

Best-fit accuracy with Audibel's Acoustic Model Optimization 2.0: Lab evaluations



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Key takeaways:

- Audibel continues to offer faster and more accurate hearing aid fittings with Acoustic Model Optimization 2.0.
- With this advancement, AMO 2.0 uses the feedback cancellation initialization process to create a predicted real-ear model, which accounts for individual differences and helps improve the first fit accuracy.
- This potentially helps reduce the number of adjustments needed when matching targets with Real-Ear Measurements.

Introduction

Gain-prescription rules such as Audibel's e-STAT 2.0 or the National Acoustic Laboratories (NAL)'s NL2 provide a convenient starting point for hearing aid fittings. In Audibel's fitting software, hearing aid gains computed in accord with the chosen prescription rule are automatically programmed into the hearing aid with a single click on 'Target Match' (to apply gains only) or 'Best Fit' (to apply gains and other hearing aid settings at once).

Ideally, gain settings applied at the start of a fitting would yield real-ear responses or gains that always match prescriptive targets precisely. In this ideal scenario, gain adjustments would no longer be required to match targets in real-ear measures (REM). In practice, real-ear responses and gains generated using automated gain settings may deviate from targets. A common reason for such deviations is that real-ear acoustics can vary markedly across individual fittings (Figure 1).

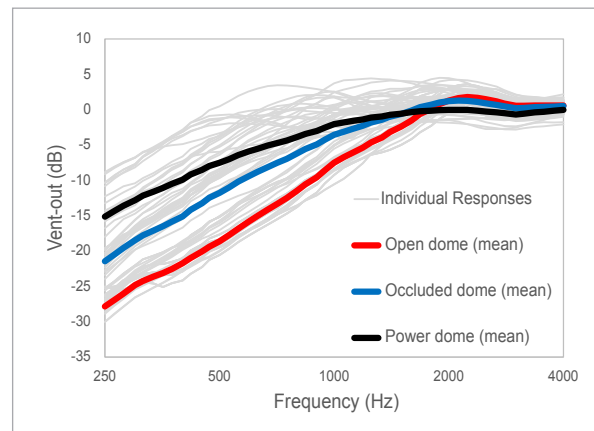


Figure 1: Individualized vent-out effects (gray lines) measured using an Occluded dome (blue line), illustrating the large inter-individual variability of acoustic couplings produced by standard RIC ear tips ('domes'). In some ears, an Occluded dome yields as much or more vent-out as measured on average for an Open dome (red line); in other ears, it yields as little or less vent-out as measured on average using a Power dome (black line).

However, at the start of a fitting (prior to any in-situ measure), the fitting software lacks any individual real-ear data and must rely on a non-individualized acoustic model to predict real-ear effects.

Deviations of real-ear aided responses (REARs) from prescriptive targets have undesirable implications. For fittings not verified with REM, professionals may not know at which frequencies, and how large, the deviations are. Consequently they must rely on other fit-verification methods (such as aided-threshold tests) and on patient feedback to guide gain adjustments. This can result in inefficient fittings, with multiple readjustments and several follow-up visits needed before a satisfactory fit is obtained. For REM-verified fittings, unless an automated procedure such as Audibel’s REM Target Match is used, gains must be adjusted manually. This can be tedious, especially when gains must be readjusted in multiple frequency bands.

To alleviate these hurdles and help increase first-fit efficiency, an Acoustic Model Optimization (AMO) feature was introduced in Audibel’s fitting software, Pro Fit (Michéyl et al., 2022). In the Aris AI product line, a new version, AMO 2.0 is available for increased first fit accuracy and efficiency. This article explains the features, illustrates its electroacoustic performance and evaluates the benefits with the feature on vs. off.

How can AMO help with fittings?

As noted earlier, REARs generated with automated initial gain settings may deviate from targets. These deviations typically arise due to one or both of the following factors: (a) practical challenges with REM (usually related to probe tube, test conditions, or ear canal); (b) mismatches between predicted and actual eardrum responses, i.e. sound pressure level (SPL) at the eardrum as a function of frequency. In the latter case, the mismatch originates from the acoustic model used to compute the Predicted REAR (Figure 2).

