Two Ear Hearing Solutions and Connectivity

TRAINING OBJECTIVES

At the end of this course, participants will be able to:

- Describe AB's two-ear solutions.
- Explain the benefits of the AB bimodal solution to your patient.
- Recommend an AB solution for every ear.

TRAINING TAKEAWAYS

1

2

3

SUPPORTING DATA

Adaptive Phonak Digital Bimodal Fitting Formula (APDB)

- Conventional hearing aid prescriptive formulas (NAL, DSL) do not align acoustic and electric signal processing.
- The bimodal fitting formula ensures that the hearing aid is complimenting the cochlear implant and not competing with it by aligning the frequency response, automatic gain control, and the compression ratio and kneepoint.
- The Naída Link M HA with APDB yielded significantly better speech intelligibility than the subjects' own HAs in quiet and in noise.
- The Naída Link HA using the APDB fitting formula was significantly better than the Naida Link fit to NAL-NL1.
- Aligned AGC improves speech understanding in noise by up to 2 dB over the standard Phonak AGC. This means recipients can receive up to 30% improvement in speech understanding.

1. 1. Taal CH, van Barneveld DC, Soede W, Briaire JJ, Frijns JH. (2016). Benefit of contralateral routing of signals for unilateral cochlear implant users. *J Acoust Soc Am,140(1)*:393. doi: 10.1121/1.4955307. PMID: 27475163.
2. 2. Dorman MF, Cook Natale S, Agrawal S. (2018). The value of unilateral CIs, CI-CROS and bilateral CIs, with and without beamformer microphones, for speech understanding in a simulation of a restaurant.

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Introduction to Advanced Bionics and Cochlear Implants

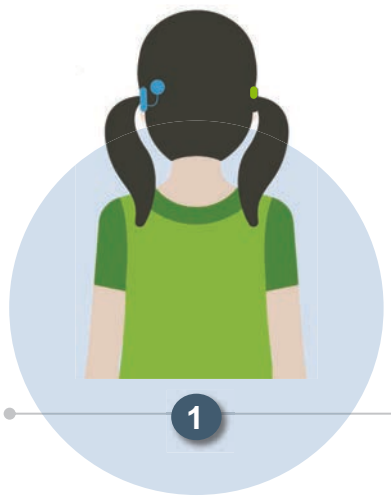
AB + Phonak Two-Ear Solutions

Kelley Dwyer, Au.D.

A Sonova brand

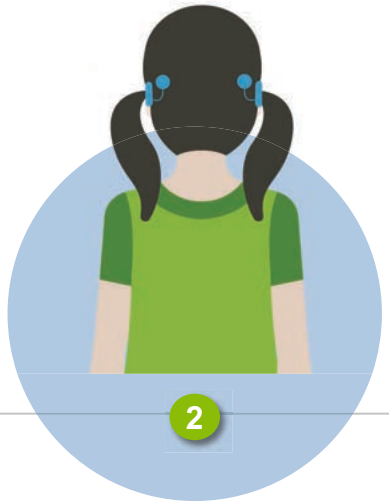
An AB Solution for Everyone

Unilateral + CROS



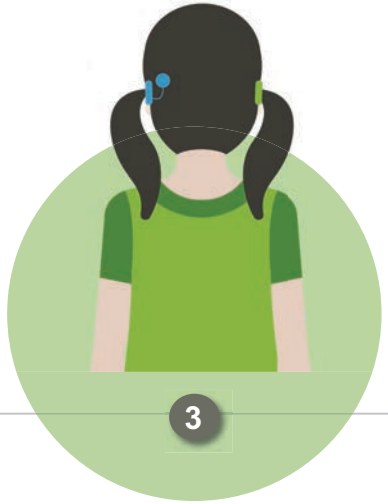
Marvel CI + Phonak CROS P13

Bilateral CIs



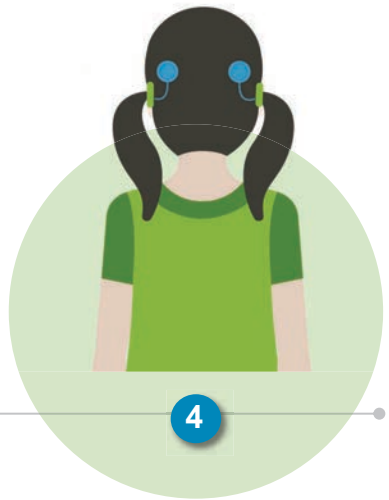
Marvel CI + Marvel CI

Bimodal



Marvel CI + Link M

Acoustic + Electric



Marvel CI + Acoustic Earhook

Naída™ CI and Sky CI™

Naída™ CI and Sky CI™ sound processors are designed to connect recipients with the moments they love and all life has to offer.

Features include*:

- Cosmetically-appealing design
- Integrated Bluetooth
- RogerDirect
- Modern waterproof solution
- Streamlined accessory options
- Mobile application
- Automatic operating system
- Streamlined fitting platform
- Wireless programming

*Product availability varies by region

Bilateral AB Sound Processors

The gold standard for bilaterally deafened recipients

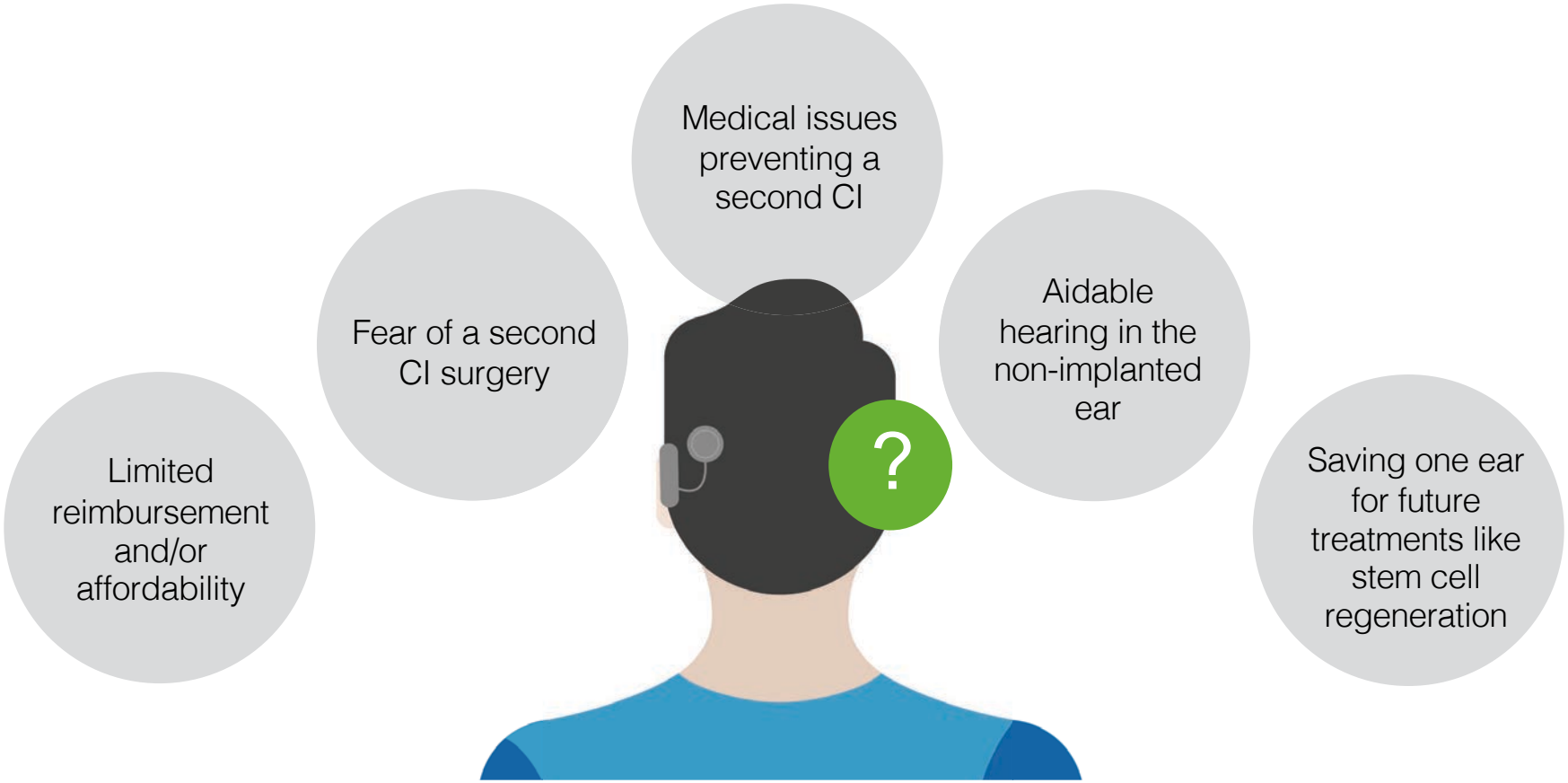
Access Binaural VoiceStream Technology™ features

Stream bilaterally with Bluetooth, RogerDirect, and AirStream devices

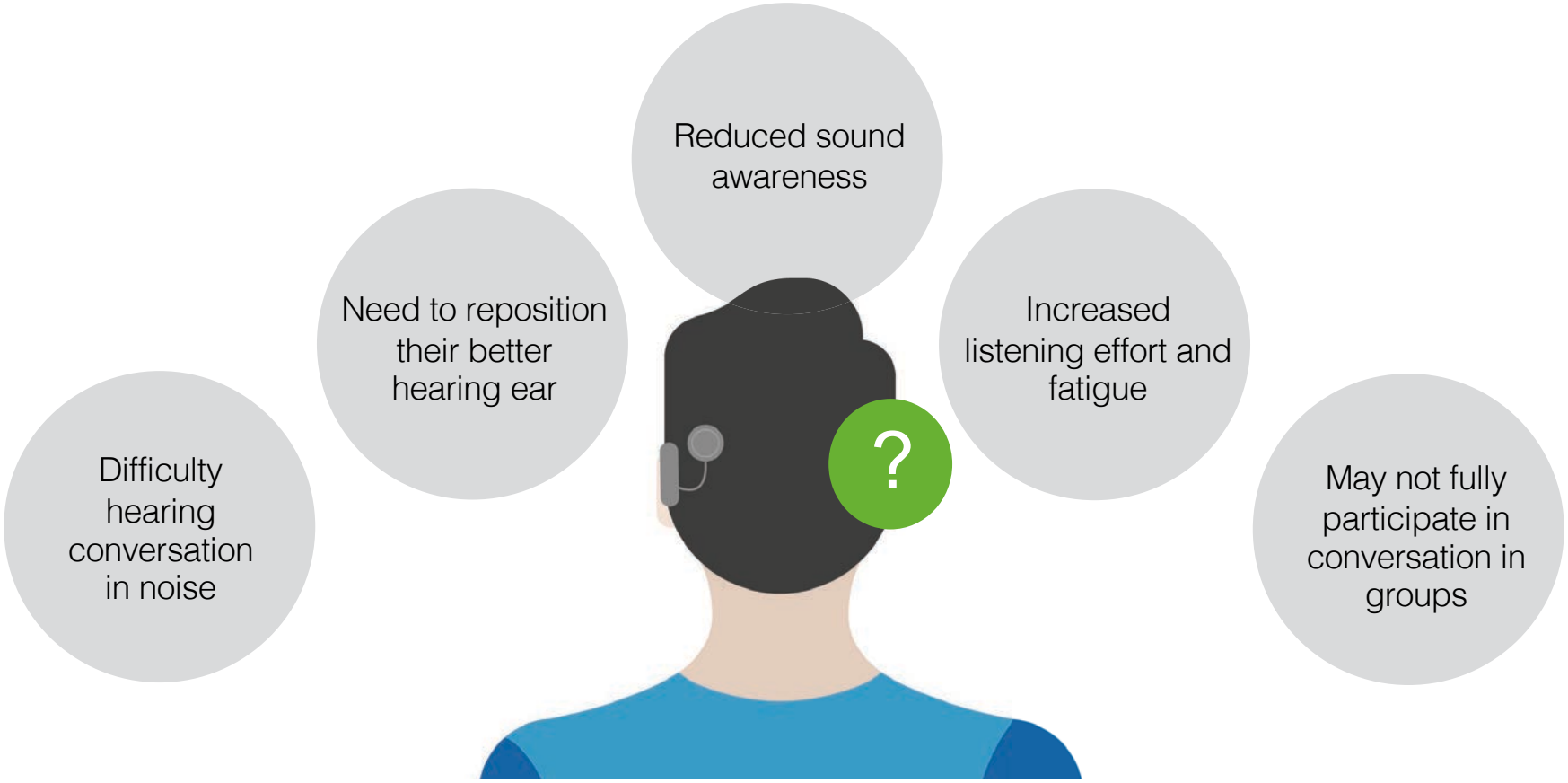
Utilize both devices with AB apps

Designed for easier, faster and smarter management of bilateral features in Target CI

Globally, the majority of CI recipients are unilaterally implanted.



Most unilateral CI users report they can cope well with conversation in quiet, but may experience difficulty when in challenging listening situations.

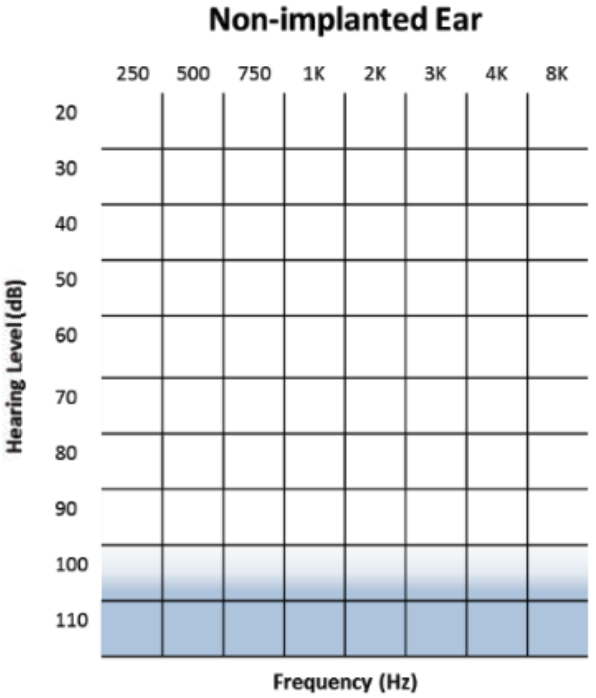


Naída CI + Phonak CROS

Who is a candidate for CROS?

