Natural directionality II: next generation asymmetric fitting

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Hearing in noise is the largest problem reported by hearing-impaired people and the problem often persists after hearing aid fitting. Hearing aid directionality is used to increase the signal-to-noise ratio, but also introduce problems as inaudibility.

To address this audibility issue GN ReSound introduced asymmetric fittings. The solution, however, contained problems related to directional microphone technology, such as noise introduced as a result of the equalizing for inherent low-frequency roll-off. To solve these issues the strategy for asymmetric fittings was further developed, resulting in the next generation of asymmetric fitting.

This article will review the background for asymmetric fittings. Results from earlier studies will be summarized and issues that have been identified with GN ReSound's launch of first generation of asymmetric fitting, Natural Directionality, will be discussed. Further research has been carried out addressing those identified issues and the solutions will be presented. Clinical data will back up improvements in GN ReSound's next generation of asymmetric fitting, Natural Directionality II.

INTRODUCTION

Understanding speech in background noise is the primary problem for hearing-impaired individuals. While hearing aids can provide increased audibility, difficulties with background noise often persists. The best way to improve speech understanding in background noise is to increase the signal-to-noise ratio (SNR).

Directionality in hearing aids has consistently been shown to markedly improve SNR in numerous laboratory investigations (Nielsen, 1973; Valente *et al*., 1995; Wouters *et al*., 1999; Pumford *et al*., 2000; Walden *et al*., 2000). However, studies as early as Nielsen (1973) have failed to establish the same striking benefits of directionality in real-life situations as are observed under controlled laboratory conditions. Reasons for this discrepancy are among others that the physical characteristics of the environment significantly affect directional benefit. Directional benefit is greatest in an anechoic environment and decreases as reverberation increases (Madison and Hawkins, 1983; Hawkins and Yacullo, 1984; Ricketts and Hornsby, 2003). Other factors related to the physical environment include location of the competing noise, separation of the signal and noise, and distance to the signal (Amlani, 2001). Walden *et al*. (2000)

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mentions the importance of hearing aid wearers learning to use the directionality feature correctly in real life and actually encounter real-life situations in which they can potentially benefit from directionality as other potential explanations for the discrepancy between directional benefit in the laboratory versus in real life.

Directional hearing aids, while beneficial in increasing the SNR, may also introduce problems. Many users experience diminished audibility for sounds of interest that do not arise from the front, or in the "look direction". As sounds from the sides and the rear are reduced in amplification, wearers may report a feeling of being cut off from much of their surroundings, resulting in a skewed perception of the listening environment as a whole.

Other issues have been reported regarding practical use of directional hearing aids. While specific directional characteristics should be preferred in specific situations, research has shown that over 30% of hearing aid wearers with manually switchable omnidirectional/directional hearing aids do not change between these modes (Cord *et al*., 2004). Reasons for this include the user not knowing when to switch, and/or not wanting to make these manual adjustments in their daily hearing aid use.

To solve this problem a number of hearing aid manufacturers, including GN ReSound, have introduced devices which automatically switch microphone mode based on the physical characteristics of the environment, also known as acoustic scene analysis. However, not all manufacturers use the same techniques for acoustic scene analysis, nor do they employ the same criteria for switching microphone mode. Automatic switching algorithms may also differ in how quickly they switch modes. Although automatic switching of microphone mode is designed to make the lives of hearing aid wearers easier, it can potentially become a source of irritation and frustration. The intent of the wearer may not always be consistent with what is predicted, based on the acoustic scene analysis. For example, when talking with someone at a party, one can choose to change the focus of one's attention to a conversation occurring off to the side and then back again. A hearing aid which automatically switches to a directional response predicts what the wearer wants to hear based on an analysis of physical data, yet it really does not have all the information necessary to accurately make this decision. It cannot actually know what the wearer wants to hear, nor can it predict when the wearer wants to shift his attention to another sound source. A listener does not perform acoustic scene analysis, but rather auditory scene analysis.