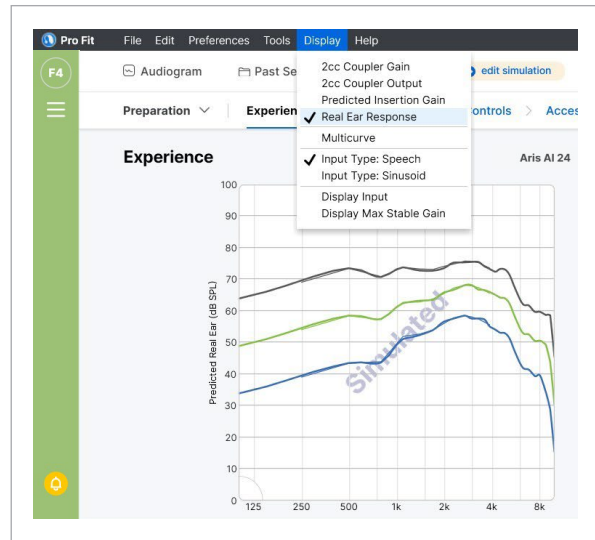


Figure 2: Example predicted real-ear response in Pro Fit.

Before AMO is run in a fitting, the predicted REAR is not based on individual real-ear data but rather on average or typical data (across many ears) for the selected fitting style. However, real-ear acoustics can vary widely across individuals—sometimes, across the two ears—even for the same fitting style. This is the case especially for the most popular fitting style today: Receiver-In-Canal (RIC) with an earbud (aka ‘dome’). Depending on factors such as the size and shape of the individual ear canal, the same Occluded dome can yield a well-occluded fit in one ear and an open fit in another ear.

These variable acoustic-coupling effects cannot be predicted precisely before the device is inserted into the individual ears. Therefore, the predicted REARs and real-ear aided gains (REAGs) displayed in Pro Fit are computed using an acoustic model based on typical or average data and cannot be correct for every individual fitting—even if the model is precisely correct on average. Since Best-Fit gains depend on the model predictions, if the latter are in error, the former will be also.

To help improve this situation, the AMO feature in Pro Fit leverages electroacoustic data collected ‘in-situ’ (in the ear) through the hearing aid, alongside the feedback canceller (FBC) initialization process. Audibel recommends running this initialization process at the start of a fitting to measure maximum stable gains (MSGs) prior to making manual gain adjustments.

Based on FBC-initialization data, the AMO algorithm updates acoustic-model settings in accord with the individual estimated real-ear acoustics. For example, if the algorithm determines that the fit is more open than predicted based on the acoustic option currently selected in Pro Fit, acoustic-model settings are updated to reflect a more open fit. Conversely, if the algorithm estimates that the acoustic coupling is more occluded than currently predicted by the fitting software, acoustic-model settings are updated to reflect a more occluding fit.

Whenever acoustic-model settings are updated, predicted REARs are automatically recomputed using the newer settings. So long as the AMO feature is enabled (toggle on feedback-canceller screen), acoustic-model updates can occur immediately after feedback-canceller initialization, without needing input from the professional. Following an acoustic-model update by AMO, the professional must decide whether to accept or reject an automatic update of hearing aid gains—based on the updated acoustic-model predictions. For initial fittings, prior to any manual gain adjustment, it is usually recommended to accept automatic gain updates when the option is offered, as doing so is expected to result in more accurate target matches. However, once gains have been adjusted manually, whether to accept or reject a gain update depends on the professional’s intentions. For example, the professional may wish to use the current hearing aid gains as a starting point for any further adjustment.

To summarize, while the AMO feature is not a substitute for fit verification using probe-tube REM, it leverages data collected and analyzed alongside FBC initialization, with the aim of improving the accuracy and efficiency of automated initial hearing aid gain settings.

In the following section, we demonstrate objective improvements in Best Fit accuracy with the most recent version of the AMO feature, AMO 2.0.

Method

To assess the performance of Audibel’s new Best-Fit process objectively and precisely, we tested it using a standard “acoustic” manikin, a ‘Head and Torso Simulator’ (HATS) (*Figure 3*). HATS allowed precise measurements of SPL in the (artificial) ear, without the need to use probe tubes—thus avoiding potential measurement errors due to improper placement or excessive constriction of the probe tube (*see, e.g., Thornton et al., 1987; van Noort et al., 2023*). An equivalent ‘eardrum’ SPL is measured directly by a calibrated microphone attached to the artificial ear. The HATS model used for this study (GRAS KEMAR 45BB) was equipped with an artificial ear (GRAS RA0045 Ear Simulator, GRAS KB0065 and GRAS KB0066 Pinna).



