An Edge in Signal-to-Noise Ratio Improvement for Noisy Environments

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Introduction

Modern hearing aids have advanced tremendously since the introduction of digital hearing aids over three decades ago. The combination of a powerful processing chip, innovative sound processing algorithms, and improvements in battery power consumption have helped improve customer satisfaction dramatically across the industry over time. However, while there has been marked improvement to helping hearing aid wearers in noisy listening environments, overall satisfaction in these environments has not reached that of one-on-one conversations, suggesting room for improvement *(Figure 1)* and highlighting better performance in these difficult listening environments as a goal to strive for.

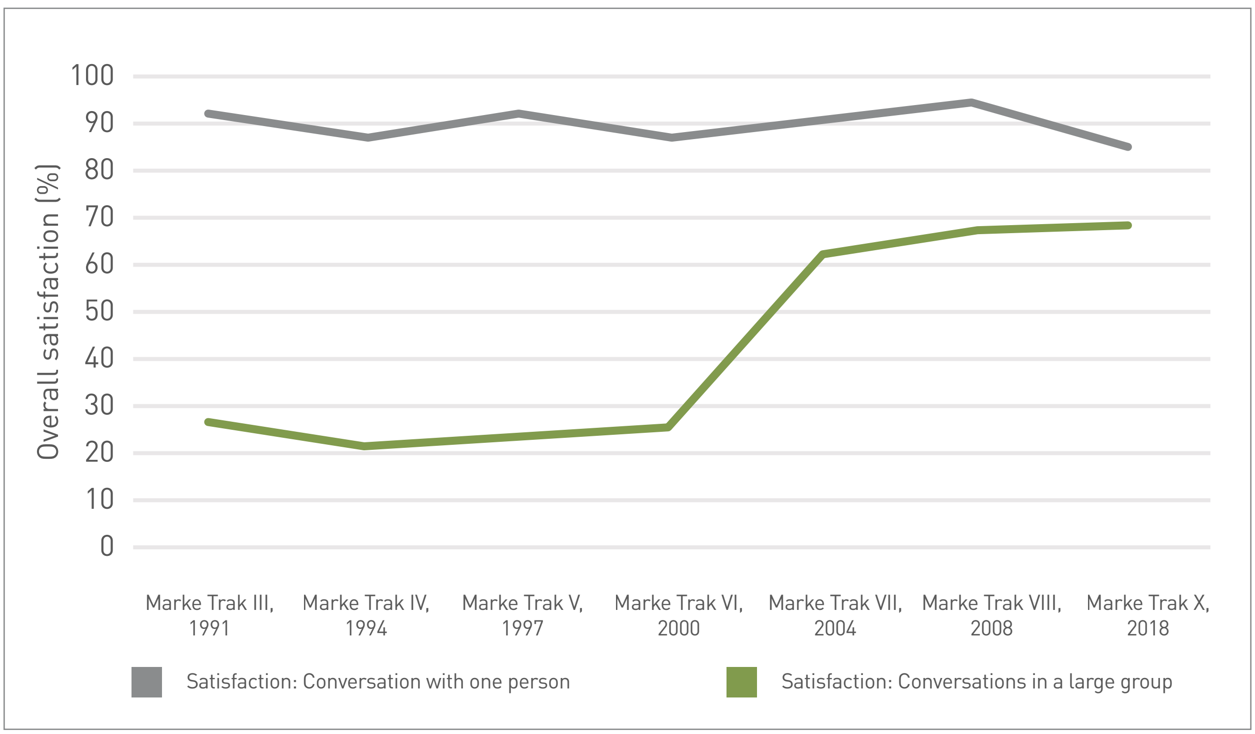

Figure 1: Overview of hearing aid wearer satisfaction ratings across various MarkeTrak surveys from 1991 to 2000 (Kochkin, 2002, 2005, 2010; Picou, 2020), with overall satisfaction rating with one person (grey) and overall satisfaction rating in a large group (green) shown.

