?

Overall, it seems clear that routine provision of a good noise management strategy is an important consideration for most children. For example, automatic activation of scaled strengths of noise management can be implemented in a series of automatic hearing aid programs that cascade their function from speech in quiet to speech in noise settings. Speech in quiet programs can use more gain, less noise reduction, and less directionality, while noise programs may offer increasing amounts of noise management. One example of this type of strategy is illustrated in Table 2, with specific settings across some of the programs within the Autosense Junior Mode. Many of these strategies are evidence-based, while others are chosen based on knowledge of acoustics and processing. For example, speech in noise programs have been tested on children and can be set to strengths that have shown benefit. Other environments such as in the car have less experimental evidence but are expected to be noisy and to include transient signals when car doors are closed; signal processing recommendations include noise reduction and transient reduction for this reason. These are default settings and so can be further personalized through adjustments to other settings. Adjustments can be informed through the use of verification, data logging, and/or outcome monitoring to determine further needs, and through enabling the use of smart device applications that give control over signal processing during real-world use.

What can we do in the future?

As noise management signal processing continues to evolve, we can expect that improvements may be environment-specific. For example, specific noise types or settings may require targeted signal processors. Existing examples include processors for wind noise (Au et al., 2019) or improved processing for use in cars (Moeller et al., 2009) which have been identified as needs for children's hearing aids. Emerging technologies are also a consideration. For example, new wireless systems that allow broadcast Bluetooth may offer access to public announcements in noisy places (Auracast | Bluetooth® Technology Website, n.d.), although their combined use with low-delay systems requires careful consideration (Bruce et al., 2025). Also, AI-based denoising is now available in hearing aids (Diehl et al., 2023), adding another noise management signal processing option in addition to directionality, transient reduction, and adaptive noise reduction. Studies of these emerging technologies for use in children are not yet available.

Ongoing development of valid verification measurements of innovations in signal processing continues to matter for pediatric noise management: as new signal processors emerge, access to objective tests of their functionality enables their use with infants and young children who may not be able to provide feedback about their hearing experiences. The validation and exploration of hearing aid signal processing for infants and children, including those with developmental differences, requires targeted study to determine how and when different programming and use of noise management is needed. For example, many children with diverse abilities are mainstreamed in educational environments alongside neurotypical peers. Although there is emerging evidence suggesting that the impact of noise on speech perception is greater for individuals with developmental differences (Anshu et al., 2024; Newman et al., 2021; Porter et al., 2014; Ruiz Callejo & Boets, 2023), limited information is available on how children with complex developmental needs may require targeted considerations in hearing aid fitting.

Recommended noise management Junior mode settings for children's hearing aids, and examples of implementation in Phonak AutoSense Sky OS

Listening environments	Evidence-based recommendations					
	Prescription	Signal processing Recommendations				
		Directionality	**Adaptive Noise Reduction (NoiseBlock)**	**Transient Reduction (SoundRelax)**	**New default settings – all age groups**	**Previous default settings in Autosense Sky**
Calm situation (Target 11.0)	For quiet	Real Ear Sound	Weak	On	NoiseBlock Weak - 6 SoundRelax Weak – 7	0 – 3 years: NoiseBlock Off Other age groups: NoiseBlock Weak - 7
Speech in Noise (Target 11.0)	For noise	Age-appropriate settings are recommended	Moderate (at least 7 to 10 dB attenuation for pink noise).	On	NoiseBlock Moderate – 14 SoundRelax Weak – 7	NoiseBlock Weak - 7
Speech in Loud Noise (Target 11.0)	For noise	Age-appropriate settings are recommended	Increase strength across programs; consider emerging technologies.	On	NoiseBlock Moderate – 16 SoundRelax Weak – 7	NoiseBlock Weak - 7
Speech in car (Target 11.2)	For quiet	Age-appropriate settings are recommended		On	NoiseBlock Moderate – 14 SoundRelax Moderate – 14	NoiseBlock Weak – 8 SoundRelax Moderate – 8
Comfort in Noise (Target 11.2)	For Noise	Age-appropriate settings are recommended		On	NoiseBlock Moderate – 16 SoundRelax Moderate – 14	NoiseBlock Weak – 8 SoundRelax Moderate – 12

Table 2: Changes to NoiseBlock and SoundRelax DSL Junior Mode defaults

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