Phonak Insight.

Changes in auditory processing and cognition – Optimizing fittings for older adults.

Changes in auditory processing and cognition are a part of normal aging and can impact a listener's speech perception, particularly in background noise. A recent review article, Windle, et.al.[1] summarizes the decline older adults experience through normal aging and the potential impact on speech understanding. This Insight summarizes the guidance for fittings and highlights key Phonak technologies designed to improve signal-to-noise ratio (SNR) and reduce listening effort.

Stacey Rich, December 2024

Key highlights

- Auditory processing and cognitive change as part of normal aging and should be considered when selecting and fitting hearing aids for older adults.
- Guiding principles and recommendations are available to optimize hearing aid settings with the aim of introducing minimal distortion and maintaining binaural cues.
- A person-centered approach is recommended to evaluate needs and abilities independently, to set shared goals and determine strategies to be successful with amplification.

Considerations for practice

- Clinicians should be aware that compression settings, noise reduction and other advanced features may introduce distortion and should be carefully considered.
- It is important to compare aided fitting configurations for optimal speech intelligibility and listening comfort.
- Directional microphones and remote microphone technology should be employed to improve SNR.

Aging, cognition and hearing

Introduction

The older population continues to increase, with the number of adults older than 65 expected to double, and the number of those over 80 years of age expected to triple by 2050[2]. The World Health Organization (WHO) attributes this rise to improvements in healthcare and healthier living[3]. In recent years there has been a significant focus on hearing and cognition, more specifically the links between untreated hearing loss and cognitive decline, and the potential benefits of hearing aid use for maintaining cognitive health. Most adults will not experience dementia. However, there remains a need to look at the auditory and cognitive changes associated with the normal aging process and understand their impact on speech perception and understanding.

In 2023, Windle, et.al.[1], published a review article that discusses the auditory processing and cognitive changes that occur as part of the normal aging process. They also describe the implications for selection and programming of hearing aids for older adults. While not specifically addressed in the review article, the authors advise that these recommendations would be equally important for older adults with hearing loss and those experiencing cognitive decline. Their key findings and recommendations are summarized here.

Changes in auditory processing and cognition

As we get older, the brain has fewer connections in areas responsible for hearing and understanding, which can affect how well an individual can process timing information, and how well they can locate where sounds are coming from. The reduction in neural connections can also impact the ability to perceive different frequencies (or pitches), making it more difficult to understand speech and music. Together, these changes make it harder to pick out specific sounds in noisy environments, focus on a particular speaker, and understand speech clearly.

The speech envelope and temporal fine structure are two crucial elements the auditory system uses to make sense of speech. The speech envelope carries cues about the overall amplitude fluctuations in speech as well as speech and frequency perception and localization. Temporal fine structure provides granular details of speech sounds like pitch and formants. Hearing loss challenges the ability to make use of these spectral and timing cues, making it more difficult to understand speech in noisy situations.

While the auditory system processes sounds, cognitive processes interpret those sounds to give them meaning and make sense of them. Windle, et.al[1] describe how cognitive abilities decline as we age, though they also point out there are likely multiple processes[4] that have cumulative effects. The processing-speed theory suggests that as our mental processing slows, some tasks take longer, which in turn uses up vital cognitive capacity, interfering with the ability to remember past events and to start more complex tasks. Meanwhile, working memory, where information relevant to a current task is stored, is finite. With limited capacity, it becomes more difficult to filter out irrelevant information. Different cognitive skills influence listening ability, particularly for challenging tasks like listening to speech in the presence of background noise. The authors describe correlations between speech-in-noise (SIN) performance and several cognitive functions including processing speed, inhibition, as well as working and episodic memory. Working memory is strongly linked to understanding speech in noise and fast speech. Executive function, inhibition and processing speed are also associated with listening ability and the amount of listening effort required[4].

