The scientific basis for prescribing advanced feature settings

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ABSTRACT

Survey data show that hearing care professionals seldom make adjustments to advanced feature settings, although default settings may not be optimum for an individual user. This paper describes a new advanced feature prescription in ReSound Smart Fit fitting software based on individual user factors and reviews the scientific literature that informed the development of this prescription.

INTRODUCTION

At the initial fitting of hearing aids, hearing care professionals (HCP) set the hearing aids according to a prescription of frequency dependent gain and output. This becomes the starting point for the fitting, and the settings may later be adjusted according to verification measurements and user report of their experiences with the hearing aids. HCPs excel at making these adjustments, and there is good agreement among HCPs regarding how to troubleshoot for user complaints.[1] Most HCPs would agree that the benefit hearing aid users get from amplification is enhanced by the advanced features in today's hearing aids, such as noise reduction and feedback control. Like gain and output characteristics, these features are adjustable by the HCP. This should allow them to suit user needs and preferences better than ever. However, unlike gain and output, advanced features are less generic in quality among different hearing aids.[2] This means that to make informed adjustments, the HCP must keep up on the specifics of these features across different brands, and even across products within the same brand. This is no easy task.

How do HCPs manage this? Current hearing aid fitting practices were investigated in a survey of nearly 250 US-based audiologists.[3] The findings support the importance of hearing aid features to HCPs, while also highlighting a wide variation in how they are set and fine-tuned. Some hearing aid features such as directional microphones, noise reduction and feedback control were shown to play a big role in the selection and fitting of hearing aids. Over 80% of respondents cited features like these were a "very important" factor in the selection process, while essentially all respondents (97-100%) reported activating directional microphones, noise reduction and feedback control during the initial fitting appointment. But there was much more variation in how the respondents adjusted these features. Most respondents relied on manufacturer defaults when setting directional microphones, noise reduction, compression time constants and feedback control and it was less common to change settings away from default than changing gain and output settings. HCPs who did change advanced feature settings primarily relied on user report at follow up visits or their own experience. Only 20-40% of the HCPs surveyed relied on external sources of information on feature settings, such as published evidence from peer-reviewed sources or manufacturers, conference proceedings or expertise from other colleagues.

These results reflect the lack of consistent, universal guidelines for setting and adjusting hearing aid features.[3] Evidence-based guidelines for setting and verifying gain in hearing aid fittings are well established[4] and often used.[3] HCPs indicate a desire to follow evidence-based guidelines for setting and fine tuning features, but at this time, best-practice recommendations are still in early stages.[3,5] Many studies have been conducted on the impact advanced features have on performance or perception, but with such a wide variety of hearing aids, technology, methodologies and test participants used in the studies, it is not possible to make universal conclusions about feature settings at this time. Differences in hearing aid feature settings have been captured using subjective user questionnaires[6] but this reflects the user's overall listening experience and may not assist in adjusting single features. That said, HCPs can make some evidence-based decisions on feature activation or settings, particularly when considering individual user characteristics. One example is the link between wide dynamic range compression time constants and the cognitive functioning of the hearing aid user. Multiple studies have shown that performance on speech intelligibility tasks can be affected by a relationship between compression time constants and performance on tests of cognitive function.[7-10]

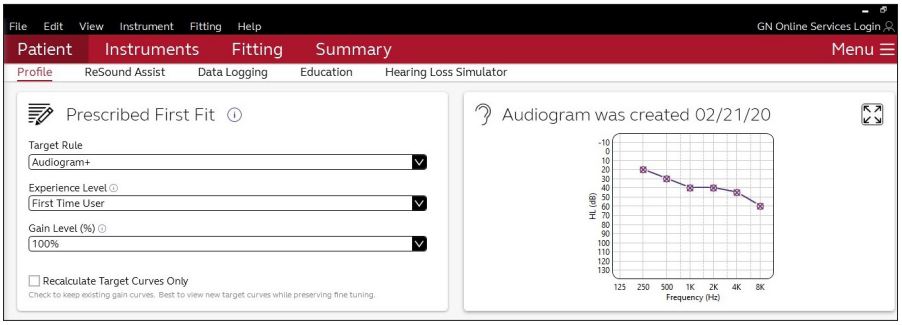

Figure 1: First fit settings can be adjusted on the Patient screen in ReSound Smart Fit 1.8. "Experience Level" and "Audiogram" are the two factors that can activate Prescribed First Fit changes.

