CLINICAL RESEARCH

Optimizing Hearing for Listeners with a Cochlear Implant and Contralateral Hearing Aid

Adaptive Phonak Digital Bimodal Fitting Formula

With the introduction of the Phonak Naída™ Link hearing aid, a new era in bimodal hearing has begun. Unilateral Advanced Bionics (AB) Naída cochlear implant recipients who can use a contralateral hearing aid will have access to (1) technologies that have been designed specifically to work together across the two devices and (2) the listening advantages of Binaural VoiceStream Technology™.

A new Phonak prescriptive fitting formula has been developed for the Naida Link to align the frequency response, loudness growth functions, and automatic gain control (AGC) characteristics between the Naída CI processor and the hearing aid. The objective is to provide the best hearing experience for AB bimodal listeners while at the same time making it easy for audiologists to program the Naída Link.

Why a new prescriptive fitting formula?

First, combined electric and contralateral acoustic stimulation provides substantial benefits to bimodal listeners, including better speech understanding in noise and voice pitch perception, enhanced localization abilities, and improved music perception.[1-3] However, conventional hearing aid prescriptions (e.g., NAL-NL2, DSL v5) do not align acoustic and electric processing, which is required for optimal bimodal hearing. For example, traditional fitting prescriptions focus amplification in frequency regions that are important for speech understanding (1 – 4 kHz), whereas low frequencies (250 – 750 Hz) may be most important for maximizing bimodal benefit.[4] Moreover, low compression kneepoints (CK < 50 dB SPL) and moderate compression ratios (CR ~ 2:1) are usually prescribed for hearing aids, while cochlear implants use very different input/output functions (e.g., Naída CI: CK = 63 dB, CR = 12:1). Finally, the dynamic behavior of AGC systems differs substantially between devices. Hearing aids typically implement syllabic compression (attack/release time < 50 ms), whereas cochlear implants use slow-acting automatic gain control (attack/release > 1 sec). Thus, using traditional fitting prescriptions for a hearing aid may cause misaligned frequency response, loudness growth, and dynamic behavior for bimodal listeners.

Second, fitting a hearing aid to work with a cochlear implant can be a time-consuming iterative procedure.[5] Thus, the audiologist must have expertise with both hearing aid and cochlear implant fitting software, and may spend considerable time fitting both devices.

Therefore, a prescriptive hearing aid fitting formula has been developed to:

- Optimize hearing for AB bimodal listeners.
- Make it easy and efficient for audiologists to fit the Naída Link.

How does the new fitting formula work?

Because the cochlear implant is the dominant provider of sound information to most bimodal listeners, the overall design goal was to align the hearing aid parameters with the cochlear implant. Specifically, modifications to a standard hearing aid prescription were implemented to align frequency response,

