Phonak
Insight

Hearing inspired by nature: the new APD 2.0 fitting formula with adaptive compression by Phonak

Woodward, J., Jansen, S., & Kühnel, V. / August 2020

Key highlights

- The new APD 2.0 fitting formula is designed to balance audibility, loudness and sound quality of Phonak Paradise, the latest generation of Phonak hearing aids.
- APD 2.0 consists of three key changes: (1) adaptive compression speed, (2) linearized high level gain and (3) new precalculation for mild to moderate hearing losses.

Benefits for Hearing Care Professionals

- APD 2.0 aims to provide the best possible starting point and spontaneous acceptance for each client with hearing loss.
- APD 2.0 applies less gain to loud inputs compared to APD so that loud sounds are more comfortable for clients, without compromising on hearing performance.
- The new precalculation for mild to moderate hearing losses modifies the gain for G65 and G80, resulting in gain targets that are more closely aligned with NAL-NL2.

Benefits for your clients

- A recent study at the Hörzentrum Oldenburg, Germany, comparing APD 2.0 to APD, showed clients with mild to severe hearing loss reported less listening effort in noise and an overall preference in real-world environments with APD 2.0 (Wright, 2020).
- Expected benefits of APD 2.0 from the literature include (1) less reverberation and background noise and improvements in sound quality thanks to the adaptive compression speed (Hassager et al., 2017; Moore, 2016; Madsen et al., 2015) and (2) natural sound quality and better speech intelligibility in noise thanks to the linearized high level gain (Lopez-Poveda et al., 2017).

Introduction

When creating our latest hearing solution, Phonak Audéo Paradise, we turned to nature for inspiration. Hearing is an intricate part of our existence and fundamental to our overall well-being. Nature is also the source of many sounds that can soothe, relax and comfort us. The Adaptive Phonak Digital (APD) 2.0 proprietary fitting formula is designed to balance audibility, loudness and sound quality of Phonak Paradise. Consisting of three new key changes – (1) adaptive compression speed, (2) linearized high level gain and (3) new precalculation for mild to moderate hearing losses – Phonak APD 2.0 aims to provide the best possible starting point and spontaneous acceptance for each client with hearing loss.

The challenges of cochlear dysfunction

Clients with hearing loss experience **elevated hearing thresholds** and **reduced dynamic range** (the area between 'just audible' and 'uncomfortable' sound levels). Loss or dysfunction of outer hair cells results in a reduction of the cochlear mechanical amplification of soft sounds, but does not reduce amplification of high-intensity sounds. As a result, clients often cannot detect low-intensity sounds but experience high-intensity sounds as loud as normal listeners, a well-known phenomenon called recruitment (e.g. Ruggero et al., 1996). It affects the audibility of many important sounds, including soft speech, and can lead to increased listening effort. This means that individuals with hearing loss may need to use more mental energy to not only detect speech but to follow a conversation. The result of hearing impairment can therefore lead to increased fatigue in daily life (Holman et al., 2019). Further, hearing loss not only affects speech understanding, but can reduce a sense of social connection and well-being (Vercammen et al., 2020).

When we fit hearing aids, the input signal must therefore fit within a reduced dynamic range. Soft sounds require amplification to become audible, whereas loud sounds must not be amplified too much to avoid them being painfully loud (Heinz et al., 2005). Reduced dynamic range and audibility creates a challenge for hearing care professionals (HCPs).

Fitting hearing aids optimally for clients

Fitting formulae provide the best starting point for hearing aid fittings and compensate for the client's hearing loss, so hearing aid users can enjoy conversations and the soundscapes around them. Fitting formulae deliver individualized level-dependent gain to help compensate for the client's hearing loss, enabling audibility of speech sounds while maintaining excellent sound quality. They generate targets of gain as a function of frequency, within the client's limited dynamic range.

Fitting formulae must balance audibility, loudness and sound quality. Hearing aids can then be fine-tuned to match the individual needs of each client. Clients should leave their HCP's office feeling comfortable to adapt to amplification, and willing to wear their instruments throughout the day.