Although one important goal of hearing aids is to help provide better speech understanding in all environments including noisy listening situations, there are varied philosophies across different hearing aid brands in how they achieve this. Some have the philosophy of providing minimal processing in hopes the brain will be able to parse out what is needed from the acoustic signal provided. Others choose to fully automate their signal processing features in hopes of having the hearing aid decide the best outcome for a given situation.

Audibel's philosophy behind sound processing stems from the way the human brain encapsulates information from various processes (e.g. acoustic information, motion, and listening intent) to deliver a great listening experience.

Neuro Sound Technology 2.0 is capable of providing an automatic, seamless experience without any input from the listener. It also recognizes that each individual and situation are unique, so providing the individual the option to select preferences when needed is important.

Edge Mode+ presents hearing aid wearers with a simple way of deciding their listening intent when their listening situation becomes more challenging. With a push of a button, double tap, or by using the My Audibel mobile app, Edge Mode+ maps out the acoustic topology of the listener's environment and adjusts several settings concurrently to help Enhance Speech or Reduce Noise around the listener.

In this white paper, we demonstrate the signal-to-noise ratio (SNR) improvement achieved by Audibel Vitality AI with two different settings, and in comparison with other flagship brands.

Laboratory setup

A few Receiver-In-Canal (RIC) style hearing aids were evaluated in this comparison. Vitality AI RIC RT hearing aids and flagship RIC hearing aids from three different leading hearing aid brands were fitted to an N3 hearing loss *(Figure 2, Bisgaard N, 2010)* using the default manufacturer prescription formula and occluding power domes. Two of the leading competitive brands market innovations in the artificial intelligence (AI) and Deep Neural Network (DNN) space, and the third brand uses a multi-stream architecture to follow multiple conversations concurrently.

The same occluding power domes were used for each pair of devices for an occluded fit on a Knowles Electronics Manikin for Acoustic Research (KEMAR). The KEMAR was set in the middle of an 8-speaker array, placed 45 degrees apart and 1m equidistant from the KEMAR in a sound-treated room *(Figure 3)*.

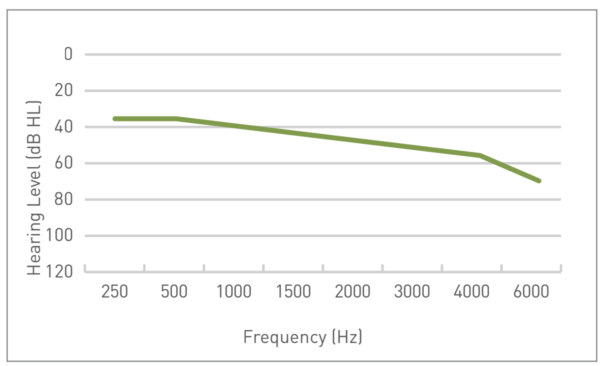

Figure 2: Audiogram of an N3 hearing loss

Hagerman method

The Hagerman method *(Hagerman & Olofsson, 2004)* is a well-researched procedure used to estimate the improvement in signal-to-noise ratio (SNR) provided by hearing aids. This method involves presenting speech and noise simultaneously and making two measurements, with one of the noise measurements having its phase inverted. By combining the two recorded signals, it is possible to separate the processed noise and speech signals from the recorded mixed signal, allowing for the calculation of the SNR improvement. Speech Intelligibility Index (SII) *(ANSI, 1997)* estimates the relative importance of speech information across different bands and is used with the Hagerman method to calculate the SNR that reflects the relative implication of different frequency bands for speech understanding. SNR benefit was calculated using omnidirectionality with noise reduction off as the reference.

Vitality AI investigation

In this investigation, comparisons between the default setting (Adaptive Directionality enabled with Speech in Noise default setting) and Edge Mode+ with "Reduce Noise" were made in a series of challenging realistic noisy environments. All other Vitality AI hearing aid features were at default settings. Machine noise reduction and feedback cancelation were switched off to avoid interactions with the Hagerman method *(Hagerman & Olofsson, 2004)*.