Figure 3: GRAS KEMAR wearing an Aris AI RIC hearing aid used in this study.

To simulate clinical REAR measurements, HATS was fitted binaurally with Audibel Aris AI 24 RIC RT with Snapfit 2.0 M receivers. The RIC receivers—fitted with Open, Occluded, or Power domes, depending on the test condition—were inserted into the manikin’s artificial ears, as they would be in human ears in a clinical fitting (*Figure 3*). Hearing aids were programmed using Audibel’s automated first-fit (Best Fit).

The two fitting rules most widely used with Audibel’s prescription hearing aids in recent years, e-STAT 2.0 and NAL-NL2, were used for these tests. For both rules, the same (flat, 40 dB HL) test-case audiogram was used. This test audiogram, calling for positive real-ear insertion gain (REIG) at both low and high frequencies, is adequate for assessing first-fit accuracy across a wide frequency range, based on REARs.

The International Speech Test Signal (ISTS) was played via a loudspeaker placed in front of HATS, 1 m away from the center of the artificial head. Stimulus level was adjusted to equal the usual ‘Moderate’ level (65 dB SPL) at a reference microphone located above the artificial head. Signals recorded by the artificial-ear microphones were analyzed using either third-octave frequency bands or frequency bands corresponding to the hearing aid (24) channels. All tests were performed in an acoustically treated, low-noise and minimally reverberant room.

The main goal of this study was to assess deviations between target and measured REARs using first-fit gains programmed with Best-Fit, with and without AMO 2.0. In particular, we sought to verify that the AMO 2.0 algorithm correctly detected when the actual, in-ear acoustic coupling was more or less occluding than predicted based on the acoustic option selected in Pro Fit. To this aim, different combinations of actual and selected acoustic coupling options were tested, including matched and mismatched combinations.

For example, in some conditions ‘Open’ domes were selected in Pro Fit while ‘Occluded’ domes were used on HATS.

The test conditions used in this HATS-based study involved mismatched acoustic options, meant to ‘tough-test’ AMO 2.0. In clinical practice, it is recommended to always select in Pro Fit the acoustic option matching the coupling style used in the ear. Nonetheless, mismatches between the selected option and actual coupling can happen due to the fitting-SW user occasionally forgetting to update the acoustic option in Pro Fit after changing the in-ear coupling. In such cases, as demonstrated below, the AMO feature can act as a ‘guard-rail’ by (1) detecting that the fit is more (or less) occluding than predicted for the selected acoustic option, (2) updating acoustic-model parameters and real-ear predictions accordingly, and (3) updating hearing aid gains based on the updated real-ear predictions.

Results

Best-Fit accuracy for Occluded-dome fittings of HATS was measured with and without AMO 2.0, using different acoustic-option settings (*Figure 4*).

Without AMO

First, consider results without AMO 2.0 (*Figure 4a*). Large deviations from targets are apparent. For example, when Open dome is selected in Pro Fit (while Occluded domes are used on the test manikin), measured REARs can exceed targets by more than 15 dB at low-to-medium frequencies.

This outcome can be explained as follows. For the flat 40-dB HL audiogram, the prescription rule calls for positive real-ear insertion gains (REIGs) at all frequencies. To achieve a positive REIG for an Open-dome fit (the selected acoustic option), the hearing aid must over-compensate the drop in real-ear SPL at low frequencies—which is anticipated based on REM data in humans.