Increased listening effort

Listening effort, as defined by the Framework for Understanding Effortful Listening (FUEL)[2], is the distribution of cognitive resources required to overcome listening challenges. Reductions in either hearing or cognitive abilities can impact the effort required for listening. Several neurological systems contribute to listening effort, which is vital for understanding speech. Additionally, listening effort is influenced by age-related cognitive changes. This can affect an individual's motivation to use hearing aids and their social engagement, ultimately impacting their quality of life and long-term health.

For older adults with hearing loss, there is a reduction in the quality of auditory input to which they have access, which makes it harder to access timing and spectral cues normally used to understand speech. Although appropriately programmed hearing aids cannot fully restore a degraded signal, auditory processing or cognitive abilities, they can improve the signal-to-noise ratio (SNR) and reduce unwanted noise, thereby reducing listening effort for the wearer.

Evidence-based principles for hearing aid programming

In their review paper, Windle, et.al.[1] propose a set of key, evidence-based principles to ensure that the auditory processing and cognitive abilities of older adults are taken into consideration for successful amplification.

The principles include:

1. Make speech audible with minimal distortion to the speech envelope
2. Maintain the quiet gaps between the elements of speech
3. Preserve interaural timing and level differences
4. Consider unilateral aiding if binaural interference is noted
5. Use directionality to improve SNR
6. Use noise reduction to minimize cognitive load and listening effort

These principles are focused on optimizing compression settings, preserving binaural cues, and minimizing distortion with the goal of improving SNR and reducing listening effort.

Fast-acting versus slow-acting compression

Fast-acting compression, for older adults, may impair speech perception by distorting speech envelope cues, amplifying noise in the gaps of speech and hindering gap detection. Additionally fast-acting compression may reduce modulation detection, which helps us to separate individual speakers, and may restrict the ability to localize in reverberant situations.

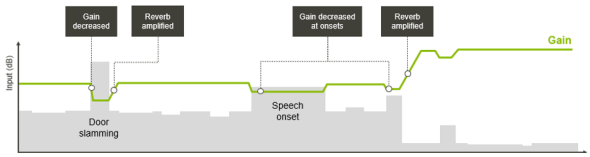

Figure 1: Display of the attack and release time for fast-acting compression.

Lastly increasing frequency bands in fast-acting compression can reduce spectral contrast and negatively affect the clarity of vowels and speech intelligibility, even in quiet.

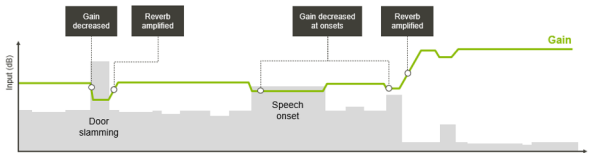

Figure 2: Display of the attack and release time for slow-acting compression.

With slow-acting compression, the main difference is recovery and the slow gain increase. High frequencies are enhanced through different amounts of gain in each channel, better preserving the speech envelope[1]. For those with lower degrees of cognition, slow-acting compression can do a better job of helping the brain understand speech clearly compared to fast acting compression in noisy situations.

In a series of studies by Gatehouse, et.al.,[5,6,7] cognitive function was shown to interact with compression speed and hearing performance. With fast-acting compression, there was a negative correlation between speech perception and cognition, meaning those with higher cognitive function benefitted while those with lower cognitive abilities showed poorer results.

Aspect	Slow Approaches (SAC)	Fast Approaches (FAC)
Speech Recognition	Non-linear slow-slow and fast-slow provided better recognition than linear strategies.	Fast-fast and fast-slow showed superior speech intelligibility under ideal conditions.
Comfort	Slow-slow offered the highest comfort and was the most preferred by users.	Fast strategies were less comfortable compared to slow-slow.
User Preference	Slow-slow and fast-slow were preferred for their balance of intelligibility and comfort.	Preference was lower for fast-fast strategies.
Performance Under Adverse Conditions	Declined moderately, maintaining reliability in poor SNR or high speech levels.	Benefits of FAC decreased significantly under poor SNR or high speech levels.

