A Sound Investment:

Hearing loops and induction coils in Genesis AI yield dramatic improvements in public spaces

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Abstract

A study was conducted to evaluate the effectiveness of public assistive hearing accessibility systems in enhancing communication for individuals with hearing impairments. Genesis AI RIC RT hearing aids collected audio-input recordings, which were analyzed using speech-to-text (STT) recognition technology and compared to performance of 20 hearing impaired subjects during a listening task that involved different signal-to-noise ratios (SNR) using both Genesis AI RIC RT and ITE R style hearing aids. Results showed that hearing loops significantly improved speech recognition performance with hearing aids in various real-world applications, highlighting their effectiveness in improving auditory accessibility.

Background

Hearing loss is a prevalent concern, especially among older adults, with research indicating that approximately one in three individuals between the ages of 65 and 74 experiences some degree of hearing loss. This prevalence increases to around half of individuals aged 75 and older *(NIDCD, 2021)*. Beyond the personal challenges it presents, hearing loss can impact various aspects of life, including social engagement, productivity, and overall well-being. Amplifying speech at a distance becomes particularly challenging in environments characterized by background noise and reverberation.

To address these difficulties, public assistive hearing accessibility technologies, such as hearing loops and neck loops, play a crucial role in keeping individuals with hearing difficulties connected and engaged.

Previous laboratory studies have demonstrated that directional microphones can improve the SNR and speech intelligibility by 1 to 6 dB for individuals using hearing aids, depending on factors such as their degree of hearing loss and the venting in the hearing aid's ear coupling *(Ricketts & Hornsby, 2006)*. However, the physical distance between the listener and the target talker can diminish the benefits of directional microphones. Additionally, many individuals with hearing loss may require even more favorable SNRs to effectively manage their listening effort, surpassing what directional microphones can offer *(Krueger et al., 2017)*.

Wireless remote microphones and FM systems have been effective in helping hearing aids overcome the challenges presented by physical distance and can provide even greater improvements in the range of 6 to 16.8 dB *(Rodemerk & Galster, 2015)*. While these systems have found success in classrooms and familiar settings like one-on-one conversations, they may not be practical for numerous public listening situations such as lecture halls, places of worship, and transportation hubs.

Legal requirements mandate most public venues to have hearing accessibility technology that is universally compatible with hearing aids and cochlear implants. Hearing loops and neck loops, when used in conjunction with the receivers of different transmitting technologies (e.g., FM, infrared, etc.), offer this type of direct audio input for hearing instruments *(ADA Accessibility Guidelines for Buildings and Facilities, 2004)*. Moreover, this type of connectivity allows an individual's own hearing instruments to optimize the sound for the individual's specific needs *(Kaufmann et al., 2015)*.

Previous studies have demonstrated the significant benefits of hearing loops and induction coils based on subjective reports or objective measurements in controlled environments, which may not fully reflect some more dynamic real-world conditions *(Faivre et al., 2016; Kochkin et al., 2014; Kociński & Ozimek, 2015)*. This study aimed to address this gap by evaluating the extent of signal-to-noise ratio (SNR) improvement provided by these assistive technology systems in various real-world listening situations.

Methods

Data was gathered from real-world hearing loop scenarios and a comparative laboratory setup to evaluate the practical efficacy of public hearing assistive technology. To understand the response of the Genesis AI telecoil in a real-world scenario, a specialized research firmware was developed to enable a set of Genesis AI hearing aids to wirelessly transmit their audio input signals to a dedicated smartphone application for further analysis and storage. Using this research firmware, a binaural set of hearing aids was configured to capture and record both the hearing aid microphone and induction coil input signals from diverse listening scenarios encountered in everyday life. This innovative approach allowed gathering of synchronized recordings of both signals to accurately compare the intelligibility and quality of sounds recorded with and without the utilization of assistive hearing accessibility systems *(Fig. 1)*.

Assessing noise reduction and speech enhancement techniques in real-world environments has historically been challenging due to multiple variables that cannot be accounted for, such as the ability to perfectly isolate speech and noise signals from recordings. To overcome this limitation, the research team at Starkey developed a practical methodology that uses the Google Speech-to-Text (STT) recognizer to assess speech intelligibility directly from field audio samples *(Betlehem et al., 2022)*. This innovative approach enabled efficient analysis of speech intelligibility differences that were observed in the various recordings collected from the microphone and telecoil inputs *(Fig 1, 2)*.

