SmartFocus™

Article 1 - Technical approach

Effective strategies for addressing listening in noisy environments

The difficulty of determining the desired amplification for listening in noise is well documented. The lack of a standard fitting formula in this area can be attributed to a combination of determinants: differing tolerance for what represents acceptable noise; constantly changing goals; and a mismatch between the fitting environment and the types of listening situations clients experience on a daily basis.

Historically, parameter adjustments have been performed based on what should theoretically make the greatest impact on listening in noise. Now there is an alternative approach that involves providing clients with real-time adjustable control over adaptive features such as speech enhancement, noise reduction, microphone strategy and overall gain – features proven to yield the most significant impact in difficult listening situations. It's called smartFocus™ and it's a powerful yet simple control that allows the wearer to easily adjust the performance of their hearing instrument through a full range, ultimately providing comfort and clarity across listening situations.

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There are many accepted fitting formulas with which to adjust a hearing instrument for optimal performance in quiet. The best known, and most widely accepted, are DSL v5[1, 2] and NAL-NL1[3]. Combining the benefits of accepted fitting formulas with the flexibility and sound quality of current multichannel digital instruments, ensures that almost all fittings can yield excellent performance in quiet without much difficulty[4].

The dilemma of listening in noise

Determining desired audibility for listening in noise is much more challenging. There are many unknown factors at the time of the fitting. While prescriptions for gain/frequency are common, there are no defined methods for adjusting adaptive parameters such as speech enhancement, noise reduction and microphone strategy; features that significantly impact noisy or reverberant environments. As such, clinicians are forced to make theoretical assumptions regarding which parameter adjustments will make the most impact in a given noise. In other words, even if a target existed for a given listening environment, it would not be easy to validate adaptive parameter settings for that same environment, while sitting in a quiet dispensing office. To further complicate matters, what counts as desirable listening for one person may represent unacceptable noise for another.

Here are some additional reasons why it's more difficult to adjust hearing instruments for listening in noise.

Constantly changing goals – In a quiet listening situation, it is reasonable to assume that an individual's amplification goal is to improve the perception of speech. However, the hearing instrument wearer's goals in more challenging environments will vary across a continuum, from speech perception to comfort or sound quality, depending on the nature of the situation and the person's reason for being there. For example, while walking along a busy street the wearer's goals will surely include awareness of alerting signals for safety. Yet that same individual may not require speech clarity, especially if clarity reduces comfort or sound quality. If walking with a spouse or colleague on exactly the same busy street, however, the same wearer may accept diminished comfort in exchange for improved speech clarity.

Acoustic variations in difficult environments – While quiet listening consists of a fairly homogeneous set of situations, there are huge acoustic variations across the range of more difficult environments. This is due to differing reverberation times, as well as background sounds from multiple sources, with differing spectral content and signal levels, all of which interact and constantly change.

A solution built on user control

An alternative to the standard clinical approach described above is based on an adjustable user control for multiple adaptive features. The approach begins with an initial fitting where the clinician presets the instruments in the office for the wearer's desired listening environments. Settings at, or near, the manufacturer's defaults are often a good starting point. A high level of precision may not be required at this stage if the hearing instruments contain a user adjustable control over the features that will yield the most demonstrable impact in difficult listening situations.

Traditionally, user control has been limited to volume control or the ability to make broad program changes according to settings the fitter thinks might be best for a particular listening environment. Automatic programs are also available but the parameters within these programs require certain assumptions on the part of the fitter; assumptions which may not always meet the needs of the wearer.

In contrast, it is highly effective to empower users to manipulate those features which impact hearing instrument output, but have no clearly associated prescription. For example, when the wearer experiences a difficult listening situation, they can control a group of parameters including: microphone directionality, speech enhancement, noise reduction and overall gain. Using one simple control the wearer can simultaneously optimize all four parameters to meet their desired goal in any listening environment in real time. Thus the wearer has the opportunity to rapidly converge on an optimized fitting in any listening environment as efficaciously as possible, increasing satisfaction and performance, while minimizing problems and complaints, even before the follow-up visit.

Planning for parameter interaction

In order for the above scenario to work as intended, it requires more than a simple control over a series of adaptive parameters. The parameters constantly interact with one another, readjusting the device's performance on a moment-to-moment basis. Thus, the features under user control must be coordinated at every setting to provide a synergistic effect converging to a common desirable outcome.