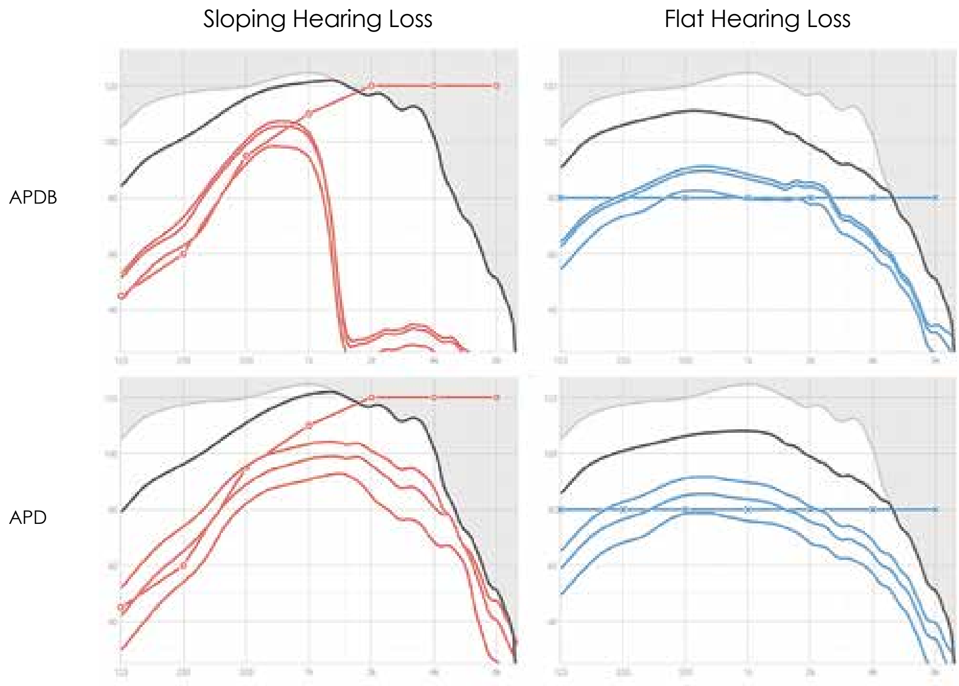

Figure. *Adaptive Phonak Digital Bimodal (APDB) and Adaptive Phonak Digital (APD) prescribed output for speech at 50, 65, and 80 dB SPL (thin lines) for a sloping and a flat hearing loss. Broken lines indicate audiometric thresholds.*

loudness growth, and dynamic behavior between the two devices. The resulting fitting formula is termed Adaptive Phonak Digital Bimodal (APDB).

The Adaptive Phonak Digital fitting formula is used as a starting point because this formula is used commonly in clinical practice for severe and profound hearing losses.[6] Three modifications are made.

First, the frequency response is adjusted to optimize low-frequency gain and bandwidth. Low-frequency gain optimization uses the model of effective audibility to ensure audibility of cues that contribute to speech understanding even in relatively quiet environments (55 dB SPL).[7] Depending upon the configuration of the audiogram, this step often results in a gain increase below 1 kHz. This gain increase is limited to make sure that speech at 65 dB SPL does not exceed the most comfortable level. Note that for certain hearing loss configurations (reversed, mild-to-moderate sloping, and flat losses), this gain increase will not be applied. Bandwidth is optimized by ensuring that (1) bandwidth is as wide as possible[8], (2) frequencies between 250 and 750 are audible[4], and (3) amplification does not extend into dead regions[9].

Second, loudness growth is aligned by implementing the input-output function of the cochlear implant in the hearing aid (CK = 63 dB SPL, CR = 12:1). And third, the dynamic compression behavior is aligned by porting the Naída CI dual-loop AGC into the hearing aid.[10] All three modifications were verified and optimized in a series of experiments with bimodal listeners (see Call Out box).

Comparisons of the Adaptive Phonak Digital (APD) and Adaptive Phonak Digital Bimodal (APDB) fitting results are shown in the figure above for a flat and a sloping hearing loss. There are almost no differences in frequency response between the two formulae for the flat audiogram. In contrast, the bandwidth is limited by APDB for the sloping audiogram because a dead region was identified. Alignment of loudness growth is reflected in the fact that output curves for speech with 65 dB SPL and 80 dB are very close for APDB, whereas APD prescribes clearly different output.

What steps are required to program the Naída Link?

Programming a Naída™ Link with Phonak Target programming software is easy. To take advantage of the optimized frequency response, loudness growth, and dynamic behavior, the fitter only needs to connect a Naida Link to Target. By default APDB is selected and will offer these benefits to bimodal listeners.

Conclusion

A new prescriptive Adaptive Phonak Digital Bimodal (APDB) fitting formula optimizes hearing for AB bimodal listeners by (1) adjusting the frequency response of the Naída™ Link in the acoustic-hearing ear, (2) aligning the loudness growth between the Naída CI processor and the Naída Link, and (3) synchronizing the dynamic behavior between the two devices. In most cases, optimum bandwidth and balanced loudness is achieved automatically when using the APDB fitting formula. APDB now is implemented in the Phonak Target software so that the Naída Link can be programmed using simple, easy-to-execute steps.

VERIFICATION AND OPTIMIZATION OF THE APDB FITTING FORMULA

Because bimodal listeners are not homogeneous, a series of studies was conducted to determine which hearing aid program modifications should be applied depending upon hearing loss and hearing aid configuration. Experiments were conducted at seven research sites in Belgium, Germany, the Netherlands, and the United States. Participant audiograms ranged from profound hearing loss (little aidable hearing at 125 and 250 Hz) to flat and sloping moderate losses (aidable hearing up to 4 kHz). Outcome measures included speech understanding in noise, sound quality ratings, and subjective preference. A randomized crossover design was applied whenever possible to evaluate the effect of bimodal fitting modifications both acutely and chronically. Results from two of these studies are summarized here.