The new Prescribed First Fit in ReSound Smart Fit 1.8 software integrates peer-reviewed evidence on advanced features into hearing aid fittings. HCPs will provide more individualized fittings with a basis in external, independent research – all without the need for any additional steps or actions.

WHAT IS PRESCRIBED FIRST FIT?

When a new hearing aid is fitted, initial settings in the software are programmed for gain per frequency and input level, output, and each advanced feature. Prescribed First Fit builds on the frequency-gain and output prescription by using published evidence to also prescribe individualized advanced features based on hearing threshold levels and the person's experience with hearing aids. ReSound makes it easy for the HCP to apply these findings clinically.

Until now, only one current ReSound advanced feature – Directional Mix – used hearing aid user-specific factors in determining the optimal default setting. Prescribed First Fit can now change default settings for three additional features – Noise Tracker II, Impulse Noise Reduction and Expansion. Prescribed First Fit can adjust these three features if evidence suggests this is a good fit for the user.

Prescribed First Fit activates for all new fittings or when selecting "Reset to Initial Fit" in a previously fitted device. When a new fitting is created in ReSound Smart Fit 1.8, Prescribed First Fit adjustments are applied to default programs as well as any new program(s) created during or after the first session. Prescribed First Fit will not apply to any existing sessions opened in ReSound Smart Fit 1.8, or if settings from a previous fitting are transferred into new devices. The hearing aid user must be an adult (age 18 years or more) for Prescribed First Fit to change any default settings.

Settings related to Prescribed First Fit can be accessed in the upper section of the Patient screen in ReSound Smart Fit version 1.8 and later (Figure 1). Here, the HCP can choose the target fitting rule, indicate the user's experience level with amplification, and apply percent gain offsets for easy global changes to gain. Note that the HCP is not required to visit the Patient screen for Prescribed First Fit changes to apply to a new fitting. But this is a convenient place to review important options for first fittings and to make those changes before moving on to the Fitting screen for fine tuning.

Hearing aid users are considered to be either new to amplification or experienced based on the Experience Level selection on the Patient screen (Figure 2). A person will be considered a new user if "First Time User" or "Comfort User" is selected, even if the hearing aid user has previous fittings saved in their file. A person will be considered experienced for both the "Experience – Linear" and "Experience – Non-Linear" amplification selections. Therefore, it's important to utilize Experience Level on an individual basis for hearing aid fittings.

RATIONALE BEHIND PRESCRIBED FIRST FIT

A conservative approach to automated feature adjustments was taken in designing Prescribed First Fit. If Prescribed First Fit does make changes, a feature only changes by one step from its default setting. The feature may also maintain its original default setting if user factors suggest this is a better choice. If there are multiple user factors identified by the software that can impact Prescribed First Fit, changes to each feature are limited to one step away from default.

Prescribed First Fit can make changes to three advanced features based on two user factors. Only features and hearing aid user factors that demonstrated a relatively robust relationship to hearing aid user outcomes in a review of peer-reviewed research studies were included. Only evidence that showed similar outcomes in multiple studies, ideally with use of different hearing aids or generations of technology were included. Features or factors with limited evidence, or conflicting evidence across studies, were excluded from Prescribed First Fit. In addition, studies that investigated the effects of hearing aid processing as a whole, instead of individual features, were excluded from Prescribed First Fit, as details on each feature were required for setting the parameters.