Table 1: Overview of hearing aid fitting strategies (linear and non-linear) using FAC (fast-acting compression) and SAC (slow-acting compression) in older adults with mild-to-moderate sensorineural hearing loss.

Binaural Processing

As we age, our ability to process sound from both ears declines. This can impact the ability to detect and make use of differences in sound levels and timing differences between ears. Binaural processing in hearing aids can help the brain integrate binaural cues to form a unified spatial representation of sound. Binaural processing can enhance the ability to distinguish a target voice from background noise by maintaining sound level and timing cures. Binaural processing can also improve SNR by reducing the impact of masking sounds[8].

In some cases, older adults may experience binaural interference, where processing sound from both ears simultaneously, becomes more challenging and they are unable to adapt to binaural hearing aid use. In these cases, better performance may be seen with only one hearing aid versus a binaural fitting. Clinicians can determine the best fitting configuration when binaural interference is suspected by evaluating both aided speech intelligibility and listening comfort in three separate configurations: binaurally aided, unilaterally aided in the right ear and unilaterally aided in the left ear.

Noise reduction

The strength and speed of noise reduction can distort the speech signal. Stronger levels of noise reduction benefit individuals with higher cognitive scores and working memory

more than those with lower cognitive or working memory abilities, particularly for complex tasks. Background noise can impact working memory function causing disruption to word recall. Noise reduction can lessen the demands on working memory. Though individual preferences will vary, moderate noise reduction is generally more preferred[1]. It improves listening comfort without interfering with speech intelligibility.

The authors acknowledge that choosing the best hearing aid strategy for a particular client can be challenging and that clinical tests may not yield clear guidance. Cognitive tests, especially those with verbal instructions or verbal delivery, are influenced by hearing loss, and their clinical usefulness is not proven. Speech testing can supplement standard audiometry and provide insight into overall ability. However, speech testing is unlikely to determine or guide specific hearing aid and feature settings.

Accordingly, Windle, et.al.[1] provide a series of practical recommendations for programming hearing aids for older adults who may be experiencing changes in auditory processing and cognition, either because of normal aging or as a result of pathological cognitive decline.

The key recommendations are summarized:

1. Be aware that compression speed/ratio, noise reduction, and frequency lowering have the potential to create distortion.
2. Consider adaptive compression algorithms, defaulting to slow acting compression for older adults in noise and minimizing the compression ratio for fast acting compression when possible.
3. Use directional microphones and remote mic technology to improve SNR.
4. Set noise reduction to moderate levels, as strong noise reduction may impair speech perception, particularly for those experiencing cognitive decline.
5. Use advanced features like frequency lowering deliberately, ensuring speech intelligibility is not compromised.
6. Compare bilateral versus unilateral fitting configurations to optimize speech understanding and listening comfort.
7. Use real-ear-measures (REM) to verify while also carefully reviewing gain and compression settings as a whole. Use appropriate validation to evaluate outcomes.

Inappropriate hearing aid settings can impact the quality of the signal, speech perception, listening comfort, and effort, particularly for older adults and those experiencing cognitive decline. Hearing care professionals should prioritize client-specific concerns, incorporate client and family input, and apply evidence-based principles to optimize potential success with amplification.

Key features and technologies from Phonak

The next section highlights key technologies, developed by Phonak, which are available in Infinio and/or Lumity hearing aids to preserve the speech envelope, increase SNR and reduce listening effort. These evidence-based features are important to understand alongside the principles and practical recommendations already discussed for older adults.

Adaptive Phonak Digital (APD) 3.0

This proprietary fitting formula employs adaptive compression speeds and linearized high-level gain[9]. It allows a wide range of sound intensities at the hearing aid input stage to be compressed into a narrow intensity at the output stage. APD 3.0 combines fast and slow compression in a dual-path using adaptive time constants to ensure gain regulation is fast, while the system release is slow with gain being more constant and linear.