AB cochlear implant candidate/recipient

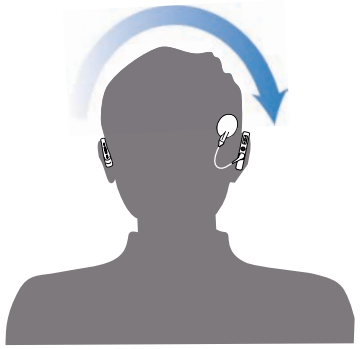
No functional hearing in the contralateral ear



Naída CI + Phonak CROS

Transmits sounds from the non-implanted ear to Naída CI via proprietary wireless streaming protocol

Provides unilateral recipients with the best hearing in quiet and noise without the need to reposition



Improved speech discrimination in noise[1-7]

Removes head shadow effect for improved sound awareness[8-11]

Microphone state matched across the two ears

Optimal performance, no matter where sound originates

Improved ease of listening[3,4,6,7,9,12]

CROS Research

Significant improvement in speech perception when speech is coming from non-CI ear

Significant improvement in general QoL when using CROS

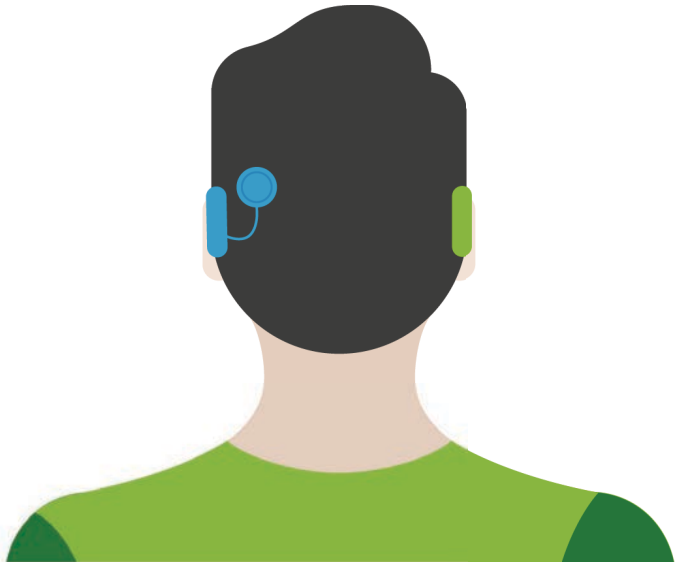
Frequent communication partners report reduction in concerns about the individual when they are using CROS device.

Johnson et al., 2025

Bimodal Solution

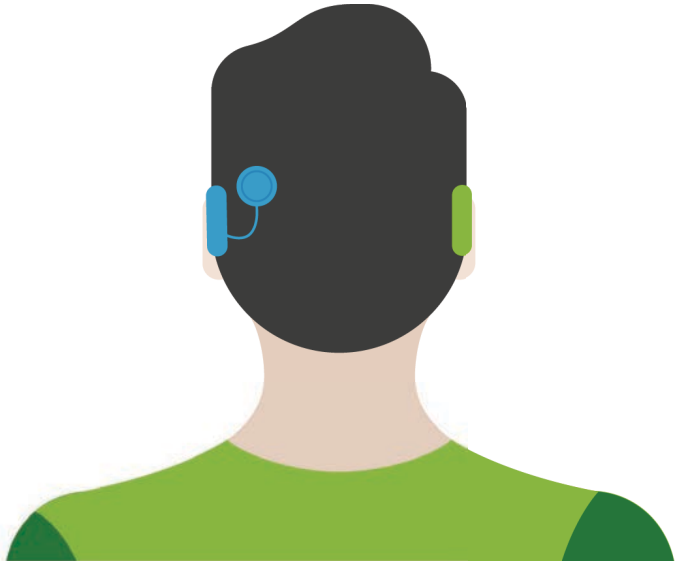
AB & Phonak Bimodal Solution:
The two-ear solution designed to work together

Benefits of Bimodal Hearing



1. Improved speech understanding in quiet and noise[14-16]
2. Feeling less tired with improved ease of listening[15]
3. Improved music appreciation with better access to low frequencies[16]
4. Improved sound awareness[17]

Who can be fit with Phonak Link Hearing Aids?



1. Patients with severe to profound hearing loss with some aidable hearing
2. Bimodal CI recipients with aidable hearing in the contralateral ear
3. CI candidates with severe to profound hearing loss bilaterally
4. Adults and pediatric recipients

AB + Phonak Solutions

Naída Link™ / Sky™ Link Bimodal Solution

Compatible with Naída CI and Sky CI

Provides aligned signal processing with the Adaptive Phonak Digital Bimodal Fitting Formula

Stream bimodally with Bluetooth, RogerDirect, and AirStream devices

Utilize both devices with AB Remote apps

Designed for easier, faster and smarter fittings in one software

Pro Tip: The underlyintier (30/90) need to match g platform (Naída/Sky) and to ensure compatibility and full access to bimodal/bilateral features.

AB + Phonak Solutions

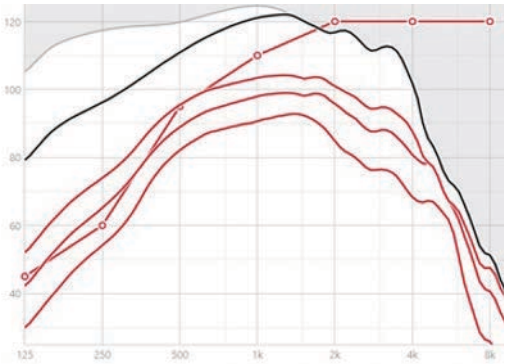
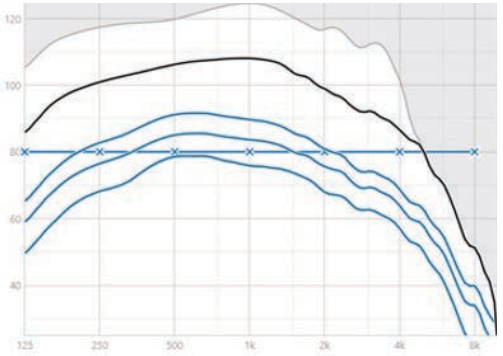
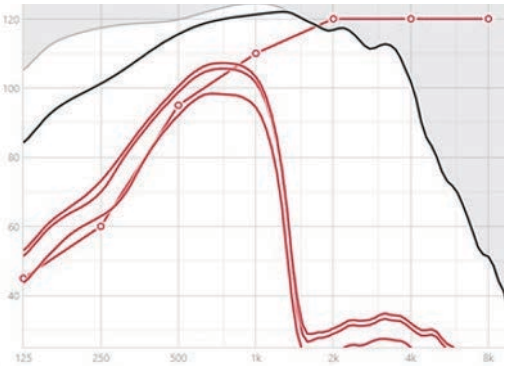
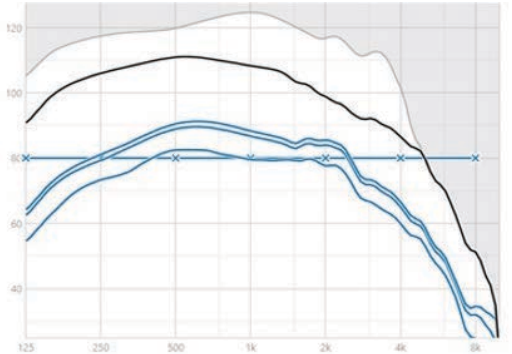
The right solution at the right time

Naida/Sky CI + Any Hearing Aid	Naida/Sky CI + Phonak Hearing Aid	Naida/Sky CI + Naida/Sky Link Hearing Aid
		Premium level technology plus the AB Advantage: Instantaneous broadband transfer of data between both devices ensures they are always balanced.
		Speech in 360° to detect where sounds are coming from and stream it to the other ear.
		One app controls both devices: balance volume and programs with one-touch control
	AutoSense AI in both devices	AutoSense AI in both devices: sounds are always classified the same in both ears
	Remote Programming of both devices	Simultaneous Remote Programming of both devices
	Hands-Free calling with either ear	Hands-Free calling with both ears, Acoustic Phones are heard in both ears
	Share accessories like TV Connector and Roger microphones	Share accessories such as: Partner Mic, TV Connector, & Roger microphones
Stream calls and entertainment to preferred ear	Universal connectivity from any Bluetooth® device to preferred ear	Universal connectivity from any Bluetooth® device to both ear
Timing: aligned by default	Timing: aligned by default	Synced Timing, compression and volume for Inter-Aural Comparison
Hearing with both ears may improve hearing	AB & Phonak devices utilize AI technology to hear better in noise	Excellent hearing – even in noise

Adaptive Phonak Digital Bimodal Fitting Formula

- Conventional hearing aid prescriptive formulas (NAL, DSL) do not align acoustic and electric signal processing
- Frequency response shifted from mid-frequencies to lower range
- Compression ratio and kneepoint to match sound processor
- The same slow-acting, dual-loop automatic gain control (AGC) as sound processor

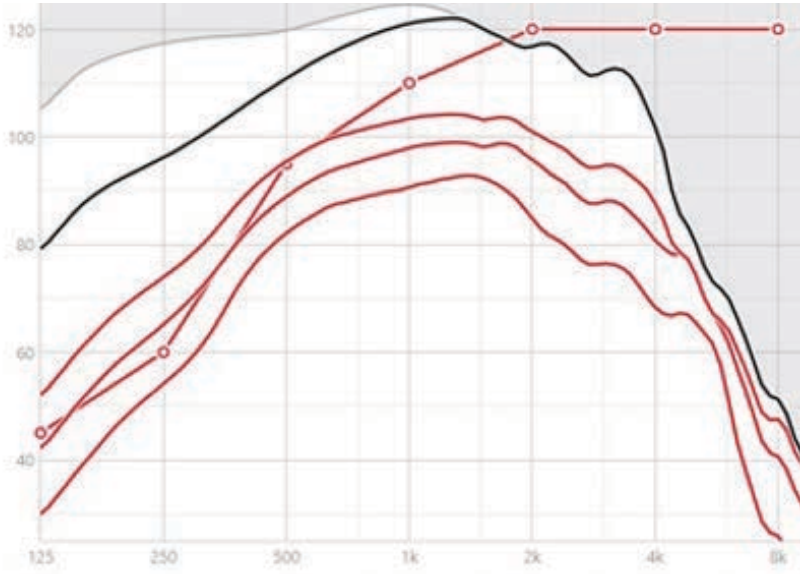
Adaptive Phonak Digital Bimodal Fitting Formula

	Sloping Hearing Loss	Flat Hearing Loss
Adaptive Phonak Digital Fitting Formula		
Adaptive Phonak Digital Bimodal Fitting Formula		

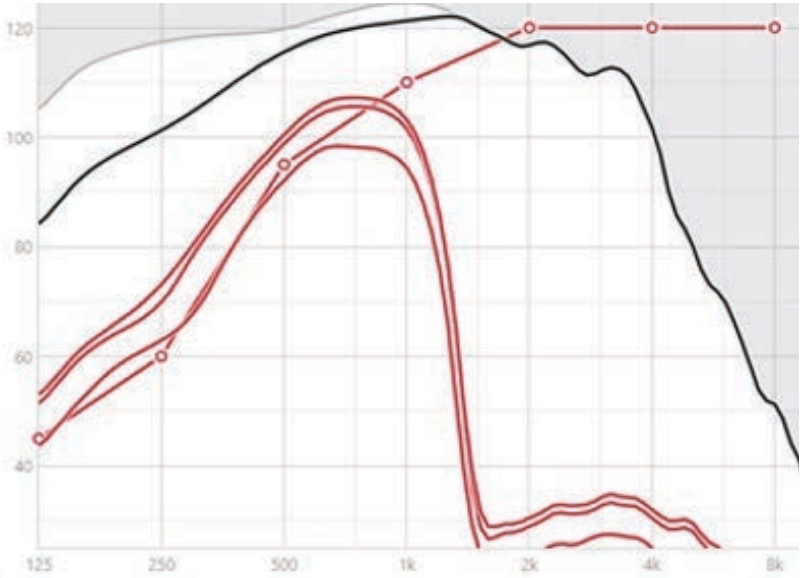
Adaptive Phonak Digital Bimodal Fitting Formula