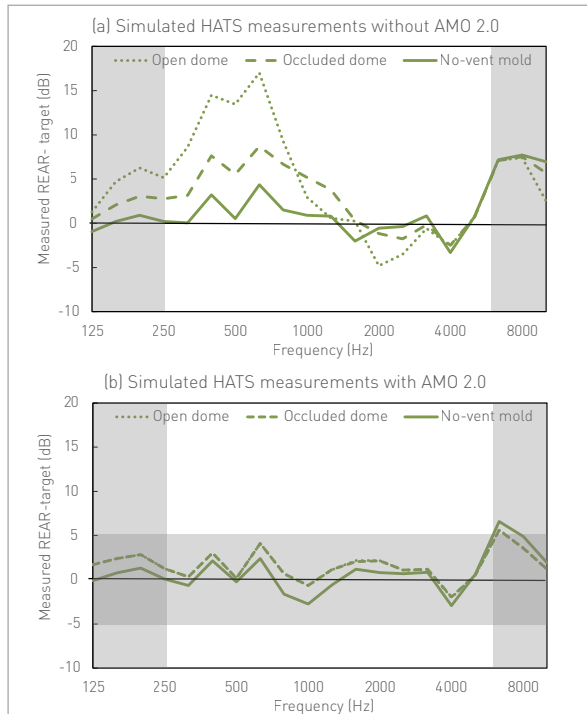


Figure 4 Differences between e-STAT 2.0 targets and Best-Fit REARs measured using occluded-dome fittings on HATS without (a) and with (b) AMO 2.0. Line styles indicate the acoustic option selected in Pro Fit: Open dome, Occluded dome, or No-vent earmold (see key in inset legend). Horizontal grey bar: 5-dB error margin. Vertical grey bars: regions outside 0.25–6 kHz. Note: In panel (b), the dotted and dashed lines are overlapped.

Accordingly, to match REIG targets—within system limits—Pro Fit sets high hearing aid gains at low frequencies. However, for this test condition, the domes actually used were occluded not open, and in addition these domes tend to yield more occluding fits on this HATS than in humans on average. In this situation, the high gains at low frequencies were overkill; hence, the overshoot of the REAR above targets below 1.5 kHz.

When a more occluding acoustic option is selected in Pro Fit, smaller deviations of REARs from targets are observed. However, deviations larger than 5 dB over 350-750 Hz are still seen, even when the acoustic option selected in Pro Fit matches the coupling used in the ear (Occluded dome). This is because the default acoustic model for Occluded domes in Pro Fit is based on average real-ear data from human ears, in which these domes often yield less occluded fits than on the HATS.

Consistent with this, with ‘No-vent earmold’ selected, REARs are within 5 dB of targets from 125 Hz to 5 kHz.

With AMO 2.0

Next, consider results with AMO 2.0 (Figure 4b). In this situation, regardless of which acoustic option was selected in Pro Fit, the HATS-measured REARs were within 5 dB of targets up to, at least 5 or 6 kHz. This demonstrates that the AMO 2.0 algorithm (a) sensed correctly that the fit was more occluding than predicted a priori based on the acoustic option selected in Pro Fit (Open dome or Occluded dome), (b) appropriately adjusted acoustic-model settings accordingly, so that (c) the programmed hearing aid gains resulted in measured REARs within 5 dB of targets over a wide frequency range (125 Hz - 5 kHz).

It should be noted that, for frequencies above about 5 kHz, REARs are often highly variable across fittings and very difficult to predict accurately and reliably.

Current audiological best-practice guidelines for target matching in REM recommend a 5-dB error margin over 250 Hz to 6 kHz ‘whenever possible’ (British Society of Audiology, 2018). In general, the AMO 2.0 feature cannot match the precision of target matching attainable using REM equipment. Nonetheless, the results show that AMO 2.0 can help bring REARs closer to targets, especially in fittings for which the real-ear acoustics deviate largely from the predictions of the ‘default’ acoustic model of the fitting software. Since it is usually not known in advance, for which fittings real-ear acoustics will depart substantially from default real-ear model predictions, these findings argue for using AMO 2.0.

With vs. without AMO 2.0

To illustrate the large improvements in first-fit accuracy that can be achieved using AMO 2.0 for the three RIC dome styles, squared deviations between prescriptive targets and Best-Fit REARs measured with and without AMO 2.0 were averaged across frequency (250 Hz - 6 kHz).