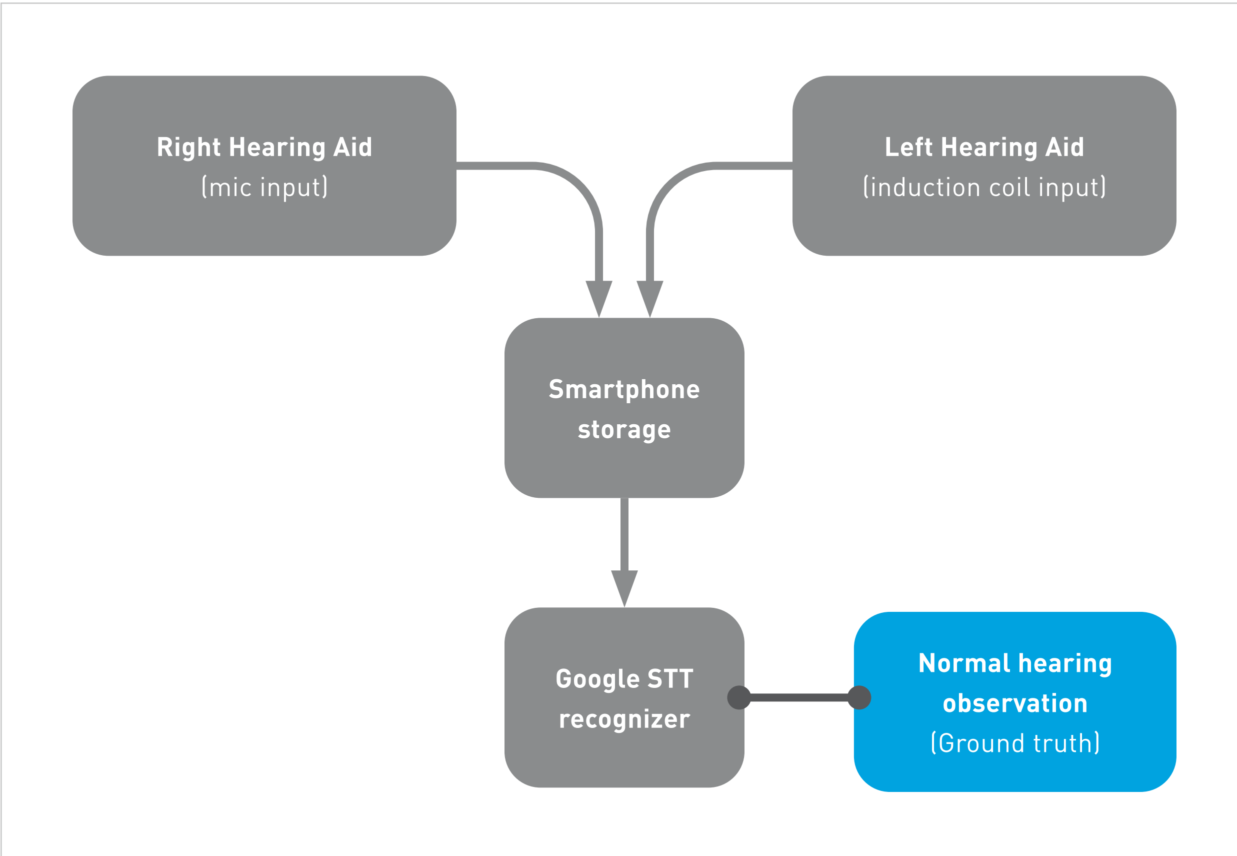

Figure 1: Visual representation of the process used to collect and analyze synchronized microphone and telecoil recordings using the Google STT recognizer.

Figure 2: Information desk at MSP International Airport in Minnesota with a hearing loop system.

Figure 3: Laboratory setup for QuickSIN stimuli recordings that were used in the study.

To further understand how Google Speech-to-Text (STT) recognizer was influenced by different levels of background noise, a controlled assessment was conducted using both the original and a systematically re-recorded version of the QuickSIN speech corpus, which was collected from the microphone and telecoil inputs of the Genesis AI RIC RT hearing aids during a laboratory simulation of a realistic environment with predetermined signal-to-noise ratio (SNR) levels. In this simulation, a talking manikin presented the QuickSIN speech corpus in the presence of multi-talker babble noise presented from a surrounding speaker array. A podium microphone was positioned within 4 inches of the manikin's mouthpiece *(Fig. 3)*, its signal was then transmitted through a hearing loop system calibrated according to the international standard (IEC 60118-4, 2014), and then re-recorded via the hearing aid's telecoil input. This portion of the analysis provided valuable insights into how the performance of the Google STT performs under real-world background noise scenarios.