Sloping Hearing Loss

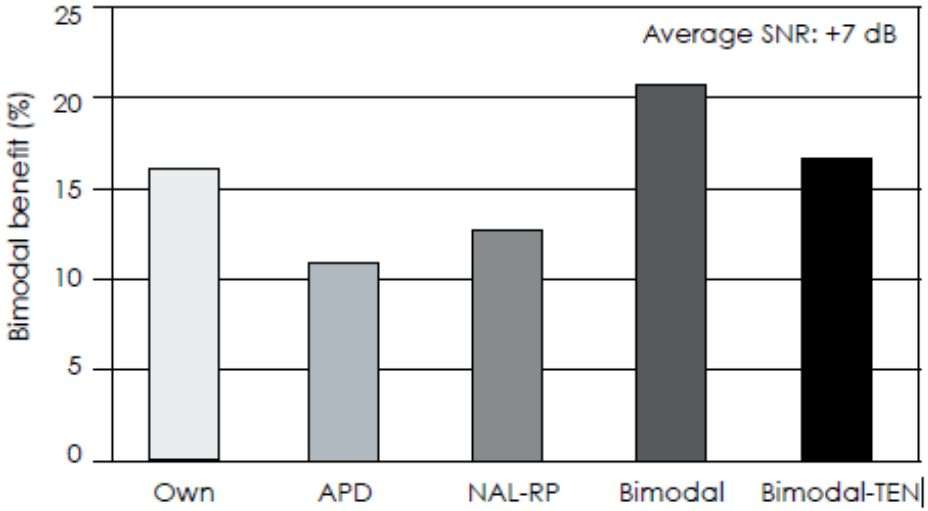
Adaptive Phonak Digital Fitting Formula

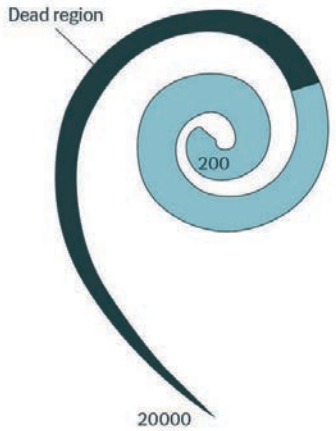


Adaptive Phonak Digital Bimodal Fitting Formula



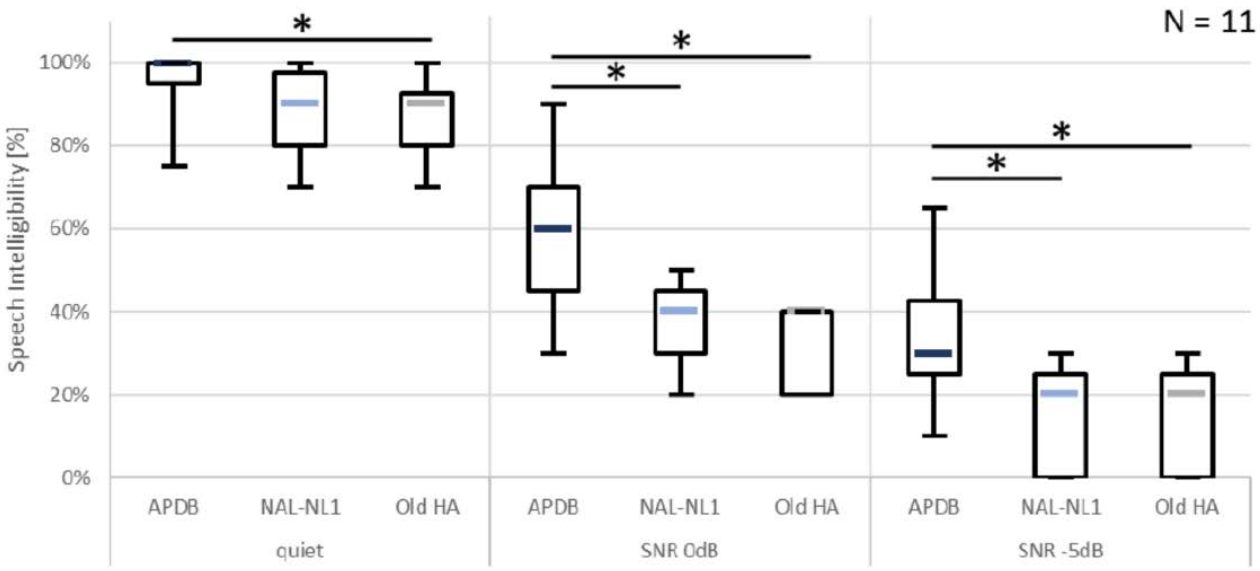
Adaptive Phonak Digital Bimodal Fitting Formula Research





Chalupper et al., 2013

Adaptive Phonak Digital Bimodal Fitting Formula Research

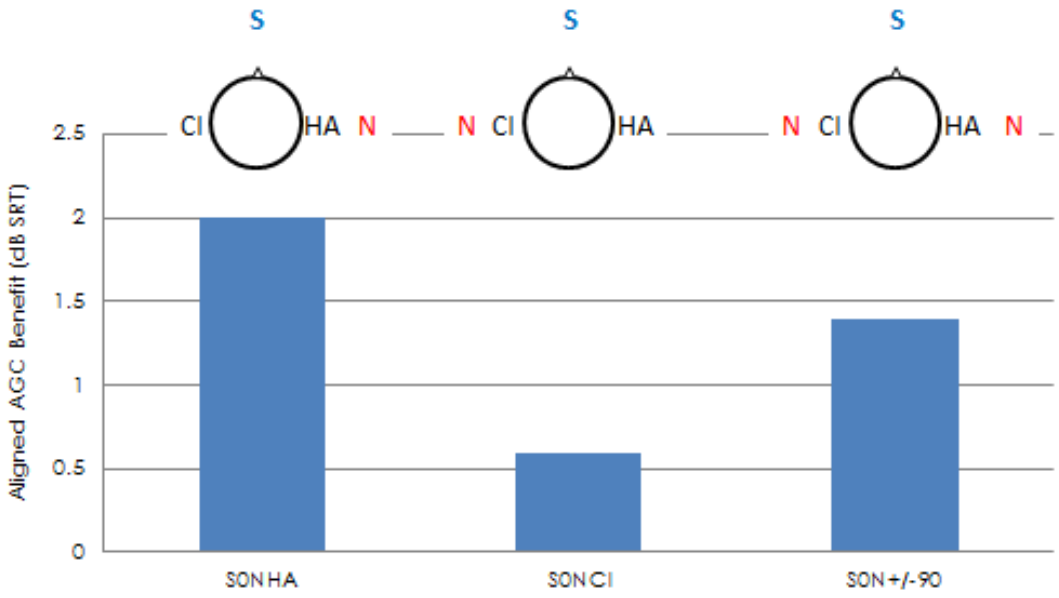


S: PB words at 65 dBA

N: 10-talker babble (5M+5F)

Auletta et al., 2021

Automatic Gain Control



Veugen et al., 2016

Knowledge Check:

What are the 3 parameters aligned with the bimodal fitting formula?

A) AGC
B) Output SPL
C) Frequency response
D) Compression ratio & kneepoint
E) Induction coil sensitivity

AB Acoustic Earhook Solution

Integrated acoustic and electric sound processing within a single device.

The Acoustic Earhook is designed for individuals with aidable low frequency hearing following cochlear implantation.

AB Acoustic Earhook Solution

Modular attachment for easy placement and removal of the Acoustic Earhook

Adaptive Phonak Digital Bimodal fitting formula aligns acoustic and electric signal processing

Access Binaural VoiceStream Technology™ features

Provides up to 55 dB of gain and amplifies up to 10,000 Hz

Receivers available for right or left side in five lengths

Stream bilaterally with Bluetooth, Roger, and AirStream devices

Transitioning to Electric-only Use

Electrical only

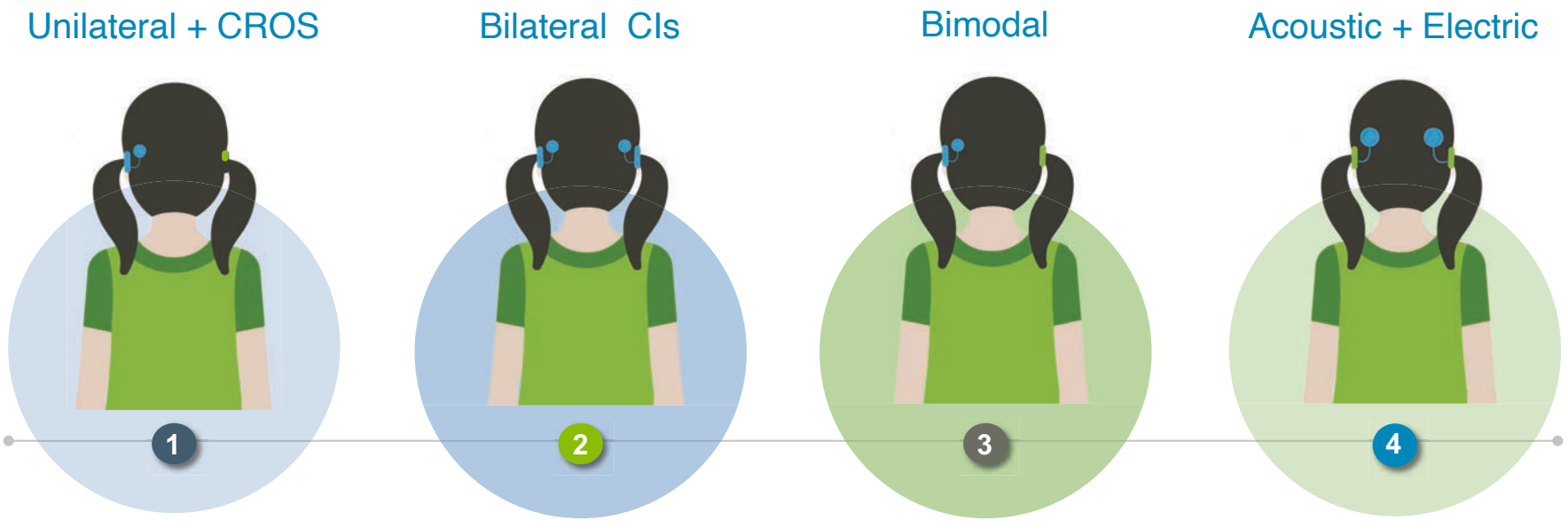
Acoustic mode

In the event that the recipient's hearing levels deteriorate over time, simply configure the Naída CI for electric-only use with a quick programming change.

The recipient can benefit from the T-Mic by simply changing the hardware using the Pin Removal Tool.

Pin Removal Tool

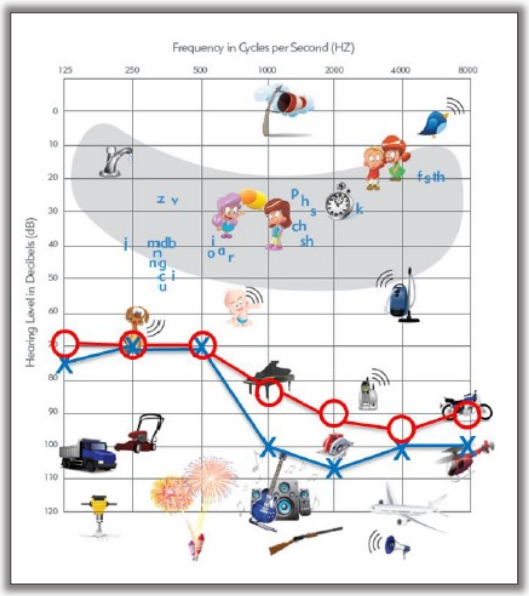
An AB Solution for Everyone



Case Studies

Debbie is an Executive Chef at one of the most popular restaurants in town. She has a bilateral profound sensorineural hearing loss and has used Phonak hearing aids consistently since age 4. She was able to communicate successfully via spoken language until 6 months ago, when her hearing rapidly deteriorated. While at work, she primarily needs to communicate with the sous chef in the noisy kitchen. Debbie is reluctant to pursue cochlear implantation, as she is fearful of losing the remaining hearing on which she feels dependent.

Which solution would you recommend for Debbie?

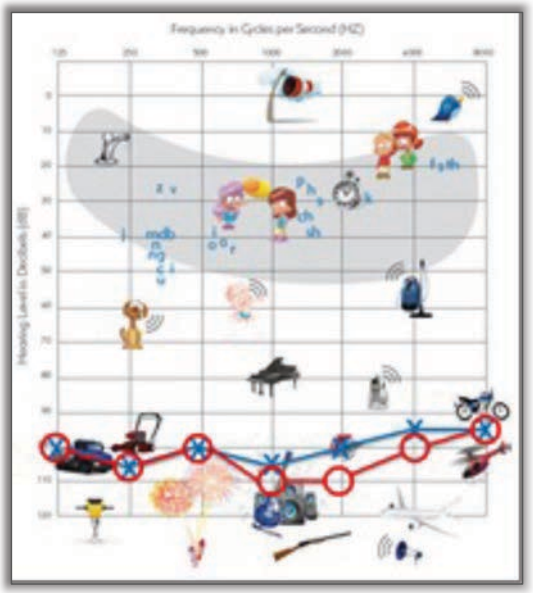


- Unilateral Naída CI device
- Bimodal Naída CI and Naída Link devices
- Bilateral Naída CI devices
- Bilateral Acoustic Earhook devices

Case Studies

Lucas is a 3-year-old with bilateral profound sensorineural hearing loss. Despite consistent hearing aid use and speech therapy, he is not making progress with auditory or speech development. His parents indicate that spoken language is a goal for Lucas, and they would like him to be able to attend a mainstreamed school.

Which solution would you recommend for Lucas?