Here is an example to illustrate this point. You have a client who regularly plays cards at a local hall every Thursday night. This client has a two dimensional problem:

- Audibility must be adequate to follow the game play and interact socially
- Comfort must be maintained through precise control of extraneous noise, speech or music

In this case, simply turning up the volume won't meet both of the client's goals. You risk achieving audibility at the expense of comfort. In fact, failure in either dimension (comfort or clarity) may lead to rejection of amplification and subsequent social isolation. However, giving this client direct control over the parameters of interest allows him to strike the desired balance, maximizing both audibility and comfort in this particular situation.

How can a clinician customize the key parameters in the hearing instrument, optimizing it for this specific situation? In this case, the key parameters and each of their possible states are shown in Table 1.

Table 1

Parameter	State			
	1	2	3	4
Microphone	Omni	Fixed Directional	Adaptive Directional	
Noise Canceller	Off	Mild	Moderate	Maximum
Speech Enhancement	Off	Mild	Moderate	Maximum

Taken alone, the impact of each feature is reasonably predictable. But what will be the aggregate effect of all three features running simultaneously in a rapidly changing noisy environment? The answer will be due, in part, to how they are set.

There are three microphone states and four possible states each for speech enhancement and noise canceller. That adds up to 48 possible unique states (3 x 4 x 4 = 48). Furthermore, each of these features has an adaptive component yielding an infinite set of possibilities within the range of adjustment. In other words, the true status of the hearing instrument amounts to the sum of all the parameter settings under the influence of the given listening situation. In addition, the impact of all these features will vary depending on whether the base gain is set appropriately. If the device does not provide audibility from the outset, considerations regarding how to set other adaptive parameters will be inconsequential.

The hearing instrument performance that ultimately occurs as a result of these parameter adjustments is neither predictable nor replicable in the clinician's office. The only way to verify the value of the modification is in a real listening environment. However, by optimizing the performance of all three parameters in relation to one another, and then putting them all under one control, it will be possible for the user to optimize the fitting in real time.

SmartFocus™: Unprecedented user control

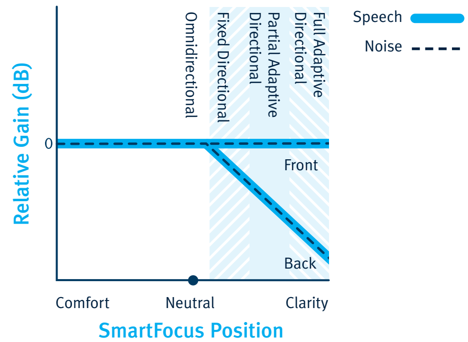
The smartFocus user control provides a range of adjustment from comfort to clarity. When adjusting towards comfort, the goal is not to maximize speech intelligibility or improve understanding, but rather to increase the overall listening comfort without losing environmental awareness. The parameter settings at the comfort end of the continuum are optimized specifically to meet these goals.

Conversely, when adjusting toward clarity, all of the parameters have been optimized to enhance the perception of speech, particularly in noisy environments.

Both comfort and clarity can be adjusted as follows:

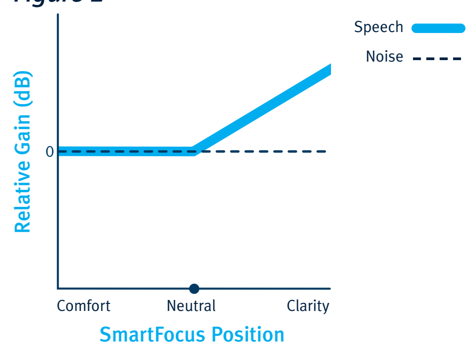
1. Microphones

Figure 1



2. Speech Enhancement

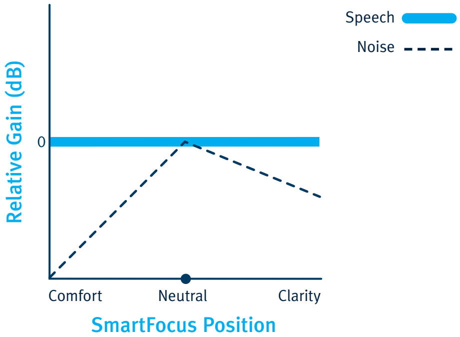
Figure 2



3. Noise Canceller

Although the noise canceller is engaged whether the control is adjusted toward comfort or clarity, its impact is different in each direction. When adjusted towards the direction of comfort, the noise canceller is more aggressive, reducing noise by up to 10 dB/band at its maximum. This is designed to meet the listening goal of comfort in noise. However, when adjusted towards the direction of clarity, the impact of the noise canceller is limited to 6 dB/band. The noise canceller is less aggressive at the clarity end of the continuum than at the comfort end because its purpose is to improve the clarity of speech signals. If the noise canceller works too aggressively in combination with speech enhancement it can actually deteriorate clarity. This is one benefit of pre-configuring the relative combination of these multiple parameters at each setting of the control. It helps ensure that parameters will be set to achieve desired goals without causing artifacts.