Frequency Response Adjustment
(Advanced Bionics LLC, Valencia, USA, Chalupper et al. 2013[10])

Seven experienced bimodal subjects (aidable hearing < 750 Hz) were tested in noise (AzBio sentences at signal-to-noise ratios that resulted in scores 50% of their scores in quiet using the implant alone) using their own hearing aid program, and a hearing aid programmed with APD, NAL-RP, a bimodal formula with aligned frequency response based on the audiogram configuration, and a bimodal formula with aligned frequency response using the result of the TEN–Test to identify dead regions. Best sentence scores in noise were seen with the bimodal formula without the TEN-Test (Figure 1). The bimodal formula outperformed both APD and NAL-RP. Administering the TEN-Test to assess dead regions did not further improve bimodal benefit because the APDB correctly identified dead regions based on the audiogram.

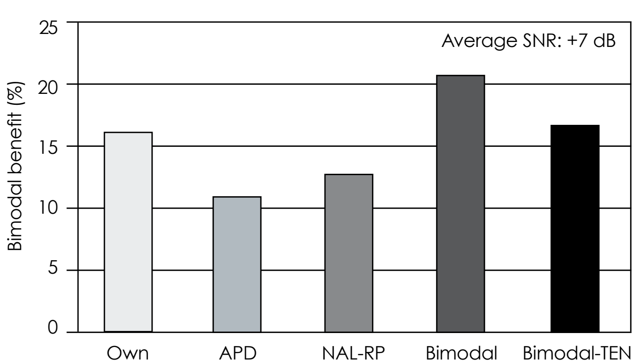

Figure 1. *Bimodal benefit (bimodal sentence score minus sentence score with cochlear implant alone) for five hearing aid fitting programs: subject's own, Phonak APD, NAL-RP, bimodal formula based on audiogram configuration, and bimodal formula based on the TEN-Test.*

AGC Alignment *(Radboud University Nijmegen, the Netherlands, Veugen et al. 2016[11])*

Fifteen experienced bimodal subjects were tested bimodally in noise (adaptive LIST test) using a hearing aid programmed with a standard Phonak AGC (syllabic) and an AGC aligned with the Naída CI processor. With target speech from the front, the aligned AGC improved speech understanding by 1.6–2.9 dB (median) compared to the standard Phonak AGC depending upon where the competing talker noise originated. When noise was presented on the hearing aid side (S0NHA), a larger improvement was achieved compared to noise presented on the CI side (S0NCI) or from both sides (S0N+/-90) (Figure 2). The vast majority of subjects preferred the aligned AGC over the standard AGC (only one patient preferred standard AGC). Take-home questionnaires did not show any changes over time, suggesting no effect of acclimatization. Questionnaires also indicated that the AGC-matched hearing aid was ranked significantly better for understanding one person in quiet, understanding one person in noise, and hearing the timbre of sounds.

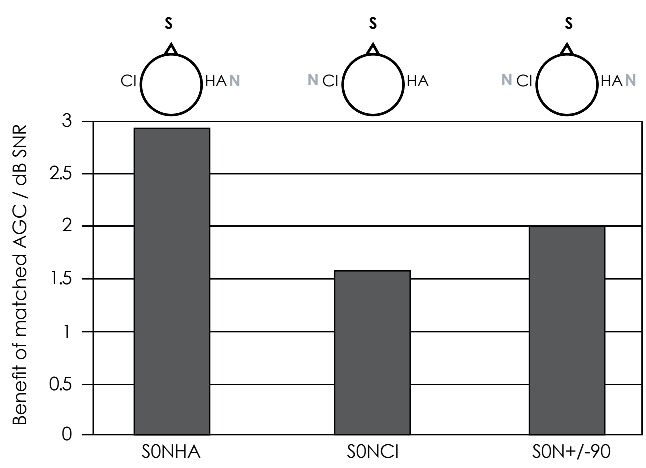

Figure 2. *Benefit of aligned AGC compared to Phonak AGC for understanding speech in noise in three listening configurations.*

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