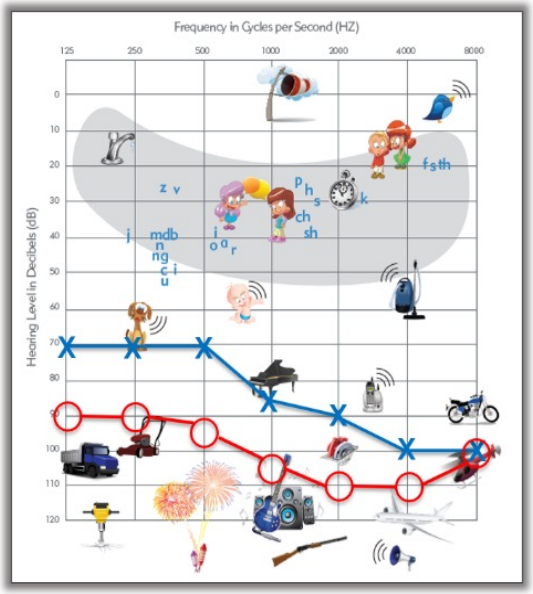


- Unilateral Sky CI device
- Bimodal Sky CI + Sky Link HA
- Bilateral Sky CI devices
- Bilateral Acoustic Earhook devices

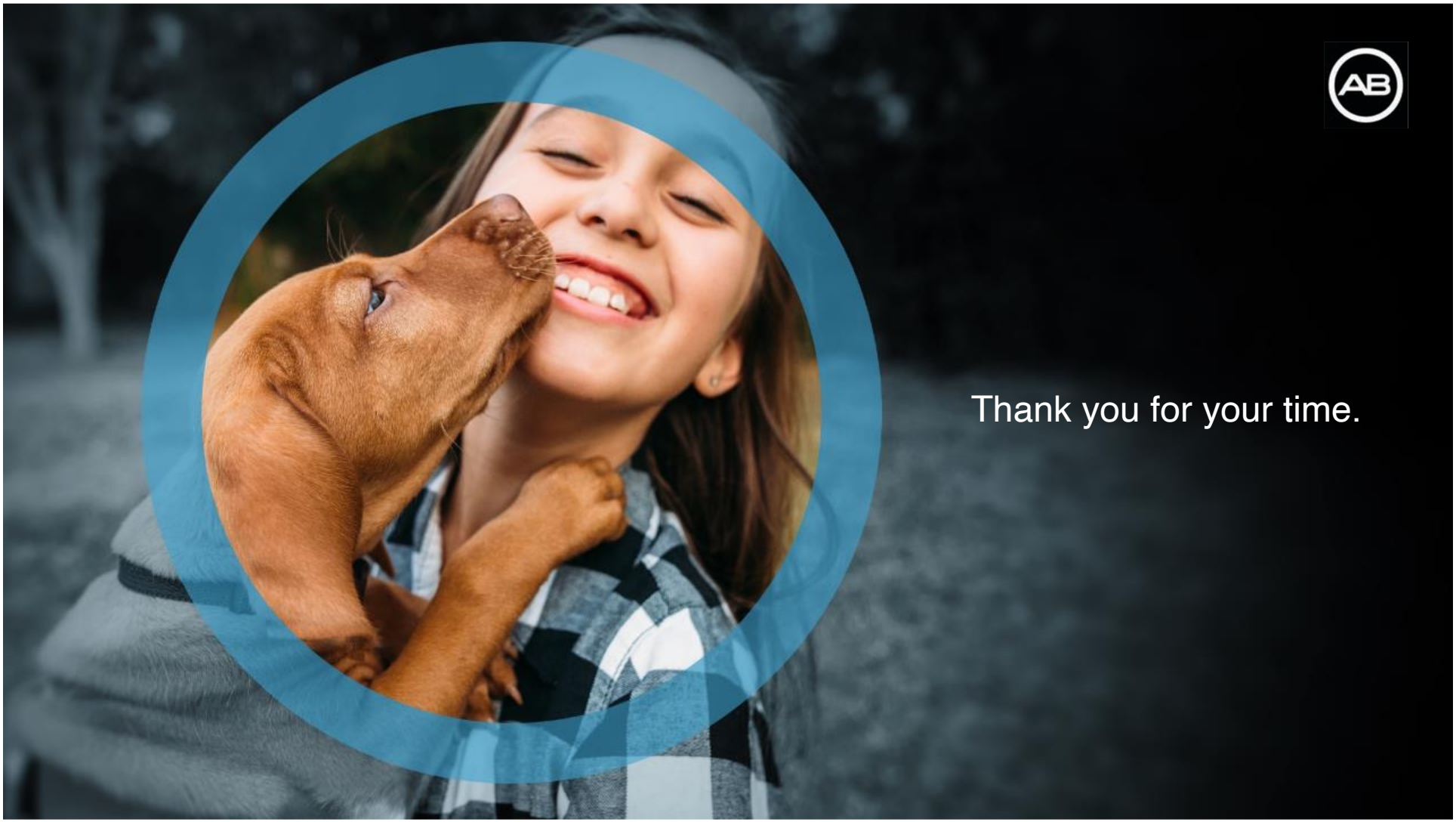
Case Studies

Patrick has a severe-to-profound sensorineural hearing loss for the left ear and a profound hearing loss for the right ear. He has been using Phonak hearing aids for the past 4 years and is familiar with the technology. He reports that hearing is his right ear has significantly deteriorated over the past 6 months, and he no longer obtains benefit from the hearing aid on this side. Patrick works as an accountant and complains that he struggles to hear in meetings and noisy environments. He avoids going out to social events as he struggles to hear in group conversations.

Which solution would you recommend for Patrick?



- Naída CI + CROS
- Bimodal Naída CI and Naída Link devices
- Bilateral Naída CI devices
- Bilateral Acoustic Earhook devices


Thank you for your time.

References

1. Taal CH, van Barneveld DC, Soede W, Briaire JJ, Frijns JH. (2016). Benefit of contralateral routing of signals for unilateral cochlear implant users. J Acoust Soc Am,140(1):393. doi: 10.1121/1.4955307. PMID: 27475163.
2. Dorman MF, Cook Natale S, Agrawal S. (2018). The value of unilateral CIs, CI-CROS and bilateral CIs, with and without beamformer microphones, for speech understanding in a simulation of a restaurant environment. Audiol Neurootol, 23(5):270-276. doi: 10.1159/000493844. Epub 2018 Dec 11. PMID: 30537753.
3. Dwyer RT, Kessler D, Butera IM, Gifford RH. (2018). Contralateral routing of signal yields significant speech in noise benefit for unilateral cochlear implant recipients. J Am Acad Audiol, 30(3):235-242. doi: 10.3766/jaaa.17117. PMID: 30461413; PMCID: PMC6542640.
4. Ernst A, Baumgaertel RM, Diez A, Battmer RD. (2019). Evaluation of a wireless contralateral routing of signal (CROS) device with the Advanced Bionics Naída CI Q90 sound processor. Cochlear Implants Int, 20(4):182-189. doi: 10.1080/14670100.2019.1586151. PMID: 30821202.
5. Kurien G, Hwang E, Smilsky K, Smith L, Lin VYW, Nedzelski J, Chen JM. (2019). The benefit of a wireless Contralateral Routing of Signals (CROS) microphone in unilateral cochlear implant recipients. Otol Neurotol, 40(2):e82-e88. doi: 10.1097/MAO.0000000000002078. PMID: 30570612.

References

6. Mosnier I, Lahlou G, Flament J, Mathias N, Ferrary E, Sterkers O, Bernardeschi D, Nguyen Y. (2019). Benefits of a contralateral routing of signal device for unilateral Naída CI cochlear implant recipients. Eur Arch Otorhinolaryngol, 276(8):2205-2213. doi: 10.1007/s00405-019-05467-9. PMID: 31102018.
7. Neumann, S., Calise, S., Dwyer, R. T., & Agrawal, S. (2024, July 10–13). The impact of a CROS device for unilateral recipients on subjective and objective listening effort [Conference presentation]. 17th International Conference on Cochlear Implants and Other Implantable Technologies, Vancouver, BC, Canada.
8. Snapp HA, Hoffer ME, Spahr A, Rajguru S. (2019). Application of wireless contralateral routing of signal technology in unilateral cochlear implant users with bilateral profound hearing loss. J Am Acad Audiol, 30(7):579-589. doi: 10.3766/jaaa.17121. PMID: 30541657.
9. Núñez-Batalla F, Fernández-Junquera AB, Suárez-Villanueva L, Díaz-Fresno E, Sandoval-Menéndez I, Gómez Martínez J, Llorente-Pendás JL. (2020). Application of wireless Contralateral Routing of Signal (CROS) technology in unilateral cochlear implant users. Acta Otorrinolaringol Esp (Engl Ed), 71(6):333-342. doi: 10.1016/j.otorri.2019.10.004. PMID: 32192730.

References

10. Stronks HC, Briaire JJ, Frijns JHM. (2022). Residual hearing affects contralateral routing of signals in cochlear implant users. Audiol Neurootol, 27(1):75-82. doi: 10.1159/000515210. PMID: 33849023.
11. Hoshino ACH, Goffi-Gomez MVS, Sierra PAS, Agrawal S, Rodriguez C, Carvalho ACM, Tsuji RK. (2022). Can the use of the CROS system provide head shadow effect contribution to unilateral cochlear implant users? Codas, 34(5):e20210071. doi: 10.1590/2317-1782/20212021071. PMID: 35385028.
12. Johnson K, Jeon EK, Dwyer R, Agrawal S, Gurgel R. (2025).The effect of Contralateral Routing of Signal devices on the quality of life of unilateral cochlear implant recipients and their frequent communication partners. Am J Audiol, 8:1-12. doi: 10.1044/2024_AJA-24-00129. Epub ahead of print. PMID: 39772865.
13. Johnson, K., Jeon, E.K., Dwyer, R., Agrawal, S., & Gurgel, R. (2025). The effect of Contralateral Routing of Signal devices on Quality of Life of unilateral cochlear implant recipients and their frequent communication partners. American Journal of Audiology, 1-12.
14. Mosnier I, Mathias N, Flament J, Amar D, Liagre-Callies A, Borel S, Ambert-Dahan E, Sterkers O, Bernardeschi D. (2017) Benefit of the UltraZoom beamforming technology in noise in cochlear implant users. Eur Arch Otorhinolaryngol, 274(9):3335-3342
15. Advanced Bionics (2016) Bimodal StereoZoom Feature: Enhancing Conversation in Extreme Noise for Unilateral AB Implant Recipients White Paper.

References

16. Morera C., Manrique M., Ramos A., Garcia-Ibanez L., Cavalle L., Huarte A., Castillo C., and Estrada E. (2005). Advantages of binaural hearing provided through bimodal stimulation via a cochlear implant and a conventional hearing aid: A 6-month comparative study. Acta Oto-Laryngol, 125: 596–606.10.1080/00016480510027493

17. Flynn MC, Schmidtke T. Benefits of bimodal stimulation for adults with a cochlear implant. (2004). International Congress Series,1273: 227–230.

18. Veugen LC, Chalupper J, Snik AF, van Opstal AJ, Mens LH. (2016) Matching automatic gain control across devices in bimodal cochlear implant users. Ear and Hearing, 37: 260-270.

19. Chalupper J, Agrawal S, Fredelake S, Spahr T. (14-19 July 2013). Rationale and implementation of a bimodal fitting formula. Presented at the Conference on Implantable Auditory Prostheses, Lake Tahoe, CA. Figshare: http://dxdoiorg/106084/m9figshare1340020 2015.

20. Auletta, G., Franze, A., Laria, C., Piccolo, C., Papa, C., Riccardi., P. Pisani, D., Sarnelli, A., Del Vecchio, V., Malesci, R., & Marciano, E. (2021). Integrated bimodal fitting for unilateral CI users with residual contralateral hearing. Audiology Research, 11(2), 200-206.

Wireless Connectivity

Overview

Carrie Spangler, Au.D.,

*Product and service availability varies by region.

A Sonova brand

D000038183 RevA

Wireless Connectivity

Marvel CI and Link M

Phonak Naída™
Link M
hearing aid

Phonak Sky™
Link M
hearing aid

Wireless Connectivity

Streaming signals

Noahlink wireless,
AB apps,
and Phonak
RemoteControl

Binaural VoiceStream
Technology™ Features

Bluetooth LE

Bluetooth Classic

Streamed phone calls;
Streamed media speech
and media music

Roger microphones

Roger™

AirStream™

TV Connector and
PartnerMic

AB recipients have access to fully integrated streaming technology that directly streams music, media, phone calls, and TV for an enhanced listening experience.

Bluetooth

Integrated Bluetooth

For ultimate ease of use, AB & Phonak devices can connect to **any** Bluetooth devices for calls or streaming!

AB recipients can connect wirelessly to Android and iOS devices without restrictions, as well as smartphones, tablets, laptops, and more!

Wireless Connectivity

Bluetooth

Two types of Bluetooth protocols:

Bluetooth Low-Energy (LE)

Bluetooth Classic

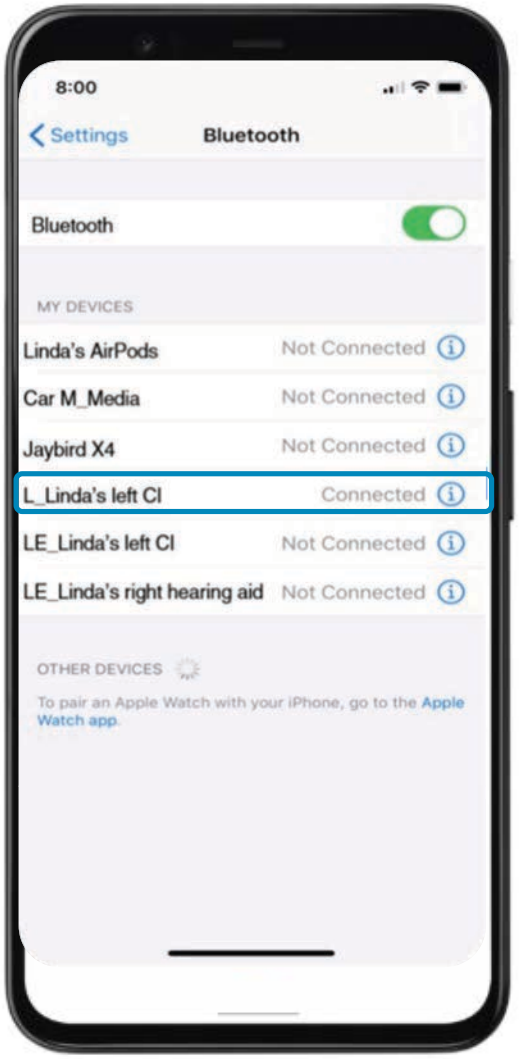
Wireless Connectivity

Bluetooth Phone Calls

Bluetooth phone calls stream directly to sound processor and/or hearing aid.

Own Voice Pickup uses the microphone on the hearing instrument to pick up the recipient's voice to provide hands-free phone calls.

Bluetooth pairing to phone



Pro Tip: When a bilateral or bimodal recipient is pairing to a Bluetooth phone, only one hearing instrument needs to be paired.

Julie H.

AB Recipient

The testimonials, statements, and opinions depicted reflect the opinions and experiences of the individual. They have been voluntarily provided and are not paid, nor were they provided with any products, services or benefits in exchange for the statements. Exact results will be unique and individual to each patient. If you have specific questions regarding your cochlear implantation, please contact your surgeon directly. This product may not be approved in your region. Please check with your local AB representative.

