While today’s hearing instruments have many features, and new features are introduced each year, one feature has withstood the test of time for the past 40 years – directional microphone technology. The application of directional technology is one of the few methods of improving speech understanding in background noise, a patient benefit which has been supported in evidence-based reviews (e.g. Bentler, 2005).

Most modern directional hearing aids are automatic and adaptive. Automatic, in that based on the signal detected by the classification system, the directional technology will either be activated or de-activated (omni-directional amplification) for individual listening situations. Adaptive, meaning that the directional polar pattern will automatically be altered to maximize speech understanding for a given speech and noise condition, which now even includes switching to anti-cardioid when speech is from behind the hearing aid user (see Chalupper et al., 2011).

When counseling patients regarding the benefits of directional technology, we often mention specific listening situations where benefit would be expected—parties, noisy restaurants, large groups, etc. In general, we talk about listening situations where the speech and noise are relatively loud, ~70 dB SPL or greater. But there are many troublesome listening situations, also with an adverse signal-to-noise (SNR) ratio, where the speech and noise signals are not as intense, maybe only 60 dB SPL, 50 dB SPL, or even softer. While we have made many advances in directional technology over the years, this is an area where improvement is still needed, and is the focus of this paper.
The two faces of noise

We all know that directional microphone hearing aids are designed to reduce noise. And for many listening situations, they do this quite well. But ironically, directional technology also creates noise at the same time it’s attempting to reduce it. This is because the low frequency sensitivity of a directional microphone is less than an omnidirectional microphone. This is an unavoidable consequence of the “delay-and-sum” procedure employed by directional microphones; something often referred to as a “low frequency roll-off,” as this is what is observed in the standard coupler response curve. If we want the hearing aid to have essentially the same amount of gain in the low frequencies in the directional mode as it does for the omnidirectional setting, and usually we do, then additional amplifier gain must be applied in the low frequencies to compensate. Depending on the design of the product (e.g., port spacing, etc), this could be an additional 10-15 dB or more. While this process will then provide adequate gain for the important incoming low-frequency speech signals, it also will amplify the microphones’ internal noise by an equal amount, which also happens to be centered in the lower frequencies. It’s possible that for some listening situations, the amplified microphone noise will be louder than the external noise.

Because of the internal noise issue, the typical implementation is that directional microphones are engaged automatically only when the ambient noise floor exceeds a certain intensity level, usually around 55-60 dB SPL.
Some manufacturers use activation thresholds even higher than this. This prevents the user from hearing the amplified microphone noise that can be louder than the noise in the environment. Even at a setting around 60 dB SPL, directional microphone noise can still be problematic for some users who have good low frequency hearing. Because of these higher noise levels from traditional directional instruments, often users can only take advantage of directionality when the noise floor of the listening situation is relatively high. As we’ve mentioned, this is a limitation which needs to be addressed, as directionality can be quite beneficial for many soft speech/soft noise listening situations.

The solution: Soft Level Directivity

To address the issue of improving the SNR when the speech and noise are both soft, Siemens has introduced “Soft Level Directivity.” With Soft Level Directivity, directional microphones can be activated automatically at a much lower noise level. The extent of this directivity, however, is adjusted according to the environmental noise level in order to keep the microphone noise always below the environmental noise level. Recall that less directivity means less directional microphone noise. As a consequence, the softer the noise level, the less directional the hearing instrument will be. This relationship is graphically illustrated in Figure 1.
Of course, when the environmental noise floor drops even below the omnidirectional microphone noise level, the user will hear the microphone noise. However, whenever the ambient noise floor is in between the noise level of omnidirectional and full directional microphone noise, the user will benefit from Soft Level Directivity, i.e. some degree of directionality, however limited in such a way that the microphone noise does not exceed the noise floor. The user, therefore, can take advantage of at least some directivity in low-noise situations (and hopefully achieve better speech intelligibility), but yet amplified circuit noise will not be annoying or even noticeable.

As illustrated in Figure 2, this feature works independently in four frequency bands. Observe that Soft Level Directivity “adds” directivity for ambient levels below the noise level of the (full) directional microphone - without Soft Level Directivity there is only the choice between omni-directional or microphone noise at these levels.
Figure 2: Illustration of the adaptation as a function of intensity and frequency for Soft Level Directivity.

**Software applications:** Soft Level Directivity is activated by default for any directional mode – actually there is no need to switch it off for fixed directional modes. To take full advantage of this fitting option in the automatic microphone mode, and to fine-tune its function, it is possible to adjust the activation threshold at which the microphones switch from the omnidirectional to directional mode. This value, noted in dB SPL, is the level that the overall environmental noise has to reach before the directional microphone is activated. The three activation threshold settings are: 48, 54 and 60 dB SPL. Thanks to Soft Level Directivity, most hearing aids equipped with this feature, will be able to provide noise-free directionality already below 48 dB. Therefore, in order to get the benefit of Soft Level Directivity also in the automatic microphone mode, it is important to select “48 dB”.
The default setting is 54 dB SPL, which is preferred by most patients. A threshold of 48 dB SPL would be for someone who requires more directivity in low-level noise. The highest settings of 60 dB SPL would be selected for patients who prefer the omnidirectional mode in most situations and for those who have a greater need to hear environmental sounds at average levels from all directions (localization or “safety” assurance), or prefer the greater “loudness sensation” that often is present with omnidirectional amplification (Wu and Bentler, 2010).