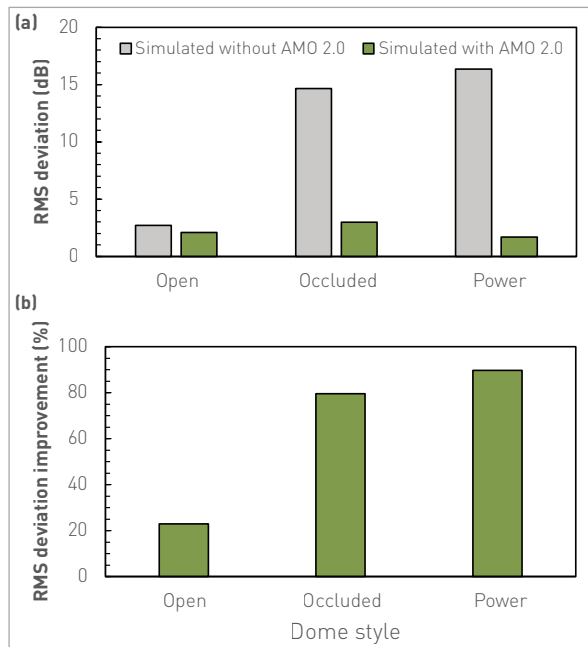


Figure 5: (a) Frequency-averaged RMS deviations between measured and target REARs for open, occluded, or power-dome fittings on the manikin, with hearing aid gains programmed using Best-Fit with and without AMO 2.0. (b) Largest improvements in RMS deviations with (versus without) AMO 2.0, across all tested Pro Fit acoustic options and fitting rules (e-STAT 2.0 and NAL-NL2). Note that the data in panel A were selected to correspond to the largest AMO-mediated improvements in panel (b).

The resulting root-mean-squared (RMS) deviations were compared, to determine those corresponding to the largest improvements with AMO 2.0 across all Pro Fit acoustic option settings and the two prescription rules tested (e-STAT 2.0 and NAL-NL2).

For this extreme test condition, the largest improvements in first-fit accuracy were obtained for Occluded- and Power-dome fittings (Figure 5).

For the latter, reductions of up to 89% in RMS deviations were found for Power and Occluded domes. For Open domes, the largest improvements observed are smaller. This is because for this dome style the predictions of the non-individualized acoustic model tended to be more consistent with the responses measured on HATS—as indicated by first-fit RMS deviations lower than 5 dB, even without AMO 2.0 (Figure 5a); thus for this dome style there was less ‘room for improvement’.

Note that the data shown in these figures illustrate AMO 2.0 performance under extreme test conditions involving large mismatches between initial and corrected real-ear response predictions. In clinical fittings, the performance of AMO 2.0 may vary depending on acoustic test conditions (e.g., ambient noise, test levels, fitting style, prescribed gains, REM technique, system limitations, and other variables). As a rule of thumb, large improvements in Best Fit accuracy with AMO 2.0 (Iverson et al., 2025) are expected only for fittings in which real-ear responses deviate widely from predictions of the Pro Fit ‘base’ model—the model used ‘by default’, when feedback-canceller initialization has not been run or AMO 2.0 is turned off.

In addition, it must be noted that the HATS manikin used in this study is designed based on physical and acoustic characteristics of human adults. Results illustrated here do not apply to hearing aid fittings of children. The AMO 2.0 feature is not designed for hearing aid fittings of individuals younger than 18 years and should not be used for such fittings; thus when the patient age entered in Pro Fit is less than 18 years, the feature is disabled.

Fitting process efficiency

How may improvements in first-fit accuracy, such as those demonstrated above, translate into more efficient fitting processes for professionals? The answer to this question can vary greatly depending on several factors, such as fitting-process habits, which may differ across professionals.

To illustrate gains in fitting efficiency that may result from improved Best-Fit accuracy with AMO 2.0, we simulated manual gain adjustments (‘clicks’) in the Pro Fit ‘Fine-tuning’ interface, needed to bring REARs as close as possible to prescriptive targets, starting from Best-Fit gain settings adjusted by AMO 2.0 or not.

The Best-Fit gain settings and corresponding REARs measured on HATS in the present study were used as inputs into these simulations.

Across all test conditions—including both fitting rules and all tested combinations of dome style and acoustic option—we found reductions of up to 90% in the number of clicks needed to precisely match targets (within ± 2 dB, the smallest gain change achievable in Pro Fit) when AMO 2.0 was used, versus not. For this best-case example, the number of clicks to match targets as precisely as possible over 125 Hz – 6 kHz went from 10 without AMO 2.0 to just 1 with AMO 2.0.

