

# Clinical verification of a hearing aid with Artificial Intelligence

By Mark C. Flynn and Thomas Lunner

A constant challenge for hearing aid manufacturers is to design a coordinated processing system that can manage and select the best response of the instrument's various individual systems, such as adaptive directionality and noise reduction. Until now, hearing instruments have relied on comprehensive prediction models combined with sequential processing to select the preferred processing option.<sup>1,2</sup>

The problem with this approach is that it requires trying to narrow the multiplicity of communication environments into a restrictive prediction-based formula. While this may work well in the laboratory, it is less effective in real communication situations where it may select the incorrect setting up to 30% of the time.<sup>1</sup> The simple reason is that prediction-based formulas and mathematical models simply cannot represent the unpredictability of complex communication environments.

A solution to this problem is to use parallel processing. Rather than relying on predictive models, this approach processes and compares the outcome of each processing scheme in order to select and implement the best solution. This ability to evaluate multiple processing schemes simultaneously is the cornerstone of the Artificial Intelligence (AI) in Oticon Syncro.<sup>3</sup> The core benefit of using AI in hearing aids is to handle the complexity of real situations, in real time, via rule-based, confirmed solutions, not simply predictions based on laboratory experiments.<sup>2</sup> Artificial Intelligence uses parallel processing to determine simultaneously the best solution from the full range of processing options. The decision making is based on which solution provides the best speech-to-noise ratio (SpNR). Applying AI to hearing aids allows new audiologic solutions to be applied through complex, problem-solving algorithms.

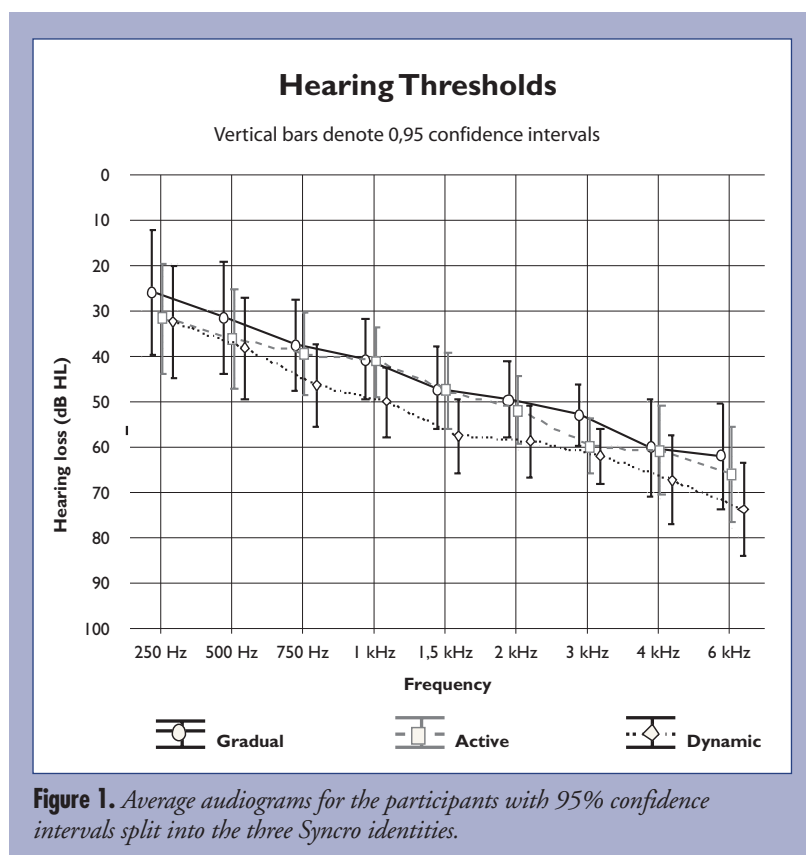
Syncro, which was introduced in 2004, is built on a new digital platform that implements advanced adaptive directionality, noise management, and wide dynamic range compression.<sup>4</sup> Artificial Intelligence is the foundation of the Voice Priority Processing (VPP) system, which oversees three signal processing approaches: Multiband Adaptive Directionality, TriState Noise Management, and Voice-

Aligned Compression. All these systems are designed to work in synergy to optimize the signal progressively, with the priority being to supply the best possible speech understanding. The unity of this signal processing goal, combined with decision making through parallel processing, is intended to ensure that correct decisions are being made and that all systems are working toward improving speech understanding in noise.