THE CONCEPT

Auditory scene analysis is the process by which the auditory system sorts and interprets the complex stream of acoustic information in natural environments. The acoustic energy from many sound sources is mixed at the ear of the listener, who can use his sense of hearing to attend to them individually, to shift attention among the different sources, as well as to draw conclusions about the physical properties of each sound source (Bregman, 1990). Auditory scene analysis is mediated by high order auditory processes, and thus remains a capability of most hearing aid wearers, whose hearing losses tend to be due to peripheral auditory system damage. Hearing aids compensate for these peripheral effects, such as loss of audibility and dynamic compression, but do not take the entire auditory system into account. Hearing aid signal processing strategies can potentially interfere with centrally mediated effects. Consequently, while automatic microphone mode switching can provide the benefit of directionality to individuals who are not capable or who do not like to select microphone mode, it can potentially work at odds with the wearer's auditory scene analysis.

The ultimate challenge to automatic switching algorithms is to determine the wearer's auditory intention:

- What does the wearer want to listen to in complex listening environments (e.g., talking to spouse while watching T.V.).
- The switching algorithm has only the acoustic input available to make a decision. It cannot reliably decide which part of the acoustic environment the wearer wishes to listen to and which the wearer wishes to ignore.
- The signal of interest is not always located in front of the listener (Walden *et al*., 2004).

GN ReSound developed asymmetric directional processing to address the concerns with manual and automatic switching between omnidirectional and directional modes. It was introduced with the launch of ReSound Azure in 2007 and is named Natural Directionality.

In asymmetric processing one ear receives a directional response ("focus ear") while the other ear receives an omnidirectional response ("monitor ear"). This option provides improved SNR benefits for sounds arising from the front, while maintaining maximum auditory awareness for sounds arising from any other direction. The hearing aid wearer benefits from both types of processing at the same time, and avoids errors that can occur with automatically-switching directionality.

Laboratory studies have shown no significant difference in directional benefit between asymmetric directionality fittings and bilateral directional fittings (Bentler *et al*., 2004; Cord *et al*., 2007; MacKenzie and Lutman, 2005). In addition, improved ease of listening for asymmetric directional fittings as compared to bilateral directional fittings has also been noted (Cord *et al*., 2007). This improved ease of listening occurs due to the availability of environmental sound inputs from the ear fitted with an omnidirectional mode, which does not occur in bilateral directional fittings. Users do not feel as isolated from sounds originating from the sides and rear due to the environmental sound cues from the omnidirectional processing that is always available to them in this mode.

Natural Directionality (NatDir) contained problems related to directional microphone technology, such as introducing noise as a result of equalizing for inherent low-frequency roll-off, phase distortions and time delays to the incoming signal that can disrupt localization cues. To solve these issues with NatDir, the strategy for asymmetric fittings has been further developed, resulting in the next generation of asymmetric fitting: Natural Directionality II (NatDirII). The NatDirII has been evaluated and the trials are reported below.

OBJECTIVES

1. Does perception of noise and "natural sounding" differ in various listening environments with the two approaches (NatDir and NatDirII); in a laboratory setting and in real-life environments?
2. Do participants prefer one setting (NatDir/NatDirII) over the other in a laboratory setting and in real-life environments?
3. Does the NatDirII approach perform equally well with regards to speech-in-noise scores in a laboratory setting compared to NatDir?

METHOD

Individuals with mild to severe hearing losses participated in clinical testing (including laboratory tests and real-life testing) with hearing aids fitted with this new asymmetric fitting approach, NatDirII. The trial participants included individuals with no experience with amplification as well as people who were experienced with a wide range of hearing aids. All participants were fitted bilaterally with different hearing aid styles ranging from in the canal (ITC) to Power BTE (behind the ear) devices. Data was collected to demonstrate that NatDirII performs equally well as NatDir with regards to speech in noise scores in a laboratory setting. It was moreover evaluated to what extent the perception of noise and 'natural sounding' would differ in various listening environments with the two settings: in a laboratory and in real-life environments, when the trial participants wore the hearing aids over the course of four to eight weeks. The objective testing included signal-to-noise ratio testing and real-ear verification of insertion gain. Subjective measures included ratings of sound quality and questionnaires of audibility, sound quality and preference of settings.

Sound quality ratings

Aspects of sound quality ("Clarity", "Naturalness" and "Total Impression") were evaluated by fitting different directional microphone devices (except ITC-Directional) with the NatDir, the new NatDirII and traditional bi-directional settings. Sound files with speech in quiet, speech in noise and music (2 of each) were randomly presented to 30 participants through a surround speaker setup in each of the three programs, also selected randomly. After each presented sound file, participants were instructed to rate sound quality on three subscales; "Clarity", "Naturalness" and "Total Impression" on a scale of 0-10 where 0 was the worst and 10 the best rating. In total, 18 sound files were rated. A statistical analysis of variance (ANOVA) was used for evaluating possible significant differences between ratings.