Common fitting formulae

The two main validated, generic fitting formulae currently used in hearing instrument fittings are NAL-NL2 (Keidser et al., 2011) and DSL v5 (adult) (Scollie et al., 2005). They use two common rationales – loudness normalization and loudness equalization. Loudness normalization aims to restore, for certain frequency bands, the loudness perception of the listener with hearing impairment to the same loudness as someone without hearing loss. Soft, medium and loud speech heard by normal listeners are amplified appropriately so that these sounds are also judged as 'soft', 'average' and 'loud' for hearing-impaired listeners. Loudness equalization equalizes the perception of loudness over a range of frequencies, rather than having lower frequencies dominate loudness, which is the case for normal-hearing listeners. Generally speaking, DSL v5 is based on loudness normalization and NAL-NL2 on loudness equalization. For an extensive overview of the similarities and differences between NAL-NL2 and DSL v5, see Johnson (2012).

All fitting formulae prescribe greater amplification at frequencies where the hearing loss is larger and more amplification for low-, rather than high-, intensity sounds. Fitting formulae therefore compress a wide range of sound intensities at the hearing aid input into a narrower range at the output (Lopez-Poveda, et al., 2017). An advantage of generic fitting formulae is that they have been validated with large populations of hearing-impaired people. However, as time is needed for validation and implementation into fitting software and real ear measurement systems, generic fitting formulae are not regularly updated and do not take into account proprietary signal processing.

To provide an optimal fitting of our hearing aid portfolio Phonak developed its own fitting rule – Adaptive Phonak Digital (APD). APD compresses a wide range of sound intensities at the hearing aid input into a narrower intensity range at the output (greater amplification for low- than for high-intensity sounds), and maps the hearing-impaired

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loudness function into a normal hearing loudness function for different hearing losses (Latzel, et al., 2013). A benefit of a proprietary fitting formula such as APD is that it can be regularly updated, and can take into account the signal processing of Phonak hearing aids. Internal Phonak Target fitting data, which analyzed changes made within Phonak Target software over multiple sites and thousands of clients, showed that 93% of our adult fittings (aged 16 and over) remain on the APD fitting formula, while the remaining 5.4% switch to NAL and 1.6% change to DSL. (Senn, 2020).

APD was first introduced with the Phonak Savia hearing aids in 2005. Based on internal and external studies, internal Phonak Target fitting data, and feedback from fitters and clients, Phonak has continually optimized APD. For example, with the Marvel platform in 2018, the goal of providing comfort at the initial fit for first-time users while still enabling excellent hearing performance in the real world was met with the new precalculation (Jansen & Woodward, 2018). Fifteen years on from the first introduction of APD, APD 2.0 continues to personalize and optimize our hearing instruments.

APD 2.0: optimizing Phonak fittings

APD 2.0 consists of three key changes: (1) adaptive compression speed, (2) linearized high level gain and (3) new precalculation for mild to moderate hearing losses.

Adaptive compression speed – intelligent compression

As discussed, people with cochlear hearing loss usually experience recruitment and a reduced dynamic range. Compression is used in hearing aids to compensate for this (Moore, 2008). Gatehouse et al. (2006) found that slow-acting compression was preferred in terms of subjective listening comfort, whereas fast-acting compression was better for reported and measured speech intelligibility.

Currently, implementation in APD is a dual-path compression approach. This means that in Speech-in-Noise (SpiN), Speech-in-Loud Noise (SpiLN), music and streaming programs there is a mix of slow and fast compression, while fast compression is applied in all other programs (Jansen & Appleton-Huber, 2019).

With APD 2.0, Phonak introduces an adaptive compression speed in the fast path of the dual compression, which further enhances the benefits of fast and slow compressive gain changes. With dual-path compression, the adaptive compression speed is available in all programs.

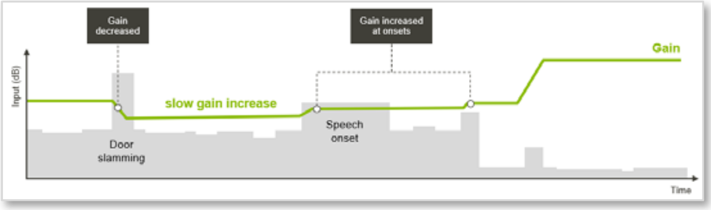

Figure 1: Adaptive compression speed in APD 2.0: fast gain decrease with door slamming, fast gain increase at speech onset, and slow, near-linear gain increase in between.