With any new hearing instrument, it is important to compare and benchmark its performance against that of other premium hearing aids to identify what critical differences among technology levels people with hearing loss may observe. This study compares Syncro with a reference advanced digital hearing instrument and each participant's own digital hearing instruments.

## METHOD

Thirty-seven participants with moderate, sloping sensorineural hearing losses took part in this study (see Figure 1). All were satisfied and current users of advanced ITE/ITC digital hearing instruments from a variety of manufacturers. They ranged in age from 31 to 87 years



(mean = 67 years). We fitted each participant with the test hearing instrument (Oticon Syncro) in a range of in-the-ear styles (ITE312, ITC312, ITE13, and ITC10) that matched their hearing loss and listening needs.

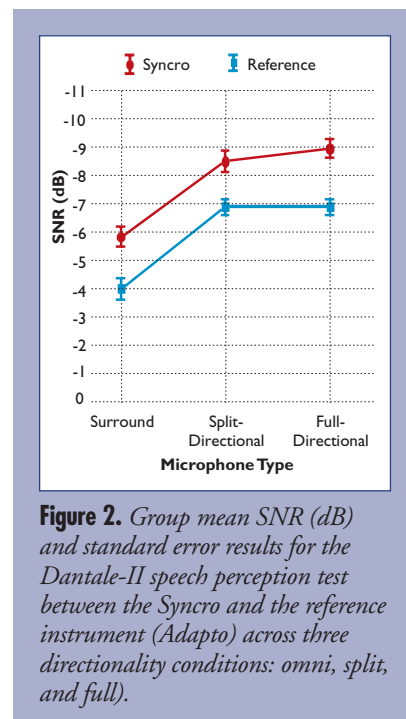
The test instrument was prescribed through the Genie 5.0 fitting software. Using the Personal Profile, we assigned a specific Syncro identity for each participant (Gradual, Active, or Dynamic). No fine-tuning was conducted other than the adaptation manager or the feedback manager. The incorporation of Dynamic Feedback Cancellation (DFC), along with a fast processing time and vent compensation, allows the user to benefit from OpenEar Acoustics. Because of the small size of the hearing instrument, we gave each user a collection vent, which had an average faceplate opening of 2.16 mm (range: 1.0 – 3.0 mm).

For purposes of comparison, the clients used their own hearing instruments, which were all premium digital ITE and ITC hearing instruments currently available. Their instruments had been fitted and

fine-tuned in accordance with manufacturer specifications, so no additional fine-tuning was performed for this study. We conducted electroacoustic tests to ensure that the instruments operated consistently with manufacturer specifications.

We used the Dantale-II speech test<sup>5</sup> in an acoustically treated room to measure speech understanding. To provide a reference to the Syncro, we compared it with the Oticon Adapto. Adapto was chosen as the reference instrument to provide a control and also because a previous blind study had shown that it provided better speech understanding and comfort than two previous levels of technology (digital and analog).<sup>6</sup> The Adapto was provided in prescribed settings based on the participant's audiogram.

Speech was presented to each participant at 70 dB SPL and noise was adjusted to provide the 50% level in speech understanding. The resulting SNR was calculated under three microphone conditions: omnidirectional, split-directional, and full-directional. For each condition, the microphone was fixed in each mode