Program preference

A Hearing Aid Use Log (HAUL) questionnaire was given to the thirty participants to take home and fill one out for each of the different listening situations they would experience during real-life testing. They all had a NatDirII setting in program 1 which was supposed to be used as the everyday program. Program 2 was programmed with a NatDir setting only to be used as reference when filling out the HAUL questionnaire in different listening situations. Participants were instructed to listen for noisiness in both programs and state if there was a perceived difference between the ears (focus ear and monitor ear) and finally what program they preferred, if any. 26 participants filled in a number of questionnaires grouped in noisy and quiet listening situations.

Fig 1: Hearing Aid Use Log questionnaire.

RESULTS

Sound quality ratings

The subjective evaluation of sound quality ("Clarity", "Naturalness" and "Total Impression") with NatDirII, NatDir and traditional bi-directional (Bi-Dir) setting (hyper-cardioid) showed no significant difference between the three settings.

Though instruction to this test was given very carefully it should be noted that subjects found it very hard to define what exactly was meant by the terms used for the three subscales and thereby what they were listening for. Moreover participants expressed difficulty in separating the tasks of listening for the noise floor of devices and judging the sound quality of the presented sound file. This might be reflected in the overall result illustrated in Fig. 2-4.

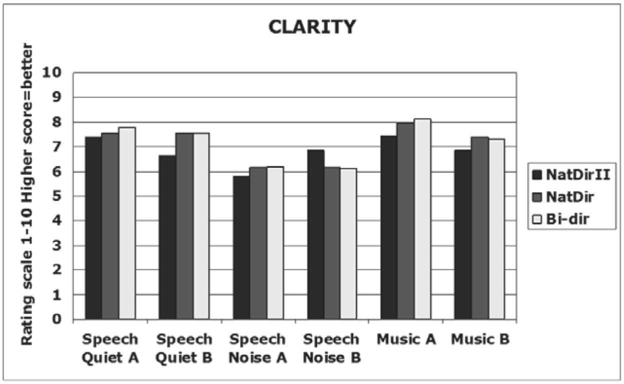

Fig. 2: Result of sound quality ratings "Clarity".

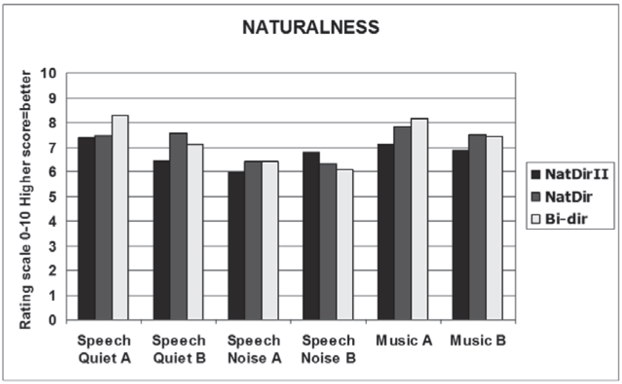

Fig. 3: Result of sound quality ratings "Naturalness".

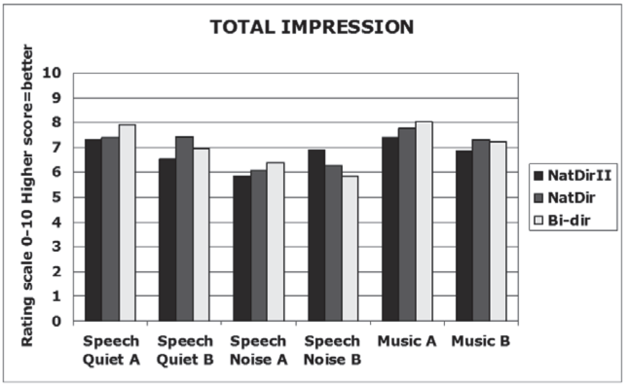

Fig. 4: Result of sound quality ratings "Total Impression".

Program preference

The results from the HAUL questionnaire are reported in Table 1. It should be noted that some participants may have assumed that program 2 was always to be used in background noise, as many hearing aids are conventionally programmed this way. This can maybe explain why some participants preferred the NatDir setting in all situations.