Two factors – hearing thresholds and previous hearing aid experience – are used in Prescribed First Fit. There is evi-

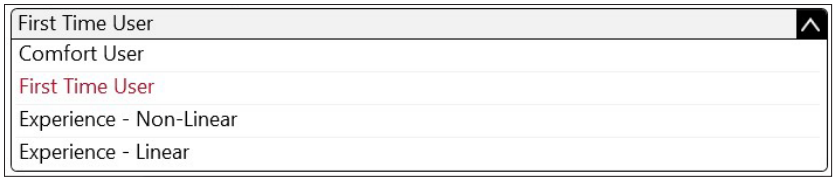

Figure 2: Experience Level in ReSound Smart Fit. During the initial fitting, selecting Comfort User or First Time User will categorize the hearing aid user as a new user, while Experience – Non-Linear or Experience – Linear will categorize the hearing aid user as an experienced user.

dence suggesting many other individual factors, including cognitive status, working memory ability, and tolerance and acceptance of noise can interact with hearing aid settings to influence user outcomes or preferences.[11-13] But identifying many of these factors require additional clinical testing, and many of these tests are not available to HCPs or are not routinely conducted in a clinical setting (for example, <5% of audiologists from Anderson et al[3] reported using a suprathreshold test to fine tune hearing aid features). Even if additional testing was completed, there is not a universal consensus on the amount each of these factors may contribute to differences in individual hearing aid outcomes.

SUMMARY OF LITERATURE REVIEW

The review of existing evidence was conducted in September 2019 using the list of terms related to hearing aid features and hearing aid user factors shown in Table 1. Publications were searched using PubMed and Google Scholar databases. The search terms were combined with one another and with "hearing" or "hearing aid" – for example "hearing aid, compression, audiogram". Any evidence investigating these topics with cochlear implant or bimodal (cochlear implant + hearing aid) users was excluded from the review. In addition, evidence relating exclusively to hearing aid use in children was also excluded, because the Prescribed First Fit adjustments apply only to adult hearing aid users. An emphasis was made on including studies published in 2010 or after, though older studies were also included if they supported findings in newer studies and/or demonstrated outcomes that were related to long-available technology, like expansion.

Search term	Hearing aid feature	Hearing aid user factor
"Hearing" or "Hearing aid"	Noise reduction	Acceptable noise level
	Wide dynamic range compression	Word recognition
	Time constraints	Hearing aid experience
	Compression speed	Audiogram
	Expansion	Audiometric configuration
	Transient noise reduction	Uncomfortable loudness level
	Impulse noise reduction	Loudness discomfort level
		Speech in noise
		Dynamic range
		Cognition
		Working memory

Table 1: Search terms utilized in the review of evidence for the development of Prescribed First Fit.

NOISE TRACKER II – DIGITAL NOISE REDUCTION

Digital noise reduction (DNR) is a popular feature in today's hearing aid fittings. The survey conducted by Anderson et al[3] showed that 98% of responding audiologists activated DNR in their hearing aid users' first fittings. While there is no consistent evidence that DNR contributes to improved speech intelligibility in noise, several other benefits of the feature have been observed.[14] Laboratory studies of DNR efficacy have shown it can reduce listening effort in noise[15-17], improve sound quality[17], increase listeners' tolerance of noise[18] and increase scores on measures of memory and reaction time.[15,19] Hearing aid users report perceptual benefits from DNR in real world environments as well. A randomized controlled trial with 54 older adult hearing aid users showed that DNR and directional microphones were preferred in a variety of real-world environments.[20] The participants preferred these features to be activated when asked to rate their everyday listening experiences based on listening effort, sound quality, localisaton and satisfaction.[20]