Figure 1 shows an example of how the adaptive compression speed works with loud background noise, such as a door slamming, followed by an onset of speech. The gain of the hearing aid quickly decreases when the input increases, shown in this example by the door slamming. Such a compressive gain decrease always acts fast to guarantee loudness comfort. Following this event, the gain increases only slowly in the presence of reverberation or static background noise, thereby preventing overamplification of these unwanted sounds. However, as soon as a signal onset is detected, in this example a speech onset, adaptive compression increases the gain more quickly. This fast compressive gain increase occurs to guarantee audibility, so that clients can catch the beginning of an informative sound passage such as soft speech. This approach to adaptively apply both fast and slow compressive gain changes aims to restore audibility and natural loudness perception while at the same time providing high sound quality and listening comfort.

There are many benefits of fast compression, but the disadvantages include degradation of the temporal envelope and smoothing of the spectral contrasts (Souza et al., 2015). Therefore, unless there is a sudden increase or decrease in the input, the gain remains mainly linear with slow compression. The benefits in the literature of a more linear (less compressive) system include (1) maintaining amplitude information and thus maintaining the temporal waveform, speech intelligibility and sound quality (Moore, 2016; Madsen et al., 2015), and (2) less reverberation and background noise as fast-acting compression can distort the auditory cues involved in the spatial perception of sounds in rooms (Hassager et al., 2017).

The new adaptive compression speed of APD 2.0 combines the benefits of slow and fast compression in a dynamic way in all programs.

Linearized high level gain

The implementation of an additional kneepoint for loud inputs allows fittings to be more compressive for mid-levels, while loud levels are amplified linearly and mimic the normal loudness growth function. Research has shown that linear processing for loud sounds is beneficial (Lopez-Poveda et al., 2017). Lopez-Poveda et al.'s study with 68 hearing aid users/ candidates found that intelligibility tended to improve by increasing amplification for low-intensity sounds and by using more linear amplification for high-intensity sounds. Figure 2 demonstrates that at a certain loudness input (above the loud kneepoint), the gain becomes linear and mimics normal loudness growth.

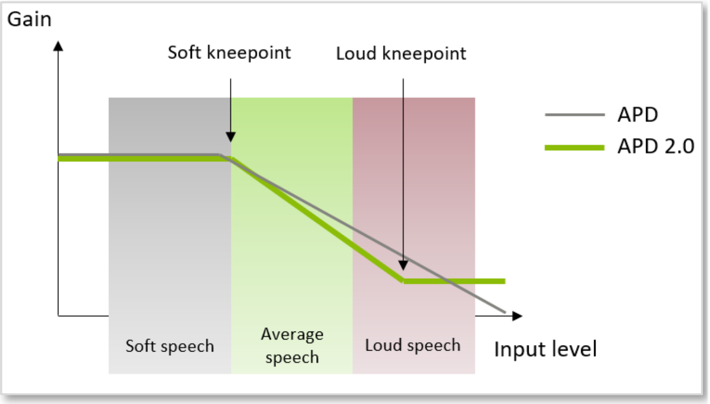

Figure 2: The new linearized high level gain in APD 2.0 compared to APD. APD 2.0 has a new loud kneepoint, which allows the gain to become linear and mimic normal loudness growth.

New precalculation for mild to moderate hearing losses

The first fit is critical in the adoption of hearing aids as it is the client's first encounter with amplification. Clients with mild to moderate hearing loss can often find loud sounds too loud at first. Analysis of internal Phonak Target fitting data from Marvel hearing aid fittings in March 2020 shows that when fine-tuning is applied to the APD first-fit, it is most often a reduction of the gain for loud sounds rather than for soft or mid-level sounds (Senn, 2020).

With APD 2.0, we have introduced more compression in the precalculation for mild to moderate hearing loss. The G50 speech target remains the same for optimal speech audibility, while G65 and G80 speech targets are reduced for mid-loud inputs so that loud sounds are more comfortable (2 dB and 4 dB respectively). This new precalculation is also more in line with NAL-NL2 targets and is applied only for mild to moderate hearing losses, independent of experience level.