Reductions in the number of gain adjustments (clicks) required to match targets after first fit is only one aspect of the potential benefits afforded to professionals using AMO 2.0. Fewer gain adjustments are likely to make the initial fitting process not only faster, but also easier (less cognitively taxing) for clinicians.

Moreover, there is a distinct potential advantage for fittings that cannot be verified using REM. Indeed, with Best-Fit gains adjusted based on in-situ data, fewer fine-tunings are likely to be needed to merely ‘compensate’ for atypical acoustic effects, thus allowing a greater focus on accommodating individual psychoacoustic (perceptual) preferences.

Conclusion

- By improving first-fit accuracy, Audibel’s Pro Fit Acoustic Model Optimization (AMO) feature can help improve hearing aid fitting efficiency by reducing the number of adjustments needed to match to prescriptive targets during real-ear measurements.
- The latest version of the feature, AMO 2.0, is available with the Aris AI product line, for adult (> 18 years) fittings.
- Electroacoustic measures on a standard hearing aid evaluation manikin objectively demonstrate potential benefits of AMO 2.0, including improved accuracy and efficiency of automated fittings.

Acknowledgements

The authors would like to express their gratitude to Michelle Hicks, Christine Tan and Jamie Hand for their thoughtful feedback during the drafting of this manuscript.

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Author Biographies



Christophe Micheyl, Ph.D., joined Starkey in 2013 and is now a Senior Principal Scientist in the Starkey R&D Advanced Development team. He specializes in audiological applications of acoustics and hearing science for hearing aid research and development. He is particularly interested in clinically relevant innovations, with a focus on improving the hearing aid fitting process for hearing care professionals and hearing aid users.



Jumana Harianawala, Au.D., currently works as a Senior Fitting Systems Design Engineer at Starkey in Eden Prairie, Minnesota. She specializes in and is responsible for improving hearing aid fittings and adaptations using progressive concepts and techniques like environment momentary assessment-based tuning. Jumana joined the Starkey team in 2011 and worked on qualitative and quantitative research investigating benefits from innovative technologies that lead to the development of new features and products. Prior to joining Starkey, Jumana lived in New York and worked as a practicing audiologist at an ENT clinic to gain a better understanding of the needs of the hearing aid wearer before pursuing her research career.



Jennifer Anfinson, Au.D., is a Clinical Audiologist on the Clinical Research team at Starkey. She holds a Bachelor of Science in Speech, Language, Hearing Sciences from University of Minnesota - Moorhead, a Master of Arts in Audiology and a Clinical Doctorate of Audiology from University of Iowa. She joined Starkey in 2022, bringing her former private practice ownership along with 13+ years of direct patient care experience in diagnostics, counseling, hearing aid programming, real ear measurement, and top-notch customer service. She administers the qualifying evaluations for clinical research participants and supports clinical research initiatives by assisting with data collection in a variety of research, validation, and usability studies. She is passionate about advocating for hearing aid users and prioritizing their hearing needs.



Meg Introwitz-Williams, B.Sc., holds a Bachelor of Arts in Speech-Language-Hearing Sciences from the University of Minnesota, Twin Cities, and a Bachelor of Science in Software Development from Western Governors University. She joined Starkey in 2021 as a Software Engineer with a focus on the development and verification of acoustic modeling and fitting prescription algorithms and has a passion for the intersection of rehabilitative audiology and engineering.



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 Smieja, M.H.Sc., is a Senior Acoustic Engineer at Starkey. He joined Starkey in 2019 with a BEng from McMaster University and an M.H.Sc. in Clinical Engineering from the University of Toronto. He is passionate about improving the next generation of hearing aids through novel transducer applications and acoustic modeling.



Laura Woodworth, Au.D., joined Starkey in 1996 and has worked in various roles including customer relations, clinical audiologist, trainer and product management. Her passion to represent the voice of the customer complements her current role as Principal Product Manager where she specializes on improvements to the fitting software and TeleHear features. Under her guidance, multiple features and improvements have been introduced to the fitting software over several product launches and TeleHear has expanded its reach and scope beyond its initial introduction. She is particularly interested in refining and releasing software features that help hearing care professionals improve their patient journey.