Knowledge Check

Louise has bilateral sound processors. She stays in touch with her grandkids using FaceTime on her iPad. She wants to hear her grandkids in both CIs.

When she is pairing her CIs to Bluetooth on her iPad, what does she need to pair to?

A. One hearing instrument

B. Both hearing instruments

C. Pairing is not required

Phonak Roger™ Technology

Wireless Connectivity

RogerDirect

Advanced Bionics CI and RogerDirect
combine the best of two worlds and offer
outstanding performance in every situation.

Marvel CI is the world's first ear-level cochlear implant sound processor to support an integrated Roger receiver with RogerDirect*!

*The Roger receiver needs to be installed into the hearing instrument.

RogerDirect

With RogerDirect, accessing Roger technology is easier than ever before!

RogerDirect is an industry-first technology to allow Roger iN microphones* to stream directly to the sound processor(s) and/or hearing aid without having to attach an external receiver.

*Product availability varies by region.

Wireless Connectivity

RogerDirect

Recipients can stream Roger to their processor inside the waterproof battery.

This allows recipients to experience the benefits of Roger while participating in sports, playing in the sand, working in the yard, and swimming!

Wilder Roberts, Au.D.

University of South Alabama

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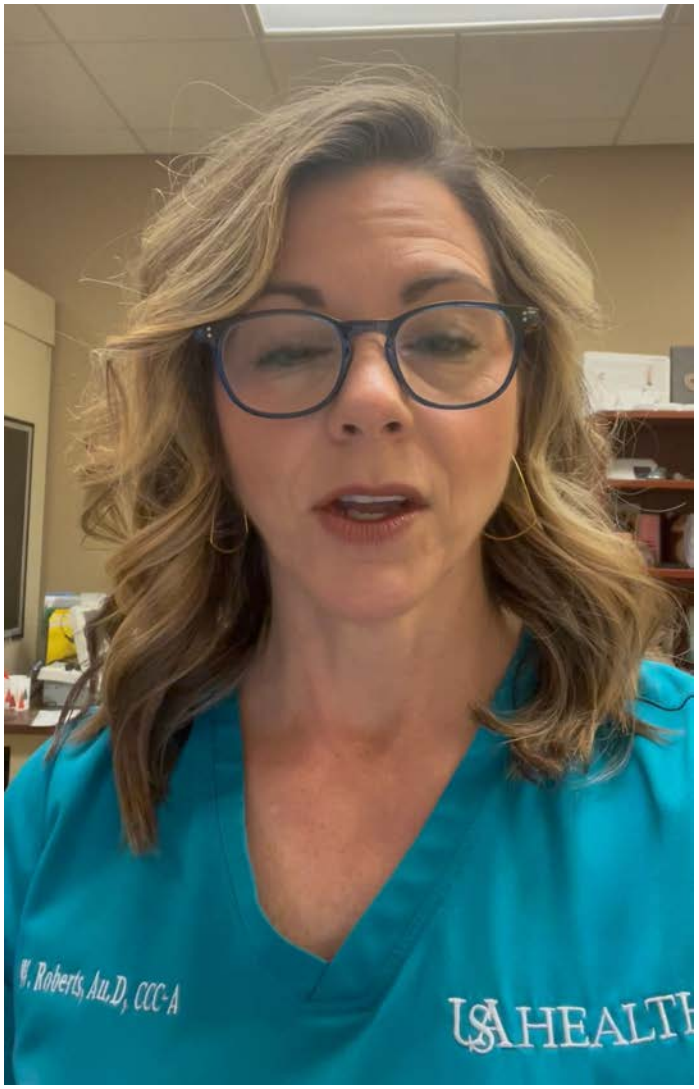


Knowledge Check

What are some advantages of using Roger for children?

A. Installation of Roger receivers for home and school in the same device

B. Ability to use Roger and waterproof battery simultaneously

C. Fully integrated without external receivers to take on and off

D. All of the above

AirStream

AirStream

AirStream™ is a Sonova Proprietary 2.4 GHz streaming protocol that provides high quality stereo audio signals.

Phonak TV Connector and PartnerMic both use this proprietary streaming protocol.

Phonak TV Connector

Phonak TV Connector is a simple plug and play interface for TVs and other audio sources.

An unlimited number of compatible devices can be connected to the TV Connector at the same time.

In households with more than one recipient with compatible devices, all recipients can connect to the same TV Connector.

Pro Tip: Recipients do not need to adjust the volume setting every time they use the TV Connector. Volume settings remain stored even after powering off the TV Connector.

Phonak PartnerMic

PartnerMic mic improves the signal-to-noise ratio over short distances and in moderate levels of noise, making it perfect for one-on-one conversations.

It is easy to use and will always be directional regardless of the microphone orientation.

Knowledge Check

Your patient is a bimodal simplest and her husband uses Phonak hearing aids. They would like to stream the TV to all four devices. What would be the simplest solution?

A) Purchase a Bluetooth TV

B) Roger transmitters

C) Phonak TV Connector

D) Telecoil

Binaural VoiceStream Technology™ Features

Wireless Connectivity

Binaural VoiceStream Technology

Binaural VoiceStream Technology (BVST) features provide full audio streaming between hearing instruments.

BVST allows bilateral and bimodal recipients to:

- Change programs and volume on both devices with one touch.
- Focus on conversation in a noisy situation with less listening effort.
- Hear phone calls in both ears.

Phonak RemoteControl

Wireless Connectivity

Phonak RemoteControl

Provides basic controls

Adjust volume and program settings

Simple

Great for non-smartphone users and recipients with limited dexterity

Digital Solutions from AB

Wireless Connectivity

Comprehensive Digital Solutions

Wireless Connectivity

AB apps

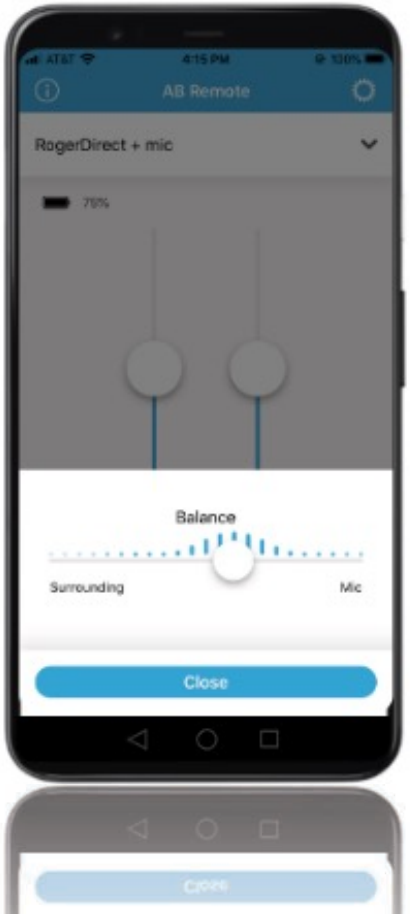
Discretely adjust volume, program, and other settings.

Participate in programming appointments from the comfort of their own homes via Remote Programming.

Take an active role in their hearing journey by tracking progress over time.

While streaming via Bluetooth, Roger, or AirStream, the environmental balance can be adjusted on the processor using the multifunction button or with the AB Remote mobile app.

Recipients can remove distractions from the environment or focus more on streaming without turning the volume up on the device.

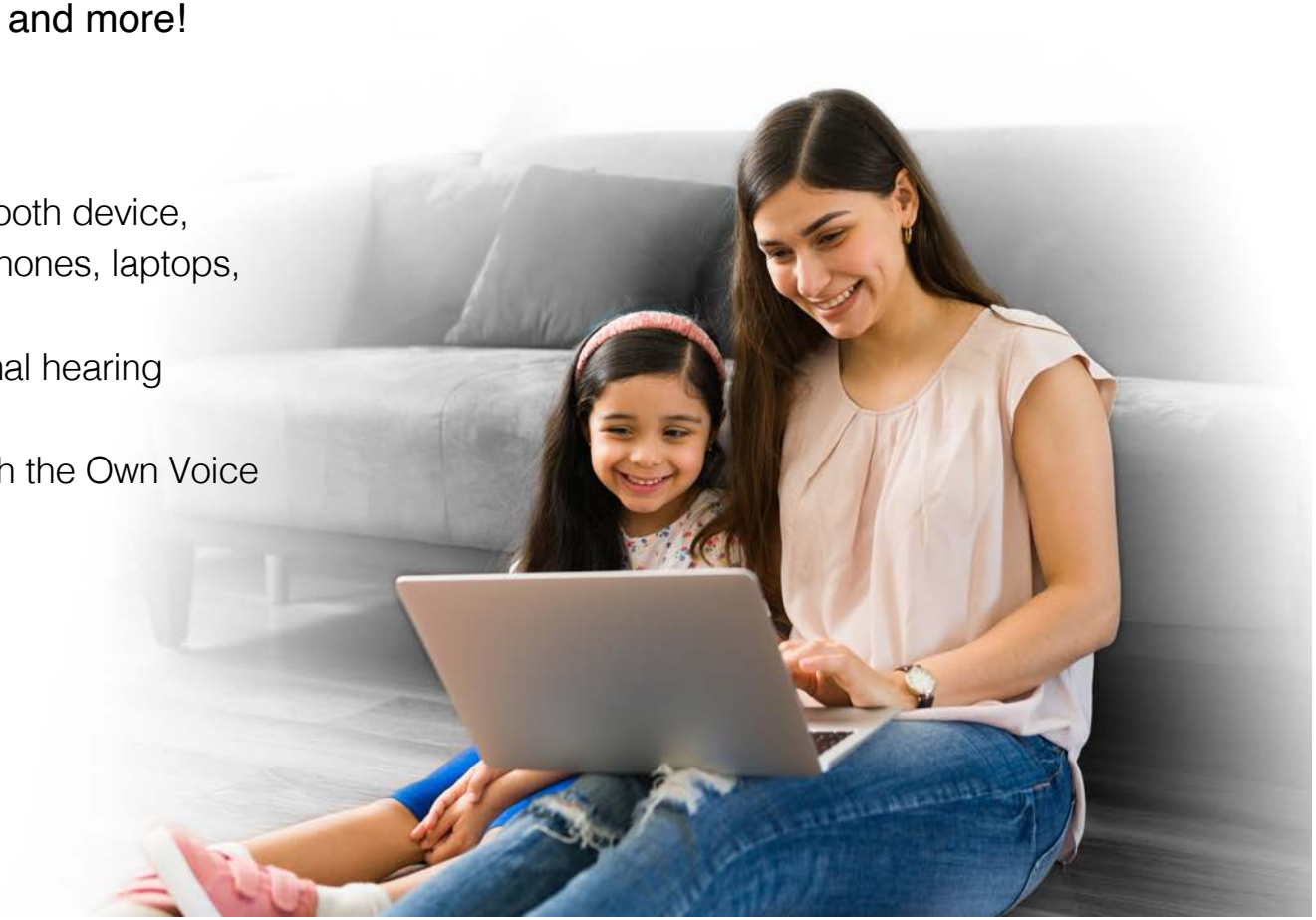


Wireless Connectivity

Connect to smartphones, TV, and more!

AB recipients can

- Stream audio from any Bluetooth device, including iOS and Android phones, laptops, tablets, and more!
- Stream to both ears for optimal hearing performance
- Conduct hands-free calls with the Own Voice Pickup feature



Understanding Patient Preferences in CI Selection

Independent research has shown:

Audiologist recommendations shape patient choices

Technology is one of the primary factors

Enhanced patient education could improve decision confidence and retention

Freeman et al., 2025

Poll Question

Jim L.

AB Recipient

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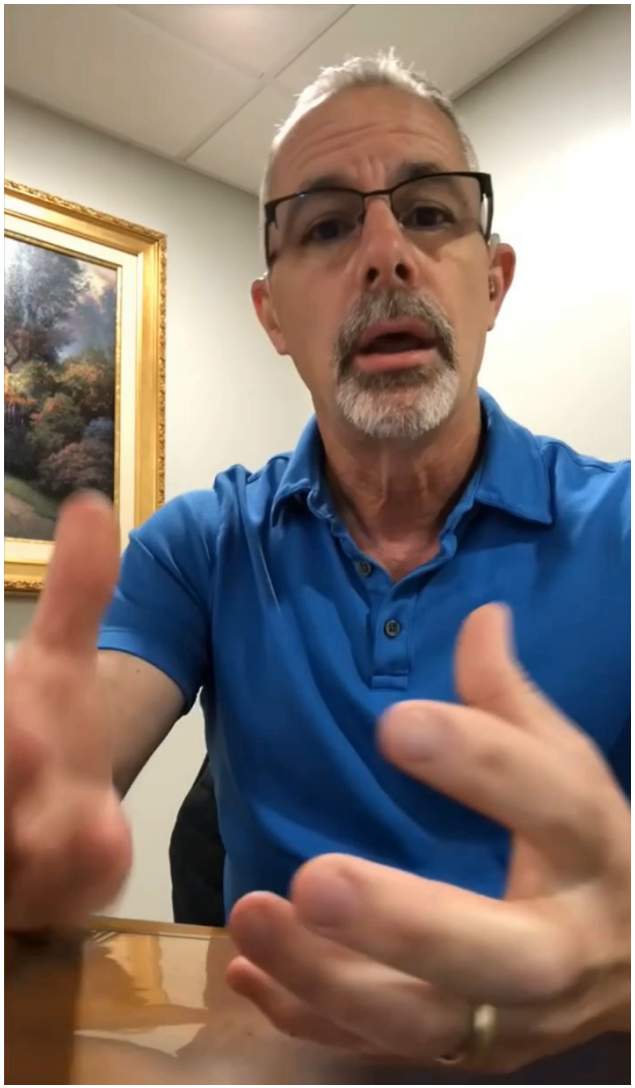


References

1. Wolfe J, Schafer E Agrawal S, Koch, D (2015). Evaluation of Speech Recognition of Cochlear Implant Recipients Using Adaptive, Digital Remote Microphone Technology and a Speech Enhancement Sound Processing Algorithm. Journal of the American Academy of Audiology.