Supporting evidence for the introduction of APD 2.0

A study carried out in the Hörzentrum Oldenburg, Germany, between May and October 2019 (Wright, 2020) evaluated APD 2.0 in comparison to the existing APD in Marvel devices, for inexperienced and experienced hearing aid users with mild to moderate and moderate to severe hearing loss (HL). Forty-one adults, aged 44–83 (average age 72) took part in the study and were split into two groups: (1) mild to moderate HL with no or short-term hearing aid experience; and (2) moderate to severe HL with long-term hearing aid experience. Several lab tests were carried out such as speech in noise tests (Oldenburg Sentence Test, OLSA, Wagener & Brand, 2005), a guided tour exposing participants to various sound environments and a home trial. Overall, the study showed a positive effect of APD 2.0 compared to APD for both groups of hearing losses and hearing aid experience. Furthermore, no negative outcomes were observed. Specifically, the study found (1) reduced listening effort in noise for subjects in both hearing loss groups as measured by Adaptive Categorical Listening Effort Scaling (ACALES), a subjective rating of listening effort (Krueger et al., 2017), (2) improved subjective experience in Speech in Noise (SpiN) and Speech in Reverberation (SpiReverb) during a guided tour and (3) overall preference in real-world environments at the end of the home trial.

Figure 3 shows that APD 2.0 leads to reduced listening effort in noise for mild to severe hearing loss groups, in comparison to APD in Phonak Marvel ($p<0.05$). In other words, with APD 2.0, participants of both hearing loss groups reached lower SNRs on the ACALES test for the same amount of listening effort.

There were also separate, specific advantages for the mild to moderate and moderate to severe HL groups in the study. For example for the mild to moderate HL group, significantly better results were observed for the ACALES and the Speech-in-Noise/Reverberation part of the guided tour for APD 2.0 compared to APD. For the moderate to severe HL group, participants reached significantly lower SNRs for the same intelligibility on the Oldenburg Sentence Test (OLSA), the same listening effort rating as measured by ACALES, and chose APD 2.0 significantly more often as the preferred setting at the end of the home trial, compared to APD.