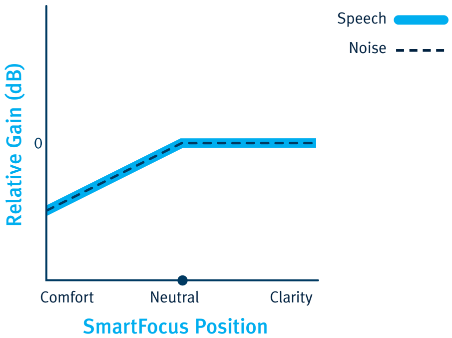
Figure 3



4. Gain Reduction

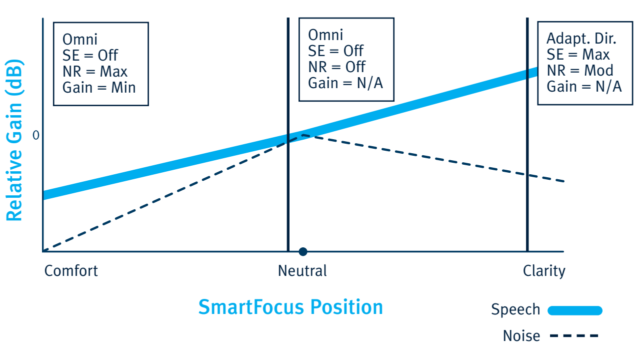
Another effect that most hearing instrument wearers associate with comfort is a slight gain reduction. As the control is moved towards comfort the gain is progressively reduced up to 8 dB.

Figure 4



The combined effect on the gain model of all parameters under adjustment is shown in Figure 5.

Figure 5



Making a noticeable difference for speech in noise

Many clients pursue a hearing instrument to improve their perception of speech in noisy environments. However, there are many noisy environments where the client would much prefer comfort over clarity. The inability to precisely meet their goals for speech in noise is one of the main reasons that clients ultimately reject hearing instruments. It would be extremely helpful if clients had a control that could address both of these pre- and post-fitting concerns.

What is the potential impact of the smartFocus control in a 'speech in noise' environment? As the smartFocus control approaches comfort, all signals, speech and noise, are reduced in amplitude, due to the overall decrease in gain. Noise is given an extra reduction due to the intelligent application of noise reduction in those bands containing noise.

As smartFocus moves toward clarity, background noise is still reduced by the combined impact of the directional microphones and the noise canceller. However, the output for speech, especially speech in the directional target area in front of the wearer, is increased considerably thanks to speech enhancement. Thus, the control provides the user with a simple, yet powerful, tool to optimize the performance of the hearing instruments.

Minimal use yields maximum results

There is the risk that constant adjustment of a user control in different listening situations will rapidly become intrusive. Therefore, the quality that makes the smartFocus user control so highly effective is its availability when needed. Furthermore, the instrument learns the wearer's preferred smartFocus and VC settings in multiple listening environments over time, through the self learning and learnNow features, thereby minimizing the required frequency of use. There are two additional components of the hearing system which make this possible.

AutoPro4™

The automatic program, which is called autoPro4™, includes the following destinations: speech only, speech in noise, noise only and music. The smartFocus control can be adjusted to a different position for each of these destinations. As the instrument cycles from one destination to the next, reflecting changes in the listening environment, it updates the position of the smartFocus control to the wearer's desired setting for the new destination.

Optimizing the control for up to four destinations significantly reduces the need for constant user adjustment, provided the correct settings have been chosen for each destination. As previously discussed, presetting adaptive features is problematic at best from the booth in the clinician's office. Therefore, it is extremely helpful if the hearing instruments can learn the client's preferred settings, reducing the need for repeated wearer interventions each day[5, 6]. Plus, fewer return visits are needed to update the device[5, 6]. Furthermore, wearers are generally more satisfied with an aid that they have optimized in their own listening environments[7].