Seven different real-life noise environments were evaluated *(Figure 4)*: Bar noise, noise from a shopping mall, restaurant noise, construction noise, crowded indoor and outdoor spaces, and city noise. For diffuse noise evaluation, 8 uncorrelated snippets from the same noise file were played through all 8 loudspeakers at 0, 45, 90, 135, 180, 225, 270, 315 degrees, with speech playing at 0 degrees. Diffuse noise was used as it is exceedingly common in real-world speech listening situations *(Wu, 2018)*.

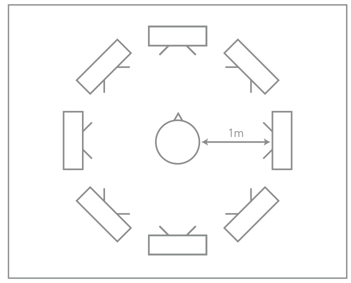

Figure 3: Overview of the laboratory setup with a KEMAR in the middle of an 8-speaker array.

For each recording, the first 30 seconds were noise only, followed by 30 seconds of speech in noise *(Figure 4)*. SNR was calculated using the 30 seconds speech in noise signal. The speech level was 70 dB SPL and noise level was 73 dB SPL, resulting in challenging listening environments that have an SNR of -3 dB.

The results *(Figure 5)* show that the combination of Adaptive Directionality and Speech in Noise default settings can achieve an SNR improvement of over 7 dB in challenging listening environments, and up to 13 dB when Edge Mode+ is enabled.

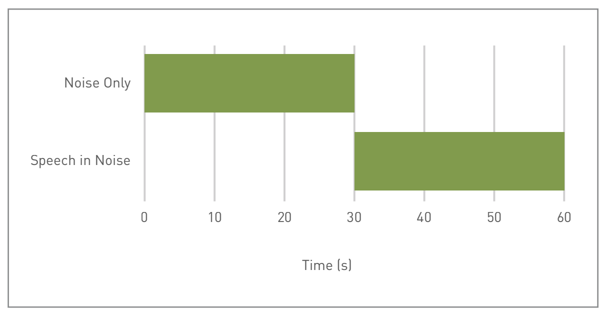

Figure 4: Sequence of audio recordings used in the Vitality AI investigation

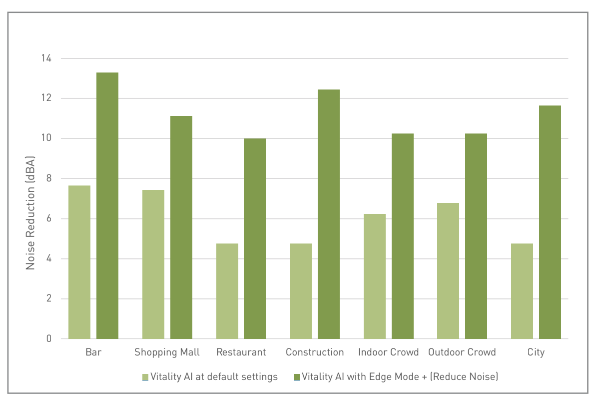

Figure 5: SII-weighted SNR improvement with a variety of challenging diffuse noise environments comparison between the automatic default settings of Vitality AI, and with Edge Mode+ (Reduce Noise) enabled.

Competitive investigation

The goal of this competitive comparison was to evaluate the performance of hearing aid features that make the most impact on SNR improvement, namely directionality and noise reduction. In this comparison, feedback management, impulse noise reduction, wind noise reduction, frequency compression, and machine noise reduction were disabled in all the hearing aids evaluated. All other features were left at default except for speech in noise strength, which was set at maximum strength. The Vitality AI hearing aids were set up with two settings – one with the automatic noise reduction setting at strength setting #4, and Edge Mode+ (Reduce Noise).

The performance of the hearing aids was evaluated with babble noise at three different SNR levels. Diffuse noise was played from 8 speakers at 0, 45, 90, 135, 180, 225, 270, and 315 degrees, and speech was played from 0 degrees. Ten seconds of the International Speech Test Signal (ISTS) *(Holube, Fredelake, Vlaming, & Kollmeier, 2010)* was used as the speech for testing, with 40 seconds used for adaptation. Speech and noise levels are shown in Table 1 below.