Marvel CI
CLINICAL TOOLS

ADVANCED BIONICS
POWERFUL CONNECTIONS

Table of Contents

Our Commitment

At Advanced Bionics, our commitment to putting patients first and providing the best possible hearing performance remains at the forefront of what we do. We are honored to have the opportunity to help those with hearing loss enjoy a life without limitations. Marvel CI offers your patients a powerful hearing experience with excellent sound quality in a variety of situations and comes with built-in connectivity solutions. Target CI fitting software is designed for easier, faster, and smarter fittings. It provides a streamlined workflow for a more efficient fitting experience. Remote Programming offers Marvel CI recipients the ability to experience complete programming sessions from a distance.

To fulfill this commitment, we have a dedicated team to support your needs. Please contact your local Advanced Bionics representative who will be glad to assist. We offer:

- CLINICAL SUPPORT: AUDIOLOGICAL, SURGICAL AND REHABILITATIVE
- CUSTOMER SERVICE

Marvel CI
SOUND PROCESSOR

HiRes™ Ultra 3D
COCHLEAR IMPLANT

Phonak Link M
HEARING AID

Phonak CROS P-13
DEVICE

For more information and online resources, please visit
AdvancedBionics.com/MarvelCI

Marvel CI
QUICK REFERENCE GUIDE

Marvel CI sound processors (Naída CI M90, Naída CI M30 and Sky CI M90) offer your patients a powerful hearing experience with excellent sound quality in a variety of situations and comes with built-in connectivity solutions. This guide provides the basic information needed to get started with the fitting, maintenance and troubleshooting.

COMPATIBILITY

Marvel CI sound processors are programmed in the Advanced Bionics Target CI fitting software and are compatible with the following implant types: HiRes Ultra 3D, HiRes Ultra, HiRes 90K Advantage, HiRes 90K and CII.

PRODUCT HIGHLIGHTS

- AutoSense OS™ 3.0 operating system automatically senses the surroundings and adjusts the signal processing to provide optimum clarity and comfort in different listening situations.
- Integrated Bluetooth® and RogerDirect technology allow recipients to stream audio and media wirelessly from their favorite devices. Recipients can stay connected with loved ones with truly hands-free phone calls.
- Unique ergonomic processor and headpiece design for a discreet, comfortable, and secure fit.
- M Waterproof Battery ideal for swimming and outdoor activities.
- Remote programming allows hearing care professionals to provide complete programming sessions in the recipient's own environment.

COMPONENTS

1. M T-Mic™ microphone with cover
2. Sound processor
3. Front microphone
4. Multi-function button with status LED
5. Back microphone
6. M Battery
7. Slim HP with integrated cable

Listening Need	Short Press (< 2 seconds)	Long Press (> 2 seconds[1])
Standard listening	Volume up or down	Program change[2]
During Audio Streaming	Streaming volume up or down	Program change
During Phone Calls	Accept phone call (while ringing) or phone call volume up or down (during call)	Reject phone call (while ringing) or end phone call (during call)

Remote Control Options

For convenient and discreet device management, the AB Remote app, myPhonak app, or myPhonak Junior app allows the recipient to make program and volume adjustments effortlessly. The AB Remote app also helps to perform a simple device check.

1. Pressing the button up or down has the same function.
2. When the multi-function button is used to change programs, whether pressing the top or the bottom part of the rocker, the programs toggle forward. To go backwards, please use the AB Remote app or toggle through the sequence.

Indicator Light (LED) Guide

The indicator light is a programmable feature that provides visual information about the sound processor status, battery life, program position, and sound processor error conditions.

Color	Behavior	Programmable	Indication
	AutoSense: 1 long green blink Program 1: 1 short green blink Program 2: 2 short green blinks Program 3: 3 short green blinks Program 4: 4 short green blinks	Yes	Program Change
	Blinks during use in response to loud input	Yes	Microphones are responding to loud sound
	3 green blinks upon command by fitting software or AB Remote app	No	Detect sound processor
	1 purple blink	Yes	Progressive level change, if enabled
	Blue blinking while streaming audio/media	Yes	Receiving streaming information
	One long orange blink at start-up after battery and program status	No	Flight mode
	Orange blinking	No	Battery status at start-up: 1 orange blink < 20% 2 orange blinks 20-49% 3 orange blinks 50-84% 4 orange blinks 85%+
	Continuous orange blinking	Yes	Low battery
	Solid red	No	Start-up issue/error
	Blinking red, faster than once per second	No	Wrong implant detected
	Blinking red, once per second after start-up	Yes	No lock to implant

CARE AND MAINTENANCE

Daily care and proper use of the sound processor and accessories will result in optimal function over time. Wipe the sound processor and components with a soft dry cloth. Do not immerse, or use solvents e.g. soap. Store the sound processor in the drying case every night. The M T-Mic covers should be replaced at regular intervals.

TROUBLESHOOTING

The checklist below and the AB Remote app will help to systematically troubleshoot the device.

- Perform a device check with the AB Remote app
- Check the indicator light
- Try a different program
- Try a different fully charged battery
- Listen to the device with the M Listening Check
- Check and change the Slim HP
- Check other equipment, e.g., charger, etc.
- Check and change the sound processor

FOR MORE INFORMATION

Refer to the Marvel CI User Guide. Refer to the AB website for wireless technology. For North America, refer to myABonline.com. Check with local AB representative for regulatory approvals and product availability in your area.

Slim Headpiece
QUICK REFERENCE GUIDE

The Slim HP offers comfort and convenience with a low profile design. This guide provides the basic information needed to get started with the fitting, counseling and maintenance of the headpiece.

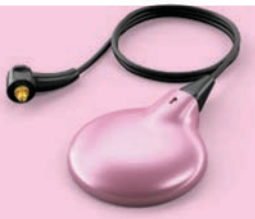
COMPATIBILITY

Implants: HiRes Ultra 3D, HiRes Ultra, HiRes 90K Advantage, HiRes 90K and CII.
Sound processors: Naída CI M90, Naída CI M30, Sky CI M90, Naída CI Q Series and Neptune (compatible with Slim HP AquaMic only).

HEADPIECE OPTIONS

SLIM HP

- No microphone.
- For sound processor on-the-ear use.



SLIM HP MIC

- Integrated microphone.
- For sound processor off-the-ear use.

SLIM HP AQUAMIC

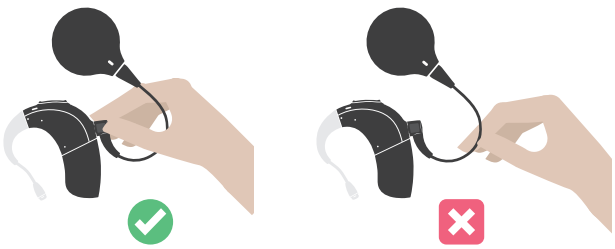
- For use with the M Waperproof Battery for complete protection against moisture, dust.
- Integrated waterproof microphone (water droplet icon on the underside).

COMPONENTS

1. Magnet well
2. 3D Magnet (**BLUE**), Standard Magnet (**BLACK**)
3. Headpiece microphone *(Only available on selected models)*
4. Headpiece cable connector with integrated cable
5. Processor cable connector
6. Color cap
7. Color cap removal tool

OPERATING INSTRUCTIONS

Always hold the cable's strain relief when attaching and removing the headpiece cable from the sound processor.

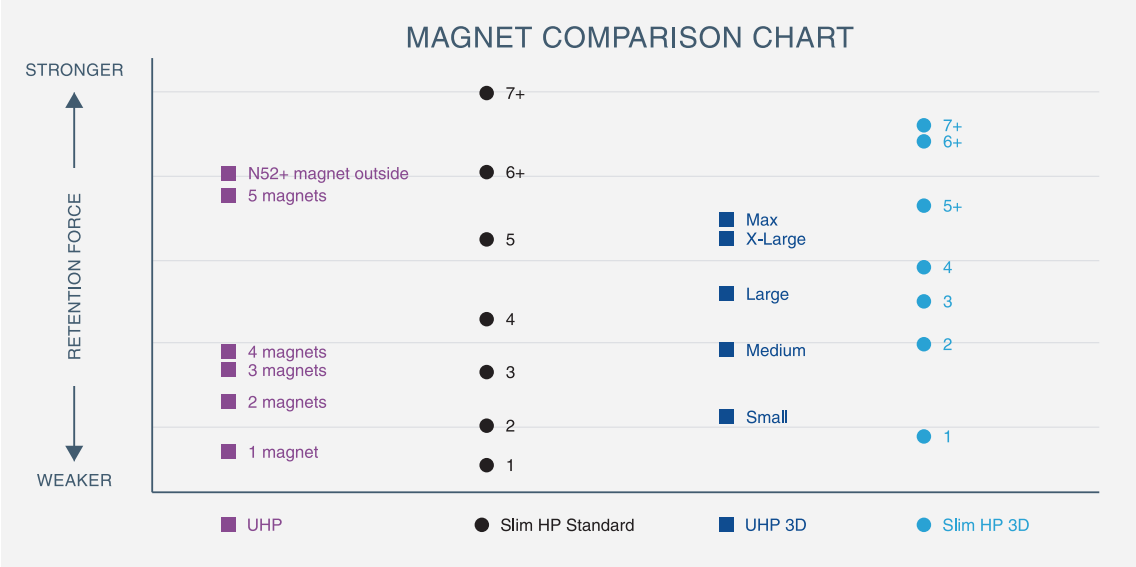


The arrow on the underside indicates the inlet where the removal tool should be inserted to remove the color cap.

MAGNET SELECTION GUIDE

The CI professional is responsible for evaluating the headpiece magnet strength. It is important to use the appropriate magnet strength to avoid discomfort or retention issues. If magnet strength is insufficient, the headpiece may fall off. If magnet strength is excessive, the user may experience irritation or discomfort.

- Slim HP 3D Magnets are **BLUE** for HiRes Ultra 3D implants. The arrow on top of the 3D magnet indicates the direction for alignment: ensure the arrow points up when the Slim HP with 3D magnet is on the recipient's head.
- Slim HP Standard Magnets are **BLACK** for HiRes Ultra, HiRes 90K Advantage, HiRes 90K and CII implants.
- Magnets are labeled from 1 to 7, corresponding to their magnetic strength.
- Insert the appropriate magnet into the magnet well. Ensure the magnet strength number is facing the underside of the Slim HP i.e. towards the patient's implant.



SLIM HP COLOR CAPS

There are two sizes of Color caps that can be used with the Slim HP, Slim HP Mic, and Slim HP AquaMic: **Standard** and **Large**. The Large Color caps are required for strongest magnet strengths (Standard Magnet sizes 6+ and 7+ and 3D Magnet sizes 5+, 6+ and 7+). These stronger magnets are **not recommended for children ages 3 years and younger**, as these color caps and magnets may become displaced if dropped.

CARE AND MAINTENANCE

Daily care and proper use of the sound processor and headpiece will result in optimal function over time. Wipe the sound processor and headpiece with a soft dry cloth and store the sound processor with the headpiece in the equipment case. Use the AB Remote app or M Listening check to troubleshoot and/or assess the microphone sound quality.

Following use of the Slim HP AquaMic in water, rinse the Slim HP AquaMic with clean water. Remove the color cap, wipe the headpiece upper surface with a soft cloth. Place in an appropriate drying system to dry completely overnight.

FOR MORE INFORMATION

Refer to the sound processor and headpiece instructions. For North America, refer to myABonline.com. If further support or information regarding product availability is required, please contact your local AB representative.

Marvel CI
PROGRAMMING GUIDE

Designed for easier, faster, and smarter fitting, Target CI provides an intuitive and streamlined workflow for a more efficient fitting experience.

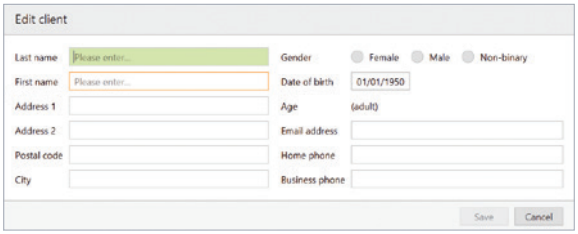
FITTING HARDWARE

Marvel CI processors are programmed in Target CI fitting software, using either the Noahlink Wireless or CPI-3 programming interface.

FITTING GUIDE

Open Target CI and follow the steps below to navigate a **unilateral CI fitting.** Work through the tabs from left to right to complete the required fitting steps.

1. CREATE THE CLIENT FILE



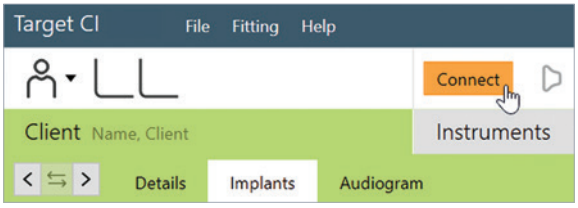
For a New client

- Select *New client*. Enter the client details and *Save*.
- Select *New session* to open a new fitting session.[1]

For an Existing client

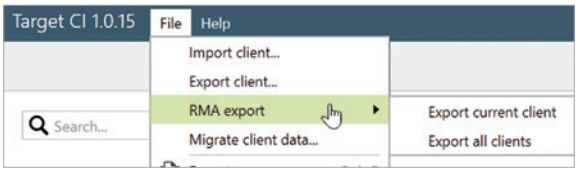
- Search and select the client's file; then, click *Open session*.[2]
- Remote Programming is available for follow-up programming sessions.