Subsequently, the results obtained from the Google STT analysis, using the recorded hearing aid microphone and induction coil inputs, were compared with the average scores of 20 hearing-impaired subjects tested with functional Genesis AI RIC RT and ITE R hearing aids in the same laboratory setup. This allowed characterization of the performance of the Google STT recognizer relative to the perceptual evaluation of the hearing-impaired individuals.

What We Learned

1. Hearing loops dramatically improve hearing performance in public spaces

The laboratory reference study *(Figure 4)* revealed that the performance of the Google STT recognizer exhibited comparable patterns to human subjects with hearing impairment (n=20) at various known SNR levels, both for the hearing aid microphone and telecoil inputs. These findings provided insights into how STT recognition technology could be utilized to estimate SNR differences between real-world recordings from hearing aid microphones and telecoils.

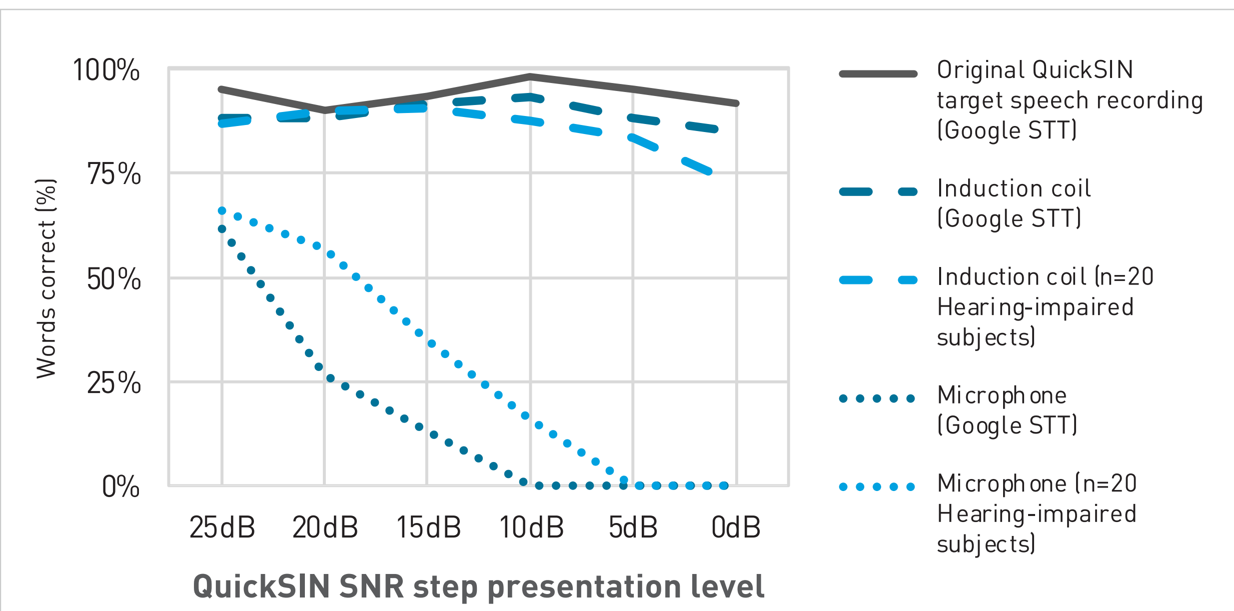

Figure 4. Performance of the Google STT recognizer when analyzing original and re-recordings of the QuickSIN in comparison to hearing-impaired listeners (n=20) tested in the same laboratory setup.

	Total words detected			Words correct		Average STT Confidence	
	Human (Ground truth)	Hearing Aid Microphone	Hearing Aid Telecoil	Hearing Aid Microphone	Hearing Aid Telecoil	Hearing Aid Microphone	Hearing Aid Telecoil
City hall (boundary microphones)	780	328	220	262	200	0.873	0.869
City hall (podium microphones)	866	585	837	494	790	0.876	0.942
Historic chapel	652	301	588	200	557	0.811	0.929
Airport baggage claim	78	9	75	2	70	0.580	0.940
Airport ticketing area	61	2	59	0	56	0.977	0.925
Information desk	528	99	287	73	249	0.805	0.874

Table 1. The total number of words detected by a human scorer and the Google STT recognizer. The Google STT recognizer output was compared to the ground-truth, normal-hearing human observations to determine the number of words correctly detected using the hearing aid microphone and induction coil recordings. The Google STT recognizer provides a confidence value for each word detected, which has previously been used to objectively compare intelligibility differences (Betlehem et al., 2022).