Self learning

The clinician presets smartFocus and the volume control for all four destinations at the fitting. The wearer takes the hearing instruments home and makes adjustments to both controls while moving through common listening situations. The hearing instruments learn the wearer's preferences in each destination and gradually updates both controls, thus optimizing smartFocus and the volume control for each of the four destinations. By the time of the follow-up visit, two to three weeks after the fitting, the instruments have applied the wearer's preference for both controls in each of the four listening destinations. The wearer now only needs to make adjustments in either novel listening environments or in instances where their goals have shifted within a known, or learned, environment.

Real life results

To validate the performance of the smartFocus control, 35 individuals experiencing a wide range of hearing loss were fitted with Unitron hearing instruments featuring a variety of shell types and venting options. Each participant wore their assigned hearing instruments for three weeks. At the end of the three weeks they were asked to rate their overall satisfaction with the instruments on a 1 - 10 scale, where 1 was "very dissatisfied" and 10 was "very satisfied." The participants were overwhelmingly either very satisfied or satisfied with the hearing instruments after three weeks of use. Their ratings are shown in Figure 6.

Figure 6

Aside from satisfaction levels, the participants also reported significant benefit from the hearing instruments on the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire[8]. The results for the new hearing instrument wearers and experienced hearing instrument wearers are shown in Tables 2 and 3.

Table 2

Category	Difference between means (benefit score, %)	p-value	Significant benefit New users
Global	21.95	<.0001	Yes
EC	19.9	0.0017	Yes
RV	18.91	0.0003	Yes
BN	28.23	<.0001	Yes
AV	-22.08	0.0039	No

Table 3

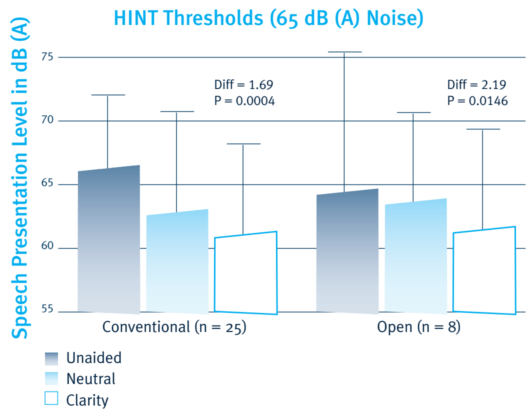
Category	Difference between means (benefit score, %)	p-value	Significant benefit Experienced users
Global	22.043	0.0054	Yes
EC	16.529	0.025	Yes
RV	31.364	0.0016	Yes
BN	18.38571	0.0023	Yes
AV	- 8.321	0.2465	No

New and experienced users are separated because benefit from wearing these hearing instruments is calculated as a decrease in problems relative to no amplification for new users, and as a decrease in problems relative to their previous hearing instruments for the experienced users.

In both cases there were significant improvements in Global aided benefit from Passport as well as in Reverberant and Noisy listening environments. The new users also showed significant improvements for quiet listening over the unaided condition. The experienced users reported about the same performance with Passport as with their existing hearing instruments in quiet listening environments.

The clarity provided by the smartFocus control was tested on another group of 33 participants. They were assessed using the HINT[9] under very challenging conditions. HINT sentences were presented from 0˚ azimuth. Speech weighted noise was presented from four separate speakers at: 0˚, 90˚, 180˚ & 270˚ azimuth at a fixed level of 65 dB (A). The HINT sentences were varied adaptively to obtain Sentence Speech Reception Thresholds (SSRTs). Analyses of the results are shown in Figure 7.

Figure 7



For the 25 participants who had conventionally fitted hearing instruments there was a significant improvement in the HINT Signal-to-Noise Ratio (SNR) for the neutral setting of the smartFocus compared to no aid and there was a further significant improvement from the neutral setting of smartFocus to the clarity setting. For the eight participants with open fitted instruments there was a significant improvement in HINT SNR for the clarity position compared to the neutral position. In both cases there was a substantial and significant improvement in HINT SNR for the clarity position over the unaided condition.

Summary

It is fairly straightforward to provide hearing instrument wearers with good performance in quiet listening situations. However, the problem becomes much more complicated when the listening situation is a noisy or reverberant environment. Clinicians must fine tune fittings without the ability to replicate each individual's listening environments in their offices.

To overcome this problem, clinicians can provide the wearer with a simple but powerful user control called smartFocus. This control allows the wearer to simultaneously adjust multiple adaptive parameters to improve comfort or clarity in any listening situation. Trials of the Unitron hearing instrument employing the smartFocus control have demonstrated that this approach substantially improves user satisfaction and benefit across a range of listening situations. These tests also suggest that this feature improves speech perception in noise as demonstrated by HINT results.

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