	Prefer NatDirII in quiet and in noise	Prefer NatDirII in quiet, NatDir in noise	Prefer NatDir in quiet and in noise	Mixed results	No difference between NatDirII and NatDir
BTE (n=5)	3		2		
PBTE (n=5)	1	1		1	1
RIE (n=10)					9
ITE-D (n=5)			2	2	
ITC-D (n=5)	4				

Table 1: HAUL questionnaire result (based on real-life listening situations).

Twenty-five wearers of directional hearing aids were asked to listen in quiet to determine if a difference in noise level and/or overall sound quality was perceived for the ear fitted with an omnidirectional response ("focus ear") between NatDirII and NatDir setting. NatDirII and NatDir were programmed into two different programs in the participants' devices and the audiologist toggled between the two programs in quiet to allow the subject to listen for differences. The participants were then asked which program they preferred and why. If there was a preference reported, the reason given was that there was noise in the focus ear for the NatDir setting. The expected results were obtained in this trial, as shown in Table 2. It should be noted that audibility of the focus ear noise is hearing aid style and hearing loss dependent. Wearers of ITC-D devices typically reported the most problems with focus ear noise in former studies of NatDir, and wearers with good low-frequency hearing are also more likely to hear the sound quality/noise difference in quiet. However, a few wearers of Receiver-in-the-ear (RIE) devices and MiniBTEs could also distinguish less focus ear noise with NatDirII.

Preference/HA style	NatDirII	NatDir	No difference
ITC-D (n=4)	3	0	1
RIE (n=11)	2	0	9
MiniBTE (n=10)	4	0	6

Table 2: Program/sound quality preference in a lab setting.

Speech in noise

Signal-to-noise ratio testing was conducted with test devices after a trial period of six to eight weeks to allow participants to acclimatize to the amplification used in this trial. All devices were directional. Nine participants using the RIE hearing aid style were tested with the Danish sentence test Dantale II (Wagener *et al*., 2003) and tested the unaided condition, NatDirII, NatDir and Omni-directional setting. Participants were also tested with own devices for comparison. This was done in order to determine if differences in performance between settings were observed. Their own devices were all in omnidirectional mode. The two different settings, NatDirII and NatDir, were programmed in two different programs in the hearing aids, see Fig. 5.

No significant differences in SNR scores were observed for the NatDirII and NatDir settings. This result was as expected.

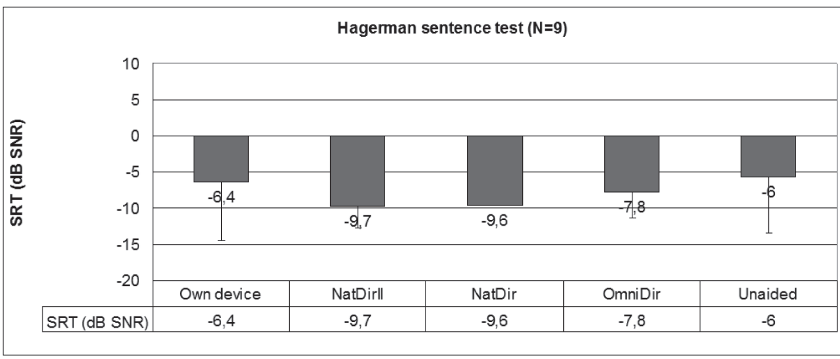

Fig. 5: Result of the Danish Dantale II.

CONCLUSIONS

There are no significant difference between Natural Directionality, Natural Directionality II and a traditional directionality settings in a laboratory investigation.

The Natural DirectionalityII setting is perceived as less noisy in quiet than Natural Directionality by some wearer, especially the ITC-D wearer. This is in comparison to earlier trials of the first NatDir concept, where ITC-D wearers had reported greater amounts of equalization noise than wearers of other form factors.

Good speech intelligibility in background noise with the NatDirII bandsplit directionality was reported by most wearers.

The preference for Natural Directionality versus Natural Directionality II was mixed. For some participants, sound quality improvements in quiet were reported for NatDirII as compared to NatDir. No one preferred the sound quality of NatDir over NatDirII.

No significant differences in SNR scores were observed for the Natural Directionality and Natural Directionality II settings. This result was as expected.

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