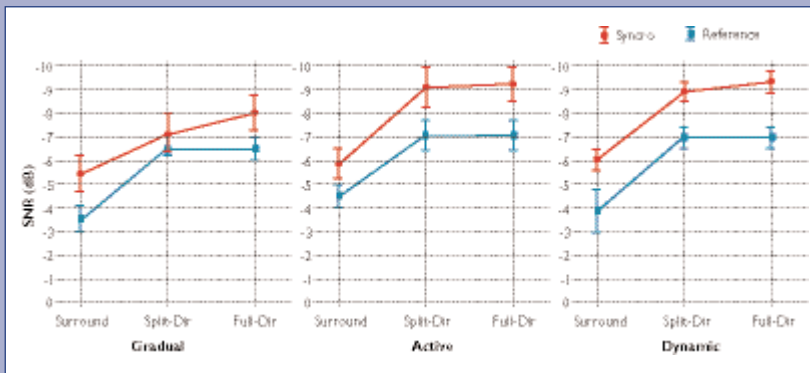
**Figure 2.** Group mean SNR (dB) and standard error results for the Dantale-II speech perception test between the Syncro and the reference instrument (Adapto) across three directionality conditions: omni, split, and full).

(omni, split, and full). It should be noted that as Adapto does not have split-directionality, we used the results for Adapto with full-directional for comparison. Speech was presented at 1.0 meter from a loudspeaker at 0° azimuth. A broadband, unmodulated noise was presented from four loudspeakers located behind the participant at a distance of 1.5 meters. The noise sources were made uncorrelated by means of a 200-ms delay between each loudspeaker.

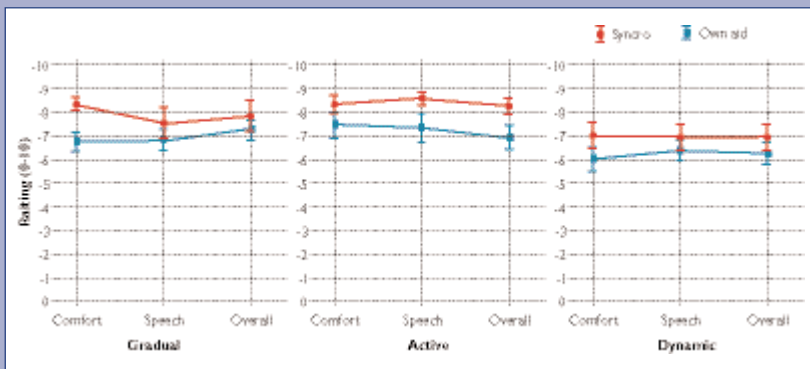
We administered two questionnaires—the HAPQ (Hearing Aid Performance Questionnaire) and a hearing aid comparison questionnaire—at the end of the 6-week study. These questionnaires investigated client preferences between their own hearing instruments and the test instrument in their day-to-day listening environments.

## RESULTS

We calculated speech understanding in terms of the speech-reception threshold in noise for both the reference hearing aid (Adapto) and test aid (Syncro) in prescribed settings (see Figure 2). Analysis of variance indicated that for each condition the test instrument provided significantly better speech understanding than the reference hearing aid ( $p < .00001$ ). This performance increase was in the region of 2 dB SNR for the omnidirectional mode and increased to more than 2 dB SNR



**Figure 3.** Results and standard error for the three directional modes across the two instruments (test vs. reference) separated into the three prescribed Syncro identities.



**Figure 4.** Mean scores and standard error values across the three Syncro identities for the comfort, speech understanding, and combined score for the Hearing Aid Performance Questionnaire (HAPQ).

when full-directionality was enabled.

Both the reference and the test hearing aids provided a large and significant directional benefit, which demonstrates the compatibility of large vent sizes and directionality when a system is designed to accommodate large vents. There was a significant difference ( $p < .0001$ ) between the microphone modes (omni, split, and full) in Syncro, illustrating the utility of the split-directional mode that delivers significant speech-understanding improvements in noise even though the first band remains in omnidirectional mode.

To examine if the effect was consistent across the three Syncro identities, we separated the results into Gradual, Active, and Dynamic (see Figure 3). The results demonstrate similar effects across all the identities. For each identity, performance was significantly better with the Syncro than with the Adapto. Performance also improved across the directional modes from omni- to split- to full-directional. The different identities were not statistically compared, as this refers to partici-

part differences (i.e., different participants were in different groups) rather than processing differences.