Individual hearing aid users do vary in their acceptance and preference for DNR settings, though most find it preferable to no DNR.[21,22] Wong et al[21] measured the variation across participants' preference for no DNR and varying levels of DNR (mild, moderate and strong) using a paired comparison task. The participants listened to continuous speech presented in cafeteria noise at a +5 dB SNR. Each DNR setting was compared to DNR off, and to one another, in a paired comparison task. The mean ratings for listening effort, comfort, speech clarity, and sound quality favored DNR on (at any setting) over no DNR. Less consistent preference was observed among the DNR strength levels, though two patterns did emerge from the data. Many participants favored moderate or strong DNR over mild DNR when rating listening comfort. There was greater preference for moderate DNR over strong when rating speech clarity and overall sound quality.

Another study by Brons et al[23] compared the sensitivity to distortion from DNR between listeners with normal hearing and those with hearing loss. Stronger levels of DNR were required for participants with hearing loss to detect distortion, but once distortion was detected, the listeners with hearing loss were at a greater disadvantage from the distortion than the participants with normal hearing. This study, along with Wong et al[21], supports the importance of balancing the benefits of DNR while also minimizing distortion or loss of clarity. This suggests that DNR should be implemented with a personalised balance between speech clarity and listening comfort. Prescribed First Fit does just that by adjusting Noise Tracker II based on the user's previous experience with hearing aids and the type of listening situations the user encounters in their everyday life.

Noise Tracker II is one step lower for users with previous hearing aid experience in everyday listening situations...

Experienced, full-time users of hearing aids tend to tolerate more noise than people who are new to hearing aids.[24] In order to promote maximum clarity for speech,

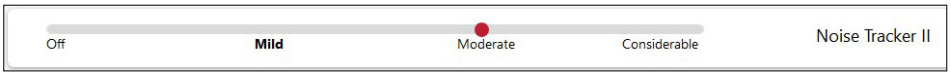

Figure 3: Display of default Noise Tracker II settings where Prescribed First Fit has taken effect (right ear only). The hearing aid user is identified as a new user, so the original default of Mild DNR (bold) is now set to Moderate (red dot).

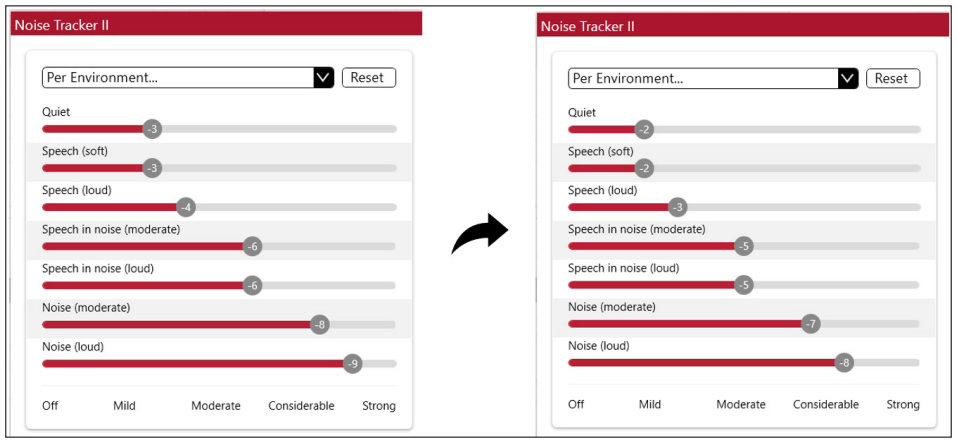

Figure 4: Noise Tracker II Per Environment default settings (left panel) and with Prescribed First Fit applied (right panel) for a hearing aid user with previous hearing aid experience. The default DNR automatically decreased by one step in all seven environments.

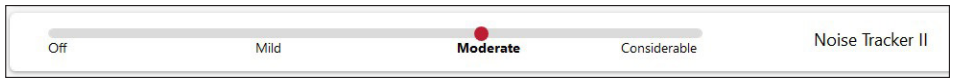

Figure 5: Noise Tracker II default setting in a Restaurant program for an experienced user (right ear only). The original default of Moderate (in bold) still applies in this program after Prescribed First Fit is applied (red dot).