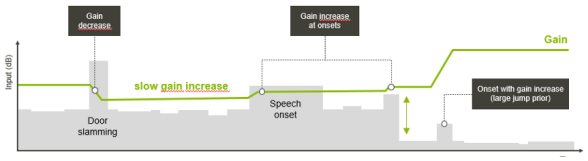

Figure 3: Adaptive compression speed in APD 3.0: fast gain decrease with door slamming, fast gain increase at speech onset, and slow, near linear gain increase in between.

The benefits of adaptive compression include more dynamic range[10], reduced amount of perceived reverberation[10], comfort in noise[11] and comfort for impulsive loud sounds[12]. The implementation of an additional kneepoint for loud inputs in APD 3.0 allows fittings to be more compressive for mid-levels, while loud levels are amplified linearly and mimic the normal loudness growth function[9].

APD Contrast 2.0 is also an option to apply slow compression in all environments to increase the envelope cues for speech for those who need it most.

The benefit of directional microphone technology is well documented[13]. The improved SNR from directional microphones, has been shown to improve speech intelligibility in typical speech in noise situations where the target speech is coming from the front direction and the noise is from side and rear[14,15]. With the fixed directional microphone mode in Phonak Lumity and Infinio hearing aids, clients can enjoy 26% better speech understanding[16].

StereoZoom 2.0 uses binaural signal processing to create a beamforming system that takes binaural directionality to the next level with smooth activation as the noise level increases; providing 3 dB better SNR when speech is coming from the front at maximum strength, and an additional 2.5 dB SNR in noisy listening environments[17]. SpeechSensor is a spatial speech detection algorithm. It constantly monitors the sound environment, creating a 360 degree 'picture' resulting in accurate detection of the direction of the primary speech signal in challenging environments.

Speech Enhancer in Infinio and Lumity hearing aids aims to increase speech understanding in quiet. It selectively amplifies the peaks of speech in these environments providing up to 10 dB of gain for soft or distant speech[18]. Speech Enhancer has been shown to reduce listening effort for soft speech in quiet and is also preferred for hearing at a distance[18].

Phonak has a long history of developing technologies aimed at improving SNR to combat speech understanding in precisely these challenging situations. The use of artificial intelligence (AI) can be tracked back to 2000 when AI was used to train the first automatic system in Phonak hearing aids. With the introduction of Spheric Speech Clarity, at maximum strength, users can now experience up to 10 dB SNR improvement in challenging listening environments (with an SNR as poor at –6 dB)[19]. Wearers with moderate to moderately-severe hearing loss are 2 times more likely to understand speech from any direction with Spheric Speech Clarity compared to without[20].

For those clients with greater need to improve SNR in more challenging group or high noise environments remote microphone technology should be considered. Roger™ provides exceptional speech understanding in group conversations and over distance[21] and 90% of users would recommend Roger to their friends and family[22].

The technologies described above aim to preserve the spectral cues of speech (APD 3.0) and/or improve SNR, ensuring clients have access to the clearest signal possible with the aim to reduce listening effort and fatigue.

Conclusion

In summary, the body of knowledge around the links between hearing loss and cognitive decline will continue to grow. It is important to remember that most adults will not experience dementia but will experience changes in auditory processing and cognitive function as a part of the normal course of aging. These changes are important for the selection and appropriate programming of hearing aids for older adults. Evidence-based recommendations from Windle, et.al.[1] include optimizing compression settings, preserving where possible binaural cues and/or considering unilateral aiding along with using noise management and advanced features to improve SNR, to reduce listening effort and to minimize cognitive load.

Phonak offers a range of advanced and adaptive features, available in Infinio and/or Lumity hearing aids, designed to preserve the speech envelope, increase SNR and reduce listening effort. These evidence-based features are important to practically apply the fitting principles and recommendations for programming hearing aids for older adults experiencing changes in auditory processing and cognitive abilities either as part of normal aging or because of pathological cognitive decline.

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