We used the Hearing Aid Performance Questionnaire (HAPQ) to compare the subjects' own aids with the test instruments. Scores relating to comfort and speech understanding were combined to provide a total score for each component and also an overall score. Examination of the scores (Figure 4) indicates that Syncro (in any of the three identities) was rated significantly higher than the participants' own aids for comfort, speech understanding, and overall. This indicates that the improvements in speech understanding did not come at the expense of other dimensions, such as sound quality or listening comfort. Interestingly, the scores for participants in the Dynamic group were lower for both their own aids and the test device. This reflects the distinctive nature of this group, who typically are younger and demand more of their hearing instruments.

To investigate further why participants preferred Syncro to their own hearing aids, we administered the hearing aid difference questionnaire (see Figure 5). Here, significant differences were noted in terms of both difficult listening situations (speech in car/bus, speech in group, and speech in street) and high noise situations (e.g., traffic). This result shows the benefit of parallel processing in which Syncro chooses the best configuration of settings for the listening environment to provide the best performance. It is when



**Figure 5.** Scores for the hearing aid comparison questionnaire with areas of significant differences highlighted.

the environment is most challenging that the benefits of parallel processing become most apparent.

## DISCUSSION

In this study, Syncro provided significant benefits over other advanced digital hearing instruments, including Adapto and the participants' own hearing aids. These benefits include greatly improved speech-understanding scores in noise and reported improvements in subjects' daily listening environment.

In terms of speech understanding, the difference between the test and the reference hearing aid were greater than 2 dB (SNR). Given that each 1 dB in SNR equals an approximate increase in speech understanding of 10%,<sup>7</sup> this indicates that Syncro delivers approximately 20% greater speech understanding than the reference instrument. To put this in perspective, the reference instrument (Adapto) recently demonstrated the best speech understanding in quiet and noise in a blind comparison with two other levels of technology (WDRC digital and analog).<sup>6</sup> Therefore, one can clearly see the improvement in speech understanding delivered by a hearing aid built on a new platform incorporating Artificial Intelligence.

In terms of user preferences, the significant reported benefits were in complex listening environments (e.g., speech in traffic or multiple talkers). It is in such situations that we would expect the parallel processing to deliver better speech understanding and greater comfort than other digital platforms through its ability to select from a vast array of possible choices the solution that provides the best possible speech-to-noise ratio.

These gains in speech understanding did not come at the expense of other dimensions such as sound quality and comfort. Therefore, one need not view hearing aids as being either speech-focused or comfort-focused. The results presented here show that the use of AI can enable a hearing aid to deliver excellent speech understanding in various environments while at the same time increasing a user's perception of comfort and overall sound quality.

Importantly, the results for the speech-understanding-in-noise test evaluated one area of contention. That is whether or not increased vent size (i.e., OpenEar Acoustics), which provides relief from occlusion, may remove the benefit of directional microphones.<sup>8,9</sup> Our study demonstrates clearly that collection vents with an average faceplate size of 2.2 mm continue to provide significant directional benefit. Directional benefit remains possible with Syncro because the hearing aid microphone system is specifically designed to work with OpenEar Acoustics.<sup>10</sup>

In terms of directionality, the results provide support for the split-directional mode. While the first band (of the four) is held in omnidirectional mode, the results demonstrated that users were able to gain a significant directional benefit. The split-directionality provides a transparent transition between the omnidirectional and full-directional modes, which allows the implementation of directionality at lower input levels than would be possible otherwise.<sup>4</sup>

Gatehouse et al. showed that matching compression characteristics to the individual and his or her auditory ecology significantly improved amplification per-

formance.<sup>11</sup> This concept is expanded in Syncro, where each client is assigned a specific identity. Each identity matches the prescription of gain, frequency response, directionality, and noise-management characteristics to the client's auditory processing skills, auditory ecology, and listening preferences. The results for each identity demonstrate the benefits in terms of performance and immediate acceptance of matching systems to individual needs rather than having one global prescription for all users.

In summary, it is crucial to remember that we observed differences between the standard digital hearing instruments and those built on a platform of parallel processing on measures of performance in background noise and complex listening situations. While standard instruments will use single pieces of information in trying to predict the auditory environment, Oticon Syncro uses parallel processing to analyze multiple processing options and select the best solution. The underlying processing strategy is to maximize the speech-to-noise ratio at all times and thereby optimize speech understanding.

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