Prescribed First Fit decreases Noise Tracker II settings in the All Around program when the Per Environment setting is used. Additional programs in the hearing aid, such as those designed for higher levels of noise (Restaurant, Outdoor) or no noise (Music) will keep the original Noise Tracker II defaults.

...and Noise Tracker II is one step higher for new hearing aid users in situations with more noise.

The benefit of stronger NoiseTracker II strength on client acceptance of hearing aids was weighed against the possible downside of reduced audibility and increased distortion. While strong DNR settings can have a negative impact on speech intelligibility[22], more moderate DNR settings do not appear to be aggressive enough to reduce intelligibility for most listeners. However, stronger levels of DNR tend to improve ratings of listening comfort in noise and tolerance for noise.[21] Prescribed First Fit helps achieve this balance by maintaining default Noise Tracker II settings in All Around, where we expect most listening is done in quieter or lower noise situations. But, in programs designed to handle higher levels of noise (Restaurant or Outdoor for example), Noise Tracker II settings increase by one step.

How it works in Prescribed First Fit

Default values for each advanced feature setting displays in bold in ReSound Smart Fit software. When any changes to the defaults are applied by Prescribed First Fit, the original default will still appear in bold, but the one step change will have applied, indicated by a red (right ear) or blue (left ear) dot. Figure 3 shows how this will look when the HCP checks the Advanced Features tab in the software after completing the first fit.

The Noise Tracker II changes applied by Prescribed First Fit will vary slightly depending on the hearing aid model and technology level. First, the Per Environment changes can only occur in premium level devices where that feature is available. If a hearing aid does not have Noise Tracker II Per Environment available, the NoiseTracker II setting in the All Around program will increase by one step for a new user, or remain at default for an experienced user.

Experienced hearing aid users (Experience – Linear and Experience – Non Linear)

Noise reduction settings in for the Noise Tracker II Per Environment feature will decrease by one step in each of the seven listening environments (Figure 4). This is designed to promote enhanced clarity for most everyday listening situations in All Around.

If any additional programs are fitted, the default Noise Tracker II settings will be preserved (Figure 5). Recall that because these programs are designed to handle more specific estimates of noise, the default noise reduction levels were maintained.

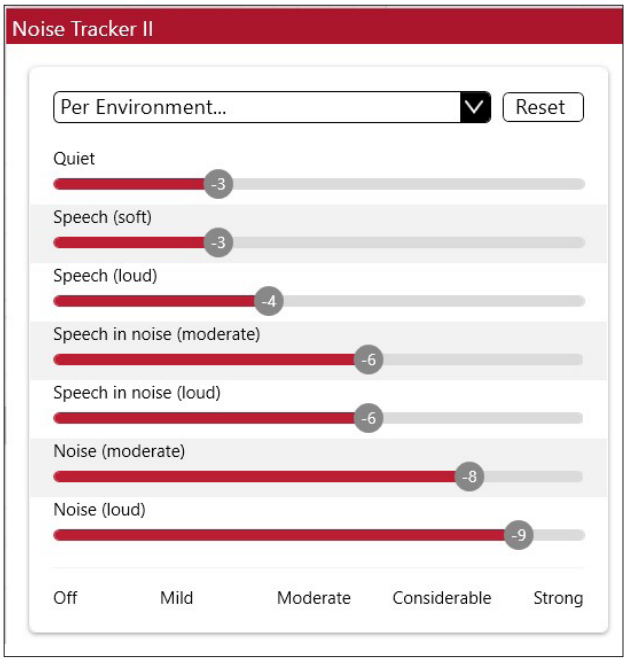

Figure 6: Noise Tracker II Per Environment default settings for a new hearing aid user. The DNR settings remain at default in all seven environments even after Prescribed First Fit has applied.