For this evaluation, combinations of speech and noise stimuli were inverted and presented simultaneously. Each stimulus for recording had 40 seconds of speech and noise followed by three repetitions of the speech and noise used for analysis, each 10 seconds long: Speech + Noise, Speech – Noise, and -Speech – Noise *(Figure 6)*. The first two repetitions were used to separate the speech and noise signal, the third was used to measure error. SNR improvement was measured relative to an unaided open KEMAR ear recording.

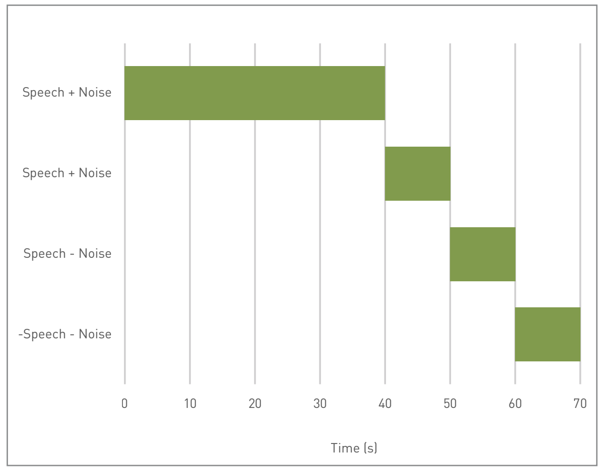

Figure 6: Sequence of audio recordings used in the Vitality AI investigation.

Table 1: Speech and noise levels investigated.

Noise	Speech Level (dB SPL)	Noise Level (dB SPL)	Calculated SNR (dB)
Babble	70	70	0
Babble	67	70	-3
Babble	64	70	-6

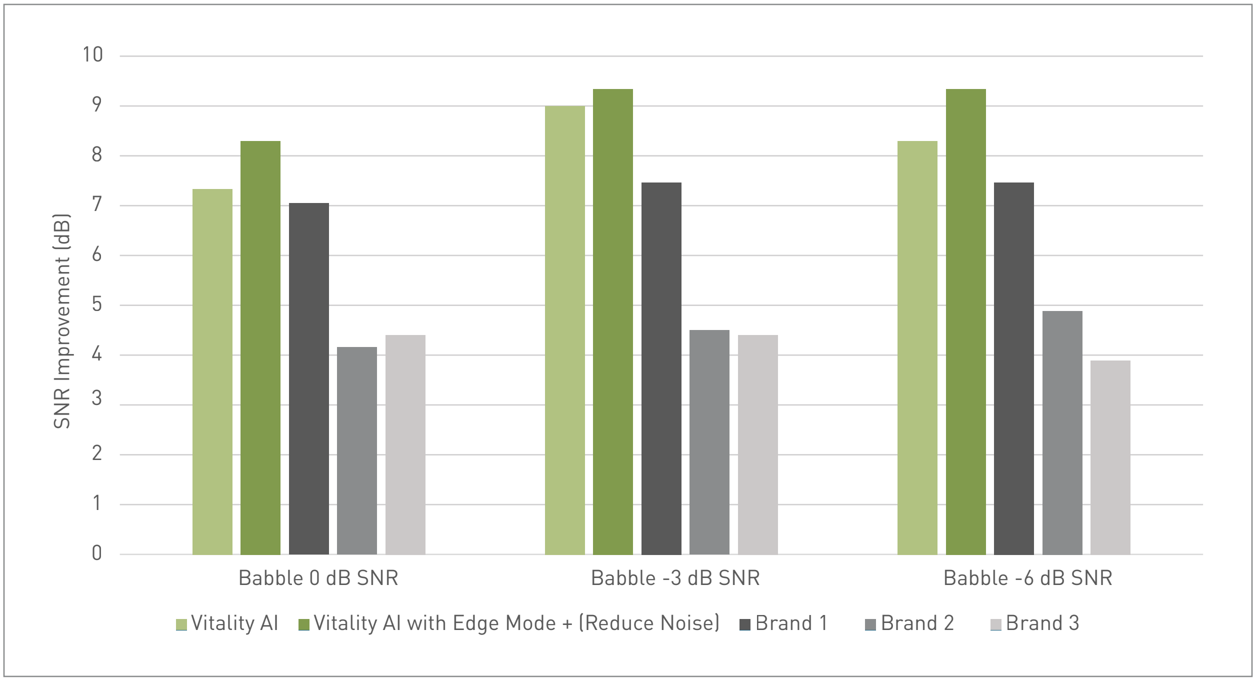

Figure 7: SII-weighted SNR improvement for Vitality AI and three other brands.