Once the field samples were collected, the Google STT was used to generate transcripts for each microphone and telecoil recording, which were then analyzed for accuracy and completeness through human review of the same recordings. In addition to generating the transcripts, the Google STT recognizer assigned confidence levels to each detected word. Table 1 presents the average confidence scores, number of correctly detected words, and total word count for both microphone and telecoil recordings across each field sample.

The accuracy of the Google STT recognizer varied greatly across the field samples for the microphone input recordings, ranging from 0% to 57.0%. However, when the telecoil input was used, the accuracy showed notable improvement, ranging from 47.2% to 91.8% for all but one of the recordings *(see Figure 5)*. Similar to hearing impaired listeners, the Google STT was sensitive to SNR differences, and the relatively higher predominance of competing talkers in the hearing aid microphone recordings resulted in fewer words detected and poorer accuracy. These findings highlight the potential benefit of utilizing the telecoil input with hearing loops in various real-world scenarios.

Particularly noteworthy is the remarkable improvement observed in the accuracy of delivering public address announcements in the airport ticketing and baggage claim areas. When the hearing aid microphone input was used, the Google STT recognizer's accuracy was extremely poor, with 0% and 2.6% respectively. However, with the telecoil input, the accuracy improved significantly to 91.8% and 89.7% respectively, providing an estimated effective signal-to-noise ratio (SNR) benefit of approximately 20 to 30 dB. Similar improvements were observed in other settings as well. For instance, during worship service in a small historic chapel, the Google STT recognizer's accuracy improved from 30.7% to 85.4%, corresponding to an estimated effective SNR improvement of 10 to 15 dB. Likewise, in the city hall meeting where podium microphones were used for both the public address and hearing loop systems, the Google STT recognizer's accuracy increased from 57% to 91.2%, indicating an estimated effective SNR benefit of approximately 10 dB when using the loop system.