**Supporting research**

While electroacoustic testing indicated appropriate automatic switching to the directional pattern for soft inputs, we also wanted to conduct behavioral speech-in-noise testing to determine the magnitude of the soft-level directional advantage. This testing was conducted at the Hearing Aid Laboratory of the University of Iowa.

The participants (n=15) had bilateral downward sloping sensorineural hearing loss and were experienced hearing aid users. They were fitted bilaterally for all experimental testing. Siemens Pure 700 and 701 hearing aids were used for testing. Both hearing aids were in the fixed directional microphone mode\(^1\). The Pure 701 employs Soft Level Directivity and the Pure 700 does not.

\(^{1}\) “directional (adaptive)” in CONNEXX fitting software
Figure 3 shows polar plots obtained with the signal cancellation technique by Wu and Bentler for two ambient noise levels (Wu & Bentler, 2009). Observe that for 50 dB – as expected – the hearing aid without Soft Level Directivity (Pure 700) shows an omni-directional pattern, whereas with Soft Level Directivity (Pure 701) the directional pattern is already similar to the full cardioid. At 65 dB, there are only negligible differences between the hearing aids. For behavioral testing, the hearing aids were fitted to the NAL-NL2 prescriptive target for each participant and real ear insertion gain (REIG) verification was conducted using the Audioscan Verifit probe-microphone system for pink-noise inputs of 55, 65 and 75 dB SPL (using target values derived from the CONNEXX fitting software). Other than Soft Level Directivity, all other parameters were the same for the hearing instruments. Testing also was conducted in the omnidirectional setting, to establish a baseline.

Figure 3: Polar plots illustrating level-dependent directivity of Soft Level Directivity.
The speech material used was the Hearing-In-Noise-Test (HINT) with aided testing conducted in the soundfield. The conventional speech-shaped background noise of the HINT was presented at 50 dB SPL from 180° azimuth. The HINT sentences (two lists/condition) were presented adaptively from a loudspeaker at 0° azimuth.

![Graph showing benefit of Soft Level Directivity compared to conventional directional microphone technology](image)

**Figure 4**: Benefit of Soft Level Directivity compared to conventional directional microphone technology

The results of the HINT testing are shown in Figure 4. The mean HINT reception threshold for speech (RTS) scores are shown plotted in benefit compared to the mean RTS scores for the omnidirectional condition. There was a significant advantage for soft-level directional (p<0.001) compared to the conventional directional mode. When Soft Level Directivity was employed, a mean HINT RTS advantage of 6.2 dB was observed (compared to the omnidirectional setting). When the conventional directional microphone was used, there was not a significant advantage (p=0.79) as only a 0.8 improvement over omnidirectional was observed.
As mentioned, the above findings were obtained with the hearing aids programmed to NAL-NL2. An alternative prescriptive fitting method available from Siemens is ConnexxFit. This fitting algorithm prescribes similar gain as the NAL-NL2 for average and loud inputs, but less gain for soft inputs. We have found that this modification facilitates “acceptance” for new hearing aid users during the initial acclimatization period. We questioned if the use of this fitting method would alter the benefit we had observed for Soft Level Directivity. The same participants, therefore, were programmed for ConnexxFit in a separate memory of the Pure 701 and tested using the HINT in the same manner (Soft Level Directivity activated).

The results of this testing is shown in Figure 5, compared to the NAL-NL2 results previously shown in Figure 4. Observe that the mean Soft Level Directivity advantage is now only 2.7 dB.
While this is still significantly superior to omnidirectional \((p=.03)\), it is substantially less than the mean 6.2 dB RTS advantage that was observed when the NAL-NL2 algorithm was employed. This illustrates the known, but sometimes forgotten fitting concept that the desired speech signal must be adequately audible if the full benefits of directional technology are to be observed. There are some patients, however, who will not “accept” the amount of gain employed by the NAL-NL1 for soft inputs, and a compromise of this type might be necessary. Ideally, following hearing aid experience, more gain can be added so that the patient will obtain the additional benefit of the directional processing for soft input signals.

**Summary**

Directional microphone technology is a well proven feature of modern hearing aids. While normally thought of as a patient benefit for listening situation where the noise level is relatively high, directional processing also can provide significant benefit when the speech and surrounding noise is soft. Activating directional technology for soft inputs can be problematic, as the directional system creates noise, which potentially could be louder than the noise that is being reduced.

We report here on a new automatic directional algorithm called Soft Level Directivity, which lowers the activation point of directional processing, but only to the extent that amplified circuit noise is not bothersome.
Research with this new technology revealed a significant improvement in speech understanding in background noise when soft-level directional was employed, as compared to a more conventional activation level. We also show that the hearing aid gain employed for soft-level inputs can impact this benefit. In general, the application of Soft Level Directivity will expand the benefits of directional microphone technology to more listening situations for the average patient, which should increase patient benefit and satisfaction with hearing instruments.

References