2. CONNECT TO THE HEARING INSTRUMENT



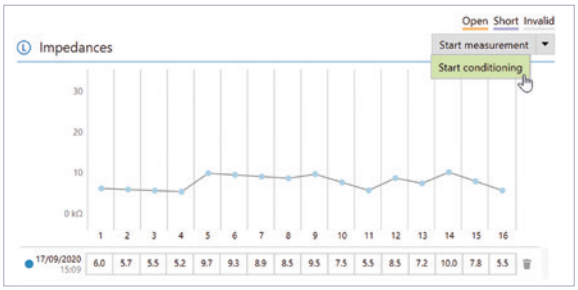
- Connect to the hearing instrument via Noahlink Wireless, CPI-3, or Remote Programming.
- When programming wirelessly, ensure that a fully charged rechargeable battery is used. Remove and re-attach the battery to put the sound processor into pairing mode. Click the *Connect* button within the 3-minute pairing window.
- Verify the side for which the device is intended to be used.
- Once device connection is successful, *Close* to proceed.

3. CONNECT TO THE INTERNAL DEVICE



- Place the headpiece on the recipient's head to achieve lock with the implant.
- For a new client, create a new implant record by clicking on the implant icon and following the prompts to add a new implant.
- Add the required implant information; then, select *Save*.

4. MEASURE IMPEDANCES AND NEURAL RESPONSE IMAGING (NRI)



- Under *Client* access the *Impedance* tab to run impedances and conditioning.
- Access the *NRI* tab to measure NRI, if desired.

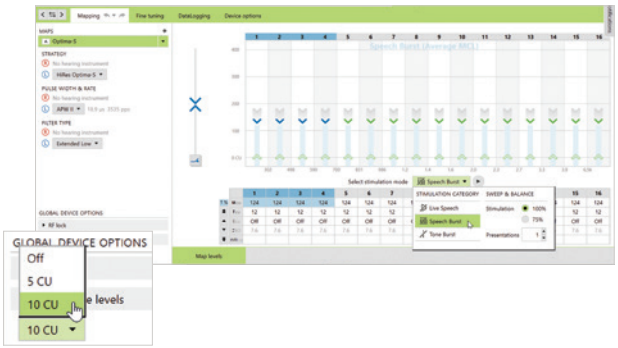
5. SELECT THE ATTACHMENTS

- Under the *Instruments* tab, go to *Acoustic parameters* and ensure that T-Mic/Standard is selected as the appropriate attachment.

1. Always enter the client's ***Date of birth*** so that the appropriate default settings can be applied.
2. Open session should be used at all follow-up visits to allow access to past impedance and NRI data.

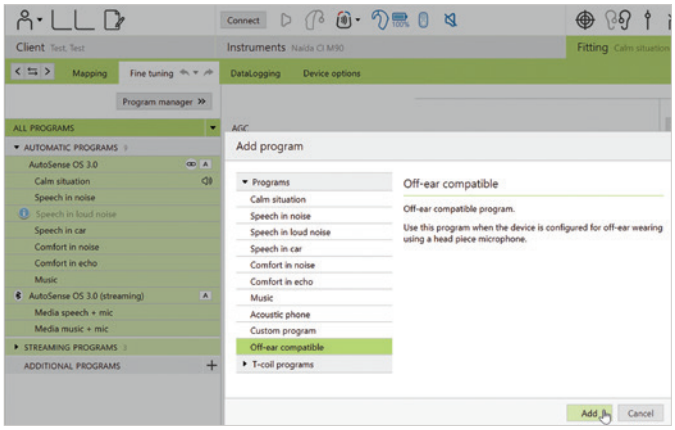
6. CREATE A MAP

- Under *Fitting*, access the *Mapping* tab to set the appropriate map parameters i.e. stimulation strategy, pulse width, etc.
- Select the *Stimulation mode* type to measure M-Levels. T-Levels will default to 10% of the set M-Levels.
- To start and stop stimulation, click the play button, or the "unmute" and "mute" control in the dashboard or press the *F-key*.
- Verify comfort using *Live Speech stimulation*.
- If desired, create progressively louder levels under *Global device options*.[3]



7. FINE TUNING

- *AutoSense OS™ 3.0* operating system offers one easy-to-use automatic program that senses the recipient's listening environment and adjusts the device automatically.
- Confirm settings for the *AutoSense OS* program, as desired.
- Add any *Additional programs [+]*, if required, based on the recipient's unique listening needs. For example, select *Off-ear compatible* for off-ear device usage with the headpiece microphone active.
- Confirm settings in the *Map options* tab, as desired.[4]
- Access the *Program options* tab to fine tune individual programs further, if desired.[5]



8. MANAGE DEVICE OPTIONS

- Access the *Device options* tab to manage Manual controls, Bluetooth®, Signals & alerts, Indicator light, Startup and Datalogging, as needed, based on each recipient's unique preferences.
- For ease of discovering the device during Bluetooth pairing, access the *Bluetooth* tab and label each side with the recipient's name.

9. SAVE AND CLOSE THE SESSION

- Select *Save & close session* to finalize the fitting session.
- Run and review the sound processor *Battery estimation*, if desired.
- Add any notes to the fitting session, if desired.
- Follow the prompts to *Save* the fitting session to the Hearing instruments and/or the Database.
- Select *Close* to complete the fitting session.

If further support is required, please contact your local Advanced Bionics representative.

3. The recipient can adjust the progressive level using the multi-functional button or the AB Remote app.
4. IDR, ClearVoice and SoftVoice settings are applied to all automatic programs and streaming programs.
5. Microphone mode and comfort features can be adjusted in the Program options tab for each individual program, if desired.

Performing NRI in Target CI
PROGRAMMING GUIDE

Neural Response Imaging (NRI) is a valuable tool used by hearing care professionals to obtain an objective measurement of the electrically-evoked compound action potential (eCAP) which can assist with intra-operative testing and post-operative cochlear implant programming. This guide provides the basic information needed to get started with performing NRI in Target CI.

FITTING HARDWARE

NRI can be performed in Target CI fitting software using a Marvel CI sound processor and either the Noahlink Wireless or CPI-3 programming interface. NRI can be conducted during a Remote Programming session also.

PERFORMING NRI MEASUREMENTS

1. OPEN TARGET CI

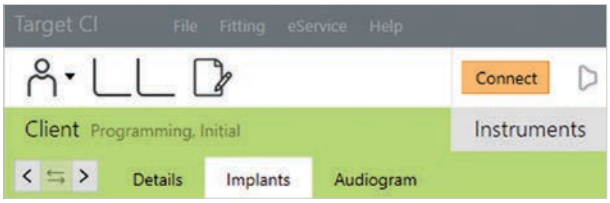
2. ACCESS THE CLIENT FILE AND OPEN A FITTING SESSION

For a New client:

- Select *New client*. Enter the client details[1] and *Save*.
- Select *New session* to open a new fitting session.

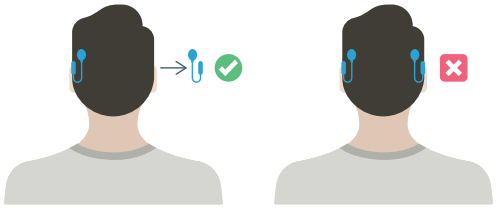
For an Existing client:

- Search and select the client's file; then, select *Open Session*[2].



3. CONNECT TO THE HEARING INSTRUMENT

- Connect to the hearing instrument via Noahlink Wireless, CPI-3, or Remote Programming.
- When programming wirelessly, ensure that a fully charged rechargeable battery is used. Remove and re-attach the battery to put the sound processor into pairing mode. Select the *Connect* button within the 3-minute pairing window.
- Verify the side for which the device is intended to be used.
- Once device connection is successful, *Close* to proceed.



4. CONNECT TO THE INTERNAL DEVICE

- Place the headpiece on the recipient's head to achieve lock with the implant.
- For a new client, create a new implant record.
- Remove the contralateral sound processor[3] prior to running NRI (if applicable). Otherwise, excessive noise will be observed in the NRI tracing.

5. REVIEW IMPEDANCES

- Under *Client*, access the *Impedance* tab to review impedances and run conditioning, if desired.
- Only run NRI on electrodes with normal impedances[4].

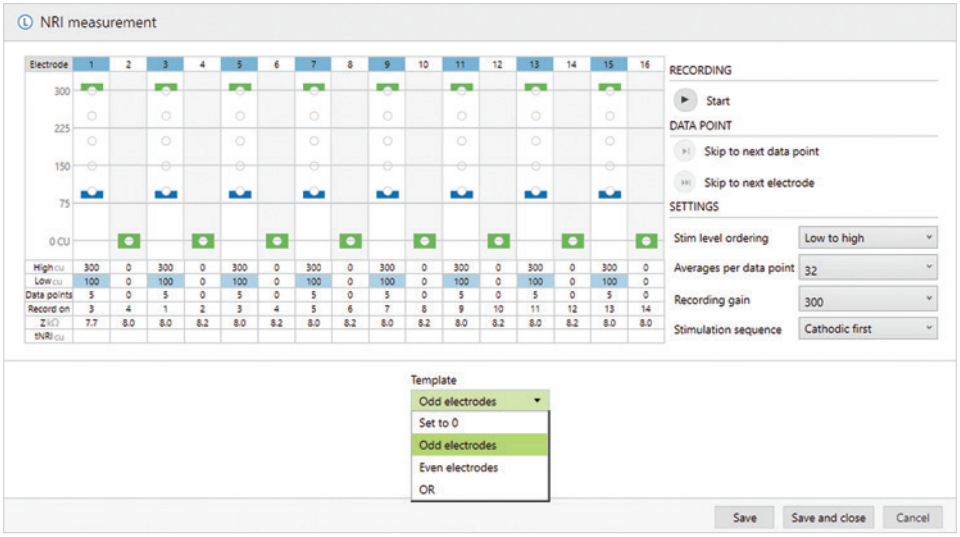
6. ACCESS NEURAL RESPONSE IMAGING (NRI)

- Under *Client*, access the *NRI* tab to measure NRI[5].
- Select *New measurement* to open the NRI measurement window.

1. Always enter the client's Date of birth so that the appropriate default settings can be applied.
2. Open session should be used at all follow-up visits to allow access to past impedance and NRI data.
3. It is okay for the recipient to wear contralateral hearing aid during NRI measurements.
4. Do not perform NRI on extra-cochlear, shorted, open, or out of compliance electrodes.
5. Due to probable impedance changes after surgery, it is best to re-run NRI in the clinic prior to creating new maps for the recipient instead of using NRI data collected in the OR.

7. DETERMINE ELECTRODES TO MEASURE

- Select a template, if desired.



- NRI template settings are automatically applied based on the recipient's age.

Adult NRI Templates

ODD ELECTRODES	EVEN ELECTRODES	OR	SET TO 0
Electrodes: 1, 3, 5, 7, 9, 11, 13, & 15 Low CU = 100 High CU = 300 Data points = 5 Stim Level Ordering = Low to high	Electrodes: 2, 4, 6, 8, 10, 12, 14, & 16 Low CU = 100 High CU = 300 Data points = 5 Stim Level Ordering = Low to high	Electrodes: 3, 7, 11, & 15 Low CU = 150 High CU = 400 Data points = 5 Stim Level Ordering = High to low	Electrodes: 1 – 16 Low CU = 0 High CU = 0 Data points = 0 Stim Level Ordering = Low to high

Pediatric NRI Templates

ODD ELECTRODES	EVEN ELECTRODES	OR	SET TO 0
Electrodes: 1, 3, 5, 7, 9, 11, 13, & 15 Low CU = 50 High CU = 250 Data points = 5 Stim Level Ordering = Low to high	Electrodes: 2, 4, 6, 8, 10, 12, 14, & 16 Low CU = 50 High CU = 250 Data points = 5 Stim Level Ordering = Low to high	Electrodes: 3, 7, 11, & 15 Low CU = 150 High CU = 400 Data points = 5 Stim Level Ordering = High to low	Electrodes: 1 – 16 Low CU = 0 High CU = 0 Data points = 0 Stim Level Ordering = Low to high

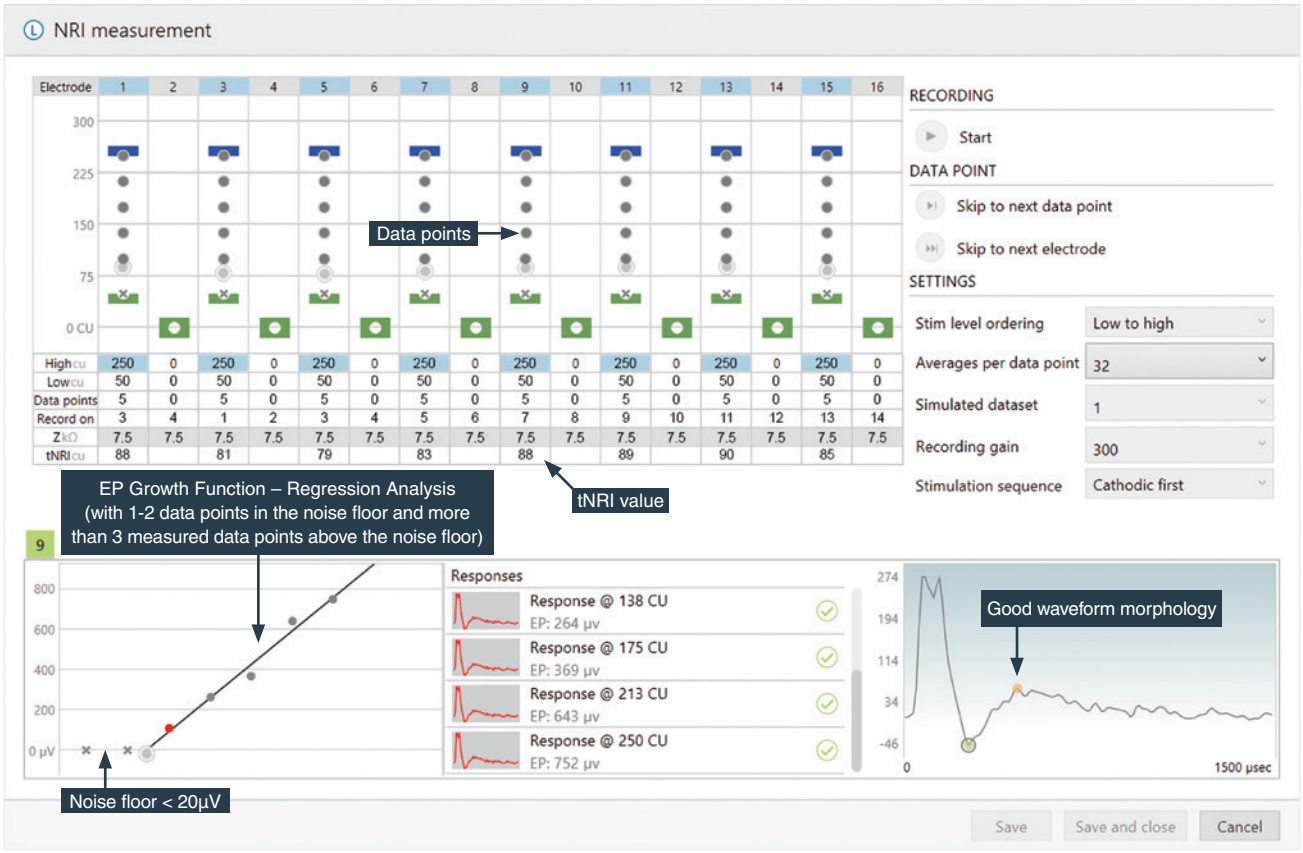
8. ADJUST NRI SETTINGS, IF DESIRED

- Set High and Low CU values for electrode(s) to be measured.
  - Behavioral M-Levels can be used as a guide to establish initial low and high CU values.
  - A minimum range of 150 – 200 CU should be considered where the low CU value results in one or two responses within the noise floor.
- Choose number of *Data points*, as appropriate.
  - Target CI will populate 5 data points by default; however more can be added, as needed.
  - Unmeasured data points are indicated by an open circle. Filled data points indicate a completed measurement.
- Choose the appropriate *Stim Level Ordering*.
  - Select Low to High for use in the clinic.
  - Select High to Low for use in the operating room.