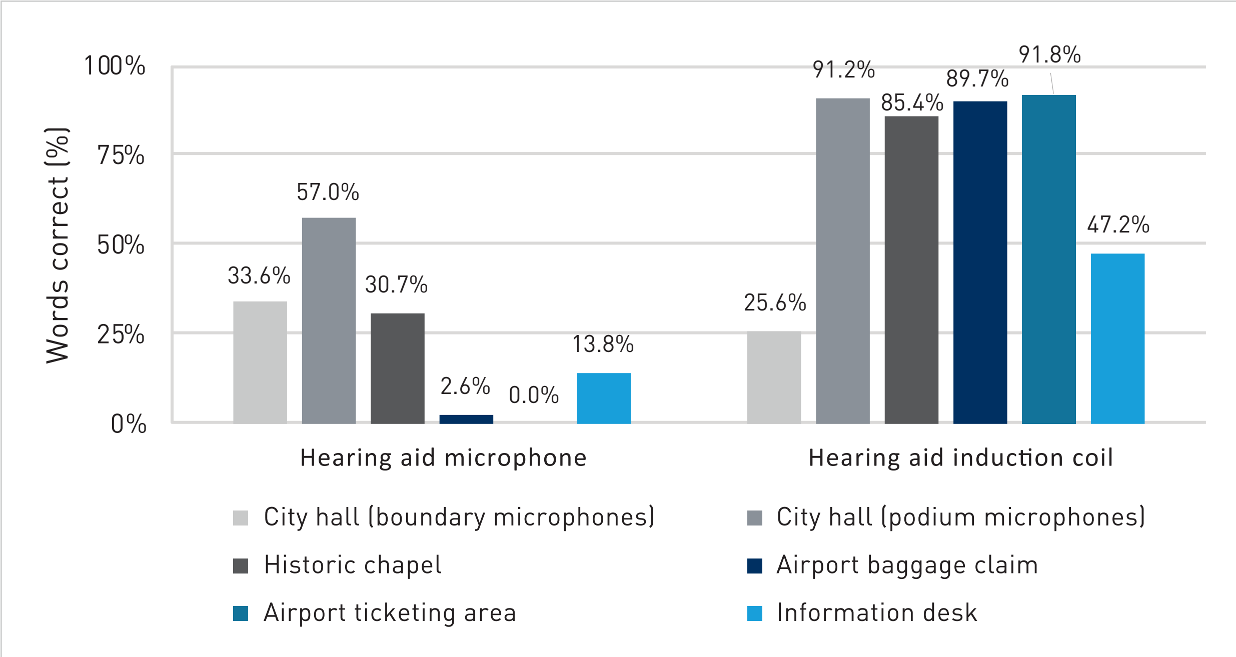

Figure 5. The accuracy of the Google STT recognizer based on the hearing aid microphone and induction coil recordings that were collected in various real-world situations. The output of the Google STT recognizer was compared to the ground-truth, normal-hearing-human observations to determine the percentage of words correctly detected for each condition.

These findings highlight the transformative effect of utilizing hearing loops and telecoil inputs in public spaces. By enabling individuals with hearing loss to connect their hearing instruments directly to the audio signals, these systems greatly enhance the speech clarity, as evidenced by the significant improvements observed with our STT-recognition paradigm. These improvements are particularly meaningful considering the relationship to the performance of the 20 individuals with hearing impairment. The dramatic enhancements observed across various scenarios emphasize the importance of implementing assistive hearing accessibility systems that are compatible with hearing aids in public venues. By doing so, equitable communication access can be offered for individuals with hearing impairments, promoting inclusivity and social participation.

2. Artificial intelligence can rapidly unlock insights into invisible accessibility issues

The innovative methodology employed in this study has provided valuable insights into the challenges individuals face in understanding speech in public spaces, while also highlighting the potential of artificial intelligence (AI) in efficiently evaluating the effectiveness of handicap-remediation strategies. Through these investigations, our findings showed hearing loops have significantly improved the accuracy of the Google STT recognizer and can be used as a means to predict human speech understanding performance with these systems. However, it is important to acknowledge instances where the effectiveness of hearing loops may be more limited.

During this study, a notable situation emerged at a city hall meeting where an array of boundary microphones was used as inputs to the hearing loop amplifier. Surprisingly, the Google STT recognizer achieved an accuracy of 33.6% with the hearing aid microphone input recording, while it only achieved an accuracy of 25.6% with the telecoil input. Additionally, at an information desk where a boundary microphone was used, the accuracy was 13.8% with the microphone recordings and 47.2% with the telecoil recordings, providing only a marginal estimated SNR benefit over what would be expected from directional microphones. These findings emphasize the importance of equipment selection as well as user instruction in the implementation of hearing loops, as they can influence their effectiveness.

The boundary array microphones used at the city hall meeting captured more ambient noises and temporal distortions, resulting in lower speech intelligibility. Comparatively, the Google STT recognizer performed much better with the telecoil input recordings in scenarios where close-miking techniques (i.e., podium microphones, lapel microphones, and handheld microphones) were used with the hearing loop. This finding highlights the complexities involved in optimizing accessibility in specific environments, and it underscores the need for careful consideration when designing and implementing assistive listening systems.

By leveraging AI tools like the Google STT recognizer, it was possible to assess the effectiveness of hearing loops in diverse real-world scenarios and uncover potential limitations that may not have been evident to include in previous laboratory designs. This efficient and objective approach enabled us to provide valuable insights, empowering venue operators, policymakers, and hearing healthcare professionals to make informed decisions.

Traditionally, venue operators might only rely on feedback and complaints from the patrons depending on these systems to identify potential issues, which could result in resolving issues too late to prevent poor user experiences or lost opportunities. However, by harnessing the capabilities of AI, it may now be possible to swiftly identify and address invisible accessibility issues, striving towards more inclusive and equitable public spaces for individuals with hearing impairments. In the future, AI could play a vital role in autonomously advocating for individuals in need of hearing accessibility systems, further enhancing their overall experience.

3. Demonstrations reveal the true value of hearing accessibility systems

In addition to the valuable quantitative data and insights derived from this study, the audio samples collected can provide a compelling demonstration of the challenges faced by individuals relying on hearing instruments, as well as the profound improvements offered through hearing accessibility systems. By accessing the provided QR code *(refer to Figure 6)*, listeners can experience the qualitative value of hearing loops and gain a deeper understanding of their impact on speech intelligibility and communication access in real-world settings.