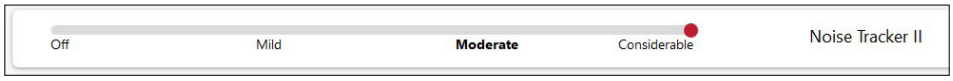

Figure 7: Noise Tracker II default setting in a Restaurant program for a new user after Prescribed First Fit is applied (right ear only). The original default of Moderate DNR (bold) is now set to Considerable (red dot).

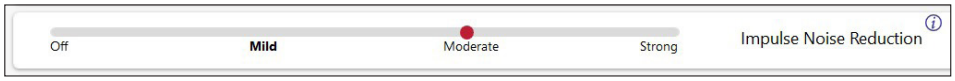

Figure 8: INR setting in a new hearing aid fitting for a hearing aid user with no previous hearing aid experience (right ear only). Prescribed First Fit has increased INR to Moderate, compared to the original default of Mild.

For new users (First Time User and Comfort User)
The opposite action occurs for Noise Tracker II in a new hearing aid user. Noise reduction settings in for the Noise Tracker II Per Environment feature will maintain the original defaults for the seven listening environments (Figure 6). This helps preserve speech clarity in everyday listening environments while also allowing Noise Tracker II to aid in adaptation to hearing aids with a higher setting than those for experienced users.

Additional programs in the fitting are where changes to Noise Tracker II for new users are observed (Figure 7). The default setting will increase by one step, in order to increase comfort in noise. The increase is capped at Considerable to prevent too much reduction from interfering with audibility. If a program is added that sets Noise Tracker II to Off as its default (Music, for example), Noise Tracker II will remain Off after Prescribed First Fit is applied.

IMPULSE NOISE REDUCTION

Impulse noise reduction is one step stronger for hearing aid users who are new to hearing aids

Impulse noise reduction (INR) is designed to reduce gain for very loud and fast environmental sounds, such as clinking glass or metal, while preserving gain for speech or other less intense sounds in the environment. It was hypothesized that, like DNR, INR may help contribute to increased acceptance of sound while using hearing aids, especially for people new to hearing aids. The majority of studies reviewed do support this. In addition, some studies demonstrated improved speech understanding in the presence of transient noise with INR on.

In Liu et al[25], a group of new hearing aid users with a wide range of sensorineural hearing loss severities compared five listening situations in a lab setting with and without INR. A variety of realistic transient sounds (such as a slamming door, a mug being placed onto a counter, a knife falling onto a ceramic block) were presented alone, and in combination with background noise, with male speech and all together. All listening conditions contained transient sounds. The study participants were asked to rate how strongly they preferred each listening situation based on sound quality. In listening conditions that contained speech, they also rated speech understanding, clarity and loudness. The users indicated a stronger mean preference for INR on in every listening situation presented in the study, as compared to no INR. The users also reported a mean improvement in speech understanding and a preference for louder speech (70 dB SPL) with INR on versus off. INR did not impact the users' perception of speech clarity.

DiGiovanni et al[26] found that INR had a positive effect on speech understanding in the presence of background noise and a loud transient noise. Subjective ratings of sound quality and comfort did not differ between INR on and INR off in this study.
Korhonen et al[27] investigated the effects of INR with a group of 13 experienced hearing aid users. The participants rated sound quality and performed speech intelligibility in quiet tasks with INR on and off. They also reported the preferred gain level in the hearing aids with INR on and off. The participants rated sound as more comfortable when using INR. Speech intelligibility in quiet was not impacted by INR. When INR was activated, there was a 2.9 dB mean increase in overall accepted gain by the users in the study. The 2.9 dB gain increase with INR on allowed for a 12% improvement in soft speech consonant identification, which suggests there is potential to improve audibility for difficult-to-hear soft speech sounds by using INR, since more gain can be tolerated by the user.