Vitality AI with Edge Mode+ achieved significantly higher SII-weighted SNR improvement at maximum strength of up to 5.3 dB *($p<0.01$)* in diffuse noise compared to the three leading brands tested. *(Figure 7)* Vitality AI at maximum speech in noise reduction also achieved higher SNR improvement than Brands 2 and 3 *($p<0.001$)*. Vitality AI trend performance was consistently better than Brand 1 across the different listening conditions but the results were not statistically significant. A contrast comparing Vitality AI and the three competitor brands shows a significantly higher than average SNR improvement for Vitality AI *($p<0.05$)*. A similar contrast comparing Vitality AI and Edge Mode+ (Reduce Noise) also shows a significantly higher average SNR improvement than the three other brands *($p<0.01$)*.

Conclusion

With every product iteration, it is Audibel's goal to make better hearing easier for each patient, especially in noisy environments. Vitality AI has delivered on this goal with up to 7 dB SNR improvement with automatic adjustments and up to 13 dB SNR improvement with Edge Mode+ (Reduce Noise). Compared to leading competitive hearing aids in the market, SII-weighted SNR improvement proved Vitality AI to be favorable in the most difficult listening conditions. Patients and professionals can rest assured that Vitality AI leads the way in delivering better performance in challenging noisy environments.

References

1. ANSI. (1997). S3.5-1997. *American National Standard: Methods for the Calculation of the Speech Intelligibility Index*. New York: American National Standards Institute.
2. Bisgaard N, V. M. (2010). Standard audiograms for the IEC 60118-15 measurement procedure. *Trends Amplif*, 14(2), 113-20. doi:10.1177/1084713810379609.
3. Hagerman, B., & Olofsson, A. (2004). A method to measure the effect of noise reduction algorithms using simultaneous speech and noise. *Acta Acustica United with Acustica*, 90(2), 356-361.
4. Holube, I., Fredelake, S., Vlaming, M., & Kollmeier, B. (2010). Development and analysis of an international speech test signal (ISTS). *International journal of audiology*, 49(12), 891–903.
5. Kochkin, S. (2002). 10-Year Customer Satisfaction Trends in the US Hearing Instrument Market. *Hearing Review*, 9(10), 14, 18-20, 22-35, & 46.
6. Kochkin, S. (2005). MarkeTrak VII: Customer satisfaction with hearing instruments in the digital age. *The Hearing Journal*, 58(9), 30, 32-34, 38-40, 42-43.
7. Kochkin, S. (2010). MarkeTrak VIII: Consumer satisfaction with hearing aids is slowly increasing. *The Hearing Journal*, 63(1), 19-20, 22, 24, 26, 28, 30-32.
8. Picou, E. M. (2020). MarkeTrak 10 (MT10) Survey Results Demonstrate High Satisfaction with and Benefits from Hearing Aids. *Seminars in Hearing*, 41(1), 21-36.

Author Biographies

Larissa Taylor, Ph.D., is an Audio Systems Engineer at Starkey. Her primary focus is ensuring the overall sound quality of hearing aids. Larissa started at Starkey in 2022 upon completing her doctorate on listening effort and sound quality with hearing aids at McMaster University, Hamilton, Ontario Canada.

Daniel Marquardt, Dr.-Ing., received his Dipl.-Ing. degree in media technology from the Ilmenau University of Technology, Ilmenau, Germany, and his Dr.-Ing. degree in speech signal processing from the University of Oldenburg, Oldenburg, Germany, in 2010 and 2015 respectively. From 2015 to 2017, he was a Postdoctoral Researcher with the University of Oldenburg, Germany. Daniel has been a Research Engineer with Starkey since 2018.

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