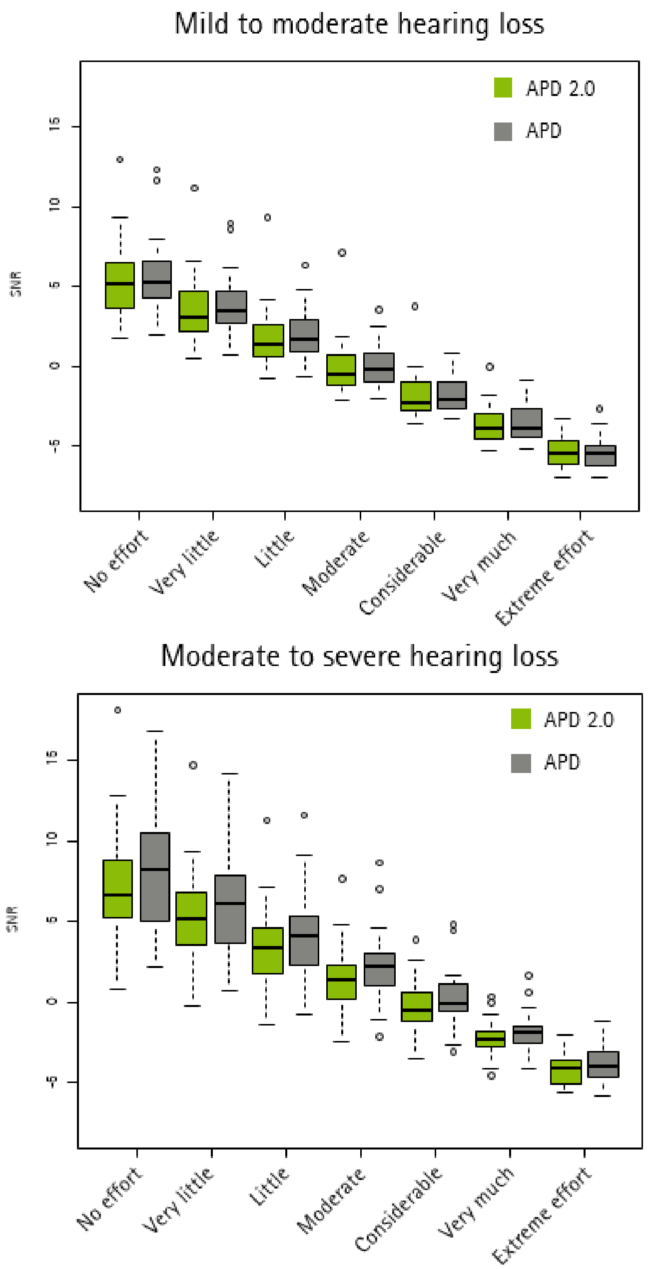

Figure 3: Boxplots of ACALES results comparing APD and APD 2.0 for each group. For each of the listening effort categories there was a significant benefit of APD 2.0 over APD ($p<0.05$). For example, 'very little' listening effort was achieved at a lower SNR with APD 2.0 compared to APD.

Benefits of APD 2.0 based on study evidence and available literature

Regardless of hearing loss, we aim to provide the best possible foundation for all of our fittings and spontaneous acceptance of first fit. The recent study carried out in Hörzentrum Oldenburg demonstrated APD 2.0 performed better than APD among experienced and inexperienced hearing aid users with mild to moderate and moderate to severe HL in terms of:

- reduced listening effort in noise as measured by ACALES
- improved subjective experiences in Speech-in-Noise and Speech-in-Reverberation situations during a guided tour
- overall preference at the end of the home trial

In addition, based on an extensive scientific literature review, we expect that clients will experience:

- less reverberation and background noise and improvements in sound quality thanks to the adaptive compression speed (Hassager et al., 2017; Moore, 2016; Madsen et al., 2015)
- natural sound quality and better speech intelligibility in noise thanks to the linearized high level gain (Lopez-Poveda et al., 2017)
- comfort at first fit thanks to the new precalculation. With APD 2.0, we have introduced more compression in the precalculation for mild to moderate hearing loss.

With the additional kneepoint, HCPs also have more freedom to fine-tune soft, mid and loud speech targets more easily.

Implementation of APD 2.0

The adaptive compression speed and linearized high level gain are applied for all fitting formulae, including NAL-NL2 and DSL v5. However, the new precalculation for mild to moderate hearing loss is only applied for APD 2.0.

Compared to the dual-path compression approach in APD, where the mix of fast and slow was a fixed ratio in SpiN, SpiLN, music and streaming programs, APD 2.0 implements a mix of adaptive compression speed and slow compression. In the quiet/calm situation program, the adaptive compression speed is on 100% in order to provide the benefit of fast compression in quiet and give maximum audibility cues. In noisier situations, for music and media streaming the adaptive compression speed is only 40% active (mixed with slow compression) to provide the benefit of slow compression in noise and give maximum temporal cues.

As the new precalculation for mild to moderate hearing losses and the linearized high level gain are part of the fitting formula, they are present in all programs.

APD 2.0 is available for Paradise devices and is not backwards compatible with older generation devices.

Hearing inspired by nature: APD 2.0

Phonak APD 2.0 is the foundation of Phonak Paradise next-level sound quality, the latest generation of Phonak hearing aids. We constantly seek to refine and further develop APD.

The recent study at the Hörzentrum Oldenburg, Germany, demonstrated that APD 2.0 showed less listening effort in noise for clients with mild to severe hearing loss and an overall preference in real-world environments at the end of the home trial compared to APD. With APD 2.0, we aim to provide the best possible starting point and spontaneous acceptance for each and every client with hearing loss.

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Volker Kühnel, PhD, received his degree in Physics in 1995. From 1995 to 1997 he worked in Oldenburg as a post-doc in the group of Medical Physics of Prof. Dr. B. Kollmeier, Oldenburg, Germany. Since 1998, at Phonak/Sonova he has worked in product development at the interface between hearing aid algorithms, fitting software and audiological design. His work focuses on the audiological quality of hearing instruments in order to achieve the highest benefit for clients.

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