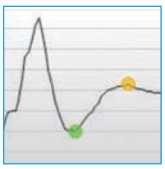
9. SELECT START

- NRI will continue to conduct measurements until all data points have been obtained.
- When measuring NRI post-operatively, monitor the recipient for signs of discomfort while NRI is running to ensure stimulus levels are not exceeding the recipient's comfort levels.
- Press *Pause* or the *F-key* to stop running a measurement at any time.

10. NRI ANALYSIS

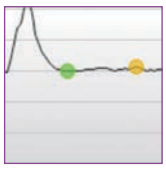


GOOD RESPONSE



- It is important to obtain 1-2 data points within the noise floor and a minimum of 3-4 data points rising from the noise floor for an accurate calculation of tNRI.
- Confirm accuracy of selected N1 and P2 peaks for each waveform. N1 and P2 latencies will remain stable with increased stimulation levels.

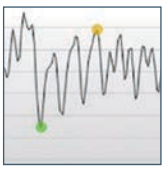
NO RESPONSE



If there is no visible response:

- Increase the stimulation level (up to levels of compliance), while monitoring recipient for comfort.
- Use a different recording electrode to measure the NRI response.

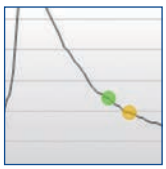
NOISY RESPONSE



If waveform tracing appears noisy:

- For bilateral recipients, confirm that the contralateral processor is removed.
- Increase the number of Averages per data point.

RESPONSE WITH ARTIFACT



If artifact is present, use a different recording electrode to measure the NRI response.

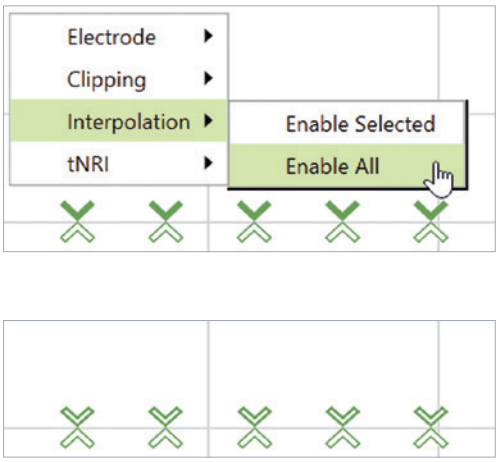
- Verifying correct tNRI values prior to saving and closing the session will ensure correct tNRI values are calculated.
- To repeat measurements in future sessions, use the copy setting function, as shown below.

11. SAVE NRI MEASUREMENT

- *Save and close* the NRI measurement.

FITTING GUIDE

1. CREATE A MAP USING NRI DATA



tNRI markers are displayed in the Mapping tab by default.

- Access the *Fitting* tab to begin the fitting process.
- In the *Mapping* tab, right-click on any channel and select *Interpolation*; then, *Enable all*. All markers will change to unfilled or open arrows.
- On channels with measured tNRI, set M-Levels to tNRI values.
- Confirm *Live Speech* as the stimulation mode.
- Globally reduce the M-Levels slightly to ensure recipient comfort and *Start stimulation*.
- Gradually increase M-Levels to find recipient's most comfortable level (level 6 on the loudness scale).
- Consider loudness balancing across each electrode.
- Verify settings (i.e. Ling Sounds, soundfield detection, etc.).

2. FINALIZE THE FITTING SESSION

- Continue with fitting process by managing program settings in *Fine Tuning Tab*.
- *Save and close* the fitting session.

NEURAL RESPONSE IMAGING (NRI) RESOURCES

- Koch, D. B., Overstreet, E.H. (2003). Neural Response Imaging: Measuring Auditory-Nerve Responses from the Cochlear with the HiResolution™ Bionics Ear System. Advanced Bionics White Paper.
- He, S., Teagle, H., Buchman, C. (2017). The Electrically Evoked Compound Action Potential: From Laboratory to Clinic. *Frontiers in Neuroscience*, Volume 11, Article 339.
- Hughes, M., Audiology Online. *Fundamentals of Clinical ECAP Measures in Cochlear Implants Part 2: Measurement Techniques and Tips.*

Marvel CI Upgrade
PROGRAMMING GUIDE

This guide provides the fitting steps needed to upgrade an existing recipient to Marvel CI.

FITTING HARDWARE

Marvel CI sound processors are programmed in the Target CI fitting software, using either the Noahlink Wireless or CPI-3 programming interface.

FITTING GUIDE

When migrating client data from SoundWave 3.2 to Target CI, it is recommended that individual client files be migrated at the time that each recipient chooses to upgrade to Marvel CI. This ensures that the most recent recipient information is transferred to Target CI at the time of the upgrade.

1. VERIFY SETTINGS IN SOUNDWAVE 3.2

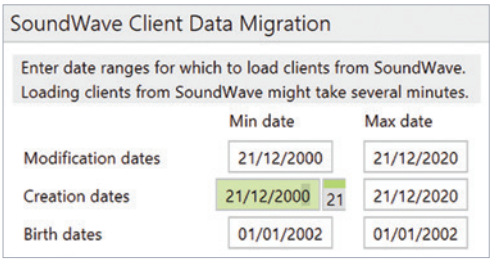
- Ensure that the recipient has a visit history for a Naída CI Q sound processor. Migration will not occur for sound processors prior to Naída CI Q. Only the most recent visit history will be migrated. If there is no Naída CI Q visit history for a given side, that side will not be migrated.
- Ensure the recipient's preferred program is saved to Program Slot 1, as information from Program Slot 1 in the most recent SoundWave 3.2 Visit History will be migrated to Target CI[1].
- Note the client's date of birth in SoundWave 3.2. Close SoundWave 3.2 fitting software[2].

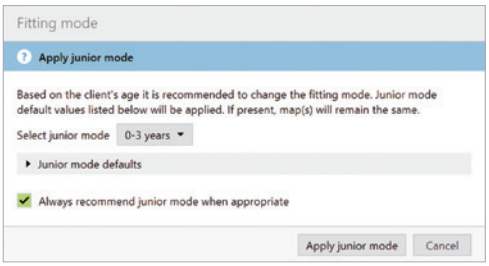
2. OPEN TARGET CI AND MIGRATE CLIENT DATA

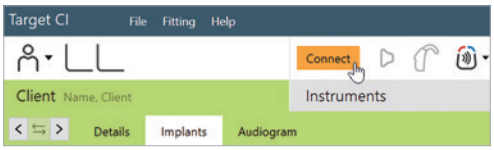
If Target CI is used as standalone software, migrating client data will add a new client to the database.

If Target CI is installed as a Noah module, it's necessary to first enter the recipient demographic information into Noah, select the client, and open a new fitting session.

- In Target CI access the *File* menu and select *Migrate client data*[3].
- Enter the required information in the *SoundWave Client Data Migration* window (Modification dates, Creation dates, Birth dates).
  - Enter the date of birth accurately.
  - Enter a wide Modification[4] and Creation date under the Min date e.g. dd/mm/2000; then, click Start.
- Verify the client's name. Confirm that the appropriate sound processor is chosen for the upgrade.
- Click *Start* and follow any prompts.
- The session is now available in the client file. The *Notes* section of the client details will indicate the session was migrated[5,6].







For pediatric Marvel CI upgrades:

- Target CI will ask if the hearing care professional wants to apply *Junior mode* default settings (based on the client's age) to the map.
- Target CI will prompt the hearing care professional to choose between *Create new fitting* or *Keep current mapping parameters and match Junior mode defaults*.
- Select *Keep current mapping parameters and match Junior mode defaults* to maintain the recipient's current map parameters.
- Select *Create new fitting* to reset the recipient's map parameters.

3. CONNECT TO THE HEARING INSTRUMENT

- Connect to the hearing instrument via Noahlink Wireless, CPI-3, or Remote Programming.
- When programming wirelessly, ensure that a fully charged rechargeable battery is used. Remove and re-attach the battery to put the sound processor into pairing mode. Click the *Connect* button within the 3-minute pairing window.
- Verify the side for which the device is intended to be used.
- Once device connection is successful, *Close* to proceed.

1. The SoundWave 3.2 file must have a Visit History and Intellilink™ enabled in order to migrate the recipient information.
2. It is important to close both SoundWave 3.2 and Target CI between migration. This ensures that the most current data is migrated from SoundWave 3.2 to Target CI.
3. Migrate one patient file at a time.
4. Modification date is the date the most recent visit history was created.
5. Client files will not be migrated if the recipient has no active implants or is identified as a test patient.
6. If the SoundWave file contains a C1 implant, the C1 data will not be migrated. If the recipient is bilateral, only data for a non-C1 implant will be migrated.

4. CONNECT TO THE INTERNAL DEVICE

- Place the headpiece on the recipient's head to achieve lock with the implant. Lock must be achieved prior to making any changes to the *Implants* tab. If lock is not achieved, the sound processor will not stimulate the implant and the fast blinking red LED will be observed.

5. SELECT THE APPROPRIATE ATTACHMENT

- Under the *Instruments* tab, go to *Acoustic parameters* and ensure that *T-Mic/Standard* is selected as the appropriate attachment.

6. MEASURE IMPEDANCES AND NEURAL RESPONSE IMAGING (NRI)

- Impedances will run automatically. Under *Client*, access the *Impedance* tab to run impedances.

7. VERIFY THE MAP SETTINGS AND COMFORT

- Under the *Fitting* tab, access *Mapping* to verify the electrical parameters like M-Levels and T-Levels, Strategy, Pulse Width, IDR, etc.The settings in the table below should be considered.
- Verify comfort using *Live Speech stimulation*.

The following settings from the SoundWave 3.2 data migration should be considered:

SETTINGS PRESERVED FROM SOUNDWAVE

- M-Levels / T-Levels
- ClearVoice – If Enabled in SoundWave 3.2, will be set to Medium in Target CI.
- SoftVoice
- IDR
- Disabled / Spanned / Clipped electrodes
- Strategy
- Filter type
- RF (Set to AutoVoltage or Manual)
- Electrical gain settings

RE-EVALUATE IN TARGET CI

- **Acoustic parameters** – The audiogram must be manually entered in Target CI.
- **Pulse Width** – May be impacted by New Impedance Measurement.

SETTINGS DIFFERENT IN TARGET CI

- **Program structure** – AutoSense OS now available
- **T-Mic + Processor Mic** – This microphone option is not available for Marvel CI

CANNOT BE MODIFIED IN TARGET CI

- QuickSync is always enabled
- Volume Min/Max (±20%)

8. FINE TUNING

- Access the *Fine tuning* tab to verify the program settings. Confirm settings in the *Map options* tab, as desired.
- Access the *Program options* tab to fine tune individual programs further, if desired.

9. MANAGE DEVICE OPTIONS

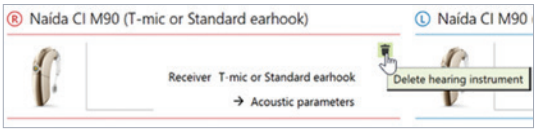
- Access the *Device options* tab to manage Manual controls, Bluetooth®, Signals & alerts, Indicator light, Startup and Datalogging, as needed, based on each recipient's unique preferences.
- For ease of discovering the device during Bluetooth pairing, access the *Bluetooth* tab and label each side with the recipient's name.

10. SAVE AND CLOSE THE SESSION

- Select *Save & close* to finalize the fitting session.
- Run and review the sound processor *Battery estimation*, if desired.
- Add any notes to the fitting session, if desired.
- Follow the prompts to *Save* the fitting session to the Hearing instruments and/or the Database. Select *Close* to complete the session.

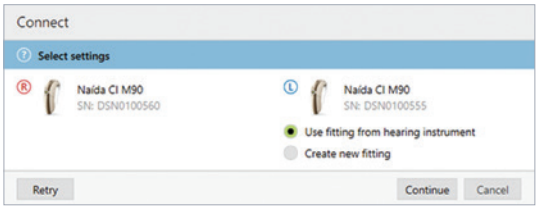
BILATERAL RECIPIENTS UPGRADING ONLY ONE SIDE TO MARVEL CI

- When migrating a recipient's SoundWave 3.2 file into Target CI, data from both sides are migrated over. For a simpler fitting experience, it may be helpful to delete the hearing instrument on the side that you