How it works in Prescribed First Fit
Prior to Prescribed First Fit, INR has been activated in all new fittings at a Mild setting. In light of the evidence that INR can positively impact user experience with hearing aids, along with a lack of negative impacts on speech intelligibility, Prescribed First Fit will automatically increase INR by one step to Moderate for a person who is identified as a new user (Figure 8). The default setting for INR does not differ across hearing aid programs, so the increase to Moderate as the INR default will be observed in all listening programs.

EXPANSION

Expansion is turned on for hearing aid users with normal or near-normal low frequency hearing

Expansion refers to a decrease in gain with a decrease in input level to the hearing aid. This reduces gain for sounds at or below the expansion threshold/kneepoint (TK), which reduces audibility of low-level background noise and internal noise generated by the hearing aid. It is intended to improve user satisfaction when listening in quiet. Indeed, studies of hearing aid use in everyday life demonstrate a mean preference for expansion activated versus expansion off when hearing aid users spent time in quiet situations during an at-home wear trial.[28,29] Interestingly, the study participants in Plyler et al[29] with moder-

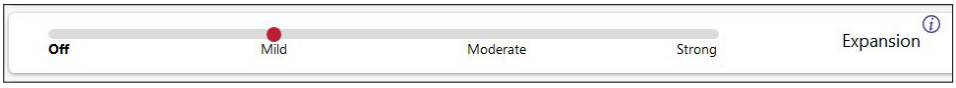

Figure 9: Expansion setting in a new hearing aid fitting for a hearing aid user with normal low-frequency hearing loss (right ear only). Prescribed First Fit has activated Expansion at a Mild setting, compared to the original default of Off.

ate to severe hearing loss preferred expansion to be activated, even though users with this degree of hearing loss aren't typically considered candidates for expansion.

On the other hand, expansion does reduce intelligibility of soft speech if speech levels are below the expansion TK.[28,30,31] Use of lower expansion TKs (~30 dB SPL)[30] and restricting expansion to low frequency channels[28] has been shown to minimize negative impacts on speech intelligibility while still improving subjective ratings of sound quality.

These studies demonstrate that expansion requires a balance of improving sound quality for quieter environments while preserving soft speech audibility. One way this is achieved is in the design of the Expansion feature in ReSound hearing aids. The expansion TK varies across channels, with lower TKs in the mid to high frequencies to reduce impact on soft speech intelligibility while still reducing background noise. Expansion TK also differs across ReSound hearing aid models, with higher power devices using higher TKs.

Expansion is a feature in ReSound Smart Fit, with a space software that has always defaulted to Off, until now. Although hearing aid users with more moderate to severe hearing losses may benefit subjectively from expansion[29], the balance between improvement in sound quality and protecting speech intelligibility has led us to only activate expansion using Prescribed First Fit for those hearing aid users with normal to near-normal hearing below 1000 Hz.

How it works in Prescribed First Fit

ReSound Smart Fit software calculates the average hearing thresholds at 125 Hz (if applicable), 250 Hz and 500 Hz. If the average PTA at these frequencies is equal to or less than 25 dB HL, Expansion is turned on to Mild (Figure 9). Basic level hearing aids will show Expansion On, as Off versus On are the only available options.

CONCLUSIONS

Prescribed First Fit is a new prescription in ReSound Smart Fit 1.8 that automatically sets hearing aid features based on evidence supporting these settings. This prescription is conservative, meaning that adjustments compared to the default feature settings were made only for features with multiple studies supporting similar outcomes, and only including individual client factor data that are already available in the fitting software. Evidence-based adjustments for hearing aid features is still in early stages, but as the body of evidence for best practice guidelines grows, Prescribed First Fit can be updated to take new knowledge into account. Prescribed First Fit is expected to be a valuable addition to supporting the HCP in providing the best care for each of their hearing aid users, with the potential to grow and evolve in the future.

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