Combining these impactful audio samples with this study's data, we aim to contribute to a comprehensive understanding of the value of hearing aids in combination with assistive hearing accessibility systems.

Starkey seeks to promote inclusivity and equity for individuals with hearing impairments, empowering the individuals who use hearing instruments to advocate for their communication needs and encouraging policymakers, venue operators, and the public to prioritize the implementation of hearing accessibility systems that are compatible with hearing aids.

Discussion

The findings of this study provide strong evidence for the positive impact of public hearing assistive technology on speech intelligibility in public spaces. The observed improvements in signal-to-noise ratio (SNR), ranging from approximately 5 to 30 dB, highlight the substantial benefits these technologies offer individuals who use hearing instruments in real-world listening situations. By implementing public assistive hearing accessibility technology, facility operators have the opportunity to address common challenges such as background noise, distance, and reverberation, thus promoting more equitable communication access for individuals with hearing difficulties.

Importantly, this study also revealed a disparity in the effectiveness of different types of input microphones used with assistive hearing accessibility systems. Specifically, some boundary microphones were less effective compared to podium and lapel microphones. This finding underscores the significance of carefully selecting equipment that is both intuitive to use and most appropriate for the particular situation when implementing these systems.

Furthermore, hearing healthcare providers play a crucial role in realizing the full benefits of these systems for individuals with hearing impairments. When recommending hearing aids, providers should consider the compatibility of the instruments with the hearing accessibility systems in use. Our previous research demonstrated the importance of additional factors such as informational counseling, live demonstrations, and encouragement to incorporate these technologies into daily routines *(Burwinkel et al., 2022)*.

By embracing public hearing assistive technology and taking proactive measures, we can create an inclusive society where individuals with hearing impairments can fully participate and engage in every environment. The impact of improved communication access extends far beyond the individual level, contributing to social integration, productivity, and equal opportunities for all.

Starkey sees the immense benefits to including telecoil options within hearing technology and continues to offer multiple options, including Genesis AI RIC RT, Genesis AI ITE R, and StarLink Remote Mic + for telecoil usage.

Figure 6. QR code link to comparative microphone and telecoil recordings collected and analyzed as part of the study presented at the Annual meeting of the American Academy of Audiology, Seattle, WA, April 2023.

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Author Biographies

Justin R. Burwinkel, Au.D, is a Senior Research Audiologist at Starkey. Dr. Burwinkel earned both his B.S. and Au.D. at the University of Cincinnati. Since 2014, his research at Starkey has encompassed a breadth of clinical and perceptual topics which have helped to guide the development of emerging noise reduction and speech enhancement techniques, the deployment of wireless assistive listening technology, and the creation of useful applications leveraging ear-level sensors. In addition, he has filed more than 50 patents for inventions relating to hearing aid connectivity, artificial intelligence, and fall risk management.

Rachel Barrett, Au.D. currently works as a clinical audiologist at a private practice in La Crosse, WI. She earned both her B.A. and her Au.D. from the University of South Dakota. For her fourth-year externship experience, she worked at a private practice in London, U.K. Throughout her time in London, she saw firsthand the increased accessibility in public spaces for those with hearing loss through the use of telecoil. She contributes her expertise to telecoil research efforts here at Starkey.

Daniel Marquardt 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 Senior DSP Research Engineer with Starkey since 2018.

Eric George, M.S., M.E., is a Signal Processing Research Engineer at Starkey. He earned his M.S. in Electrical and Computer Engineering at Carnegie Mellon University, USA and M.E. in Computer Technology at Sun Yat-Sen University, China. His main areas of expertise and research interests include digital signal processing, speech recognition, machine learning and hearing sciences. Since 2018, his research at Starkey involved developing algorithms and firmware related to speech and music technology and has contributed to the creation of a few patents.

Kenneth K. Jensen, Ph.D., recieved his doctorate in neurobiology from the University of Southern Denmark, Denmark. He has published wide-ranging research in auditory perception and vocal communication in both animals and humans, involving psychoacoustics, acoustic measurements, modeling, x-ray cinematography, and many other techniques. He has worked with hearing aids and cochlear implants over the last decade including key topics like noise reduction, environmental classification, compression, hearing aid fitting software and strategies. He is currently a Principal Signal Processing Engineer with the Algorithms and Data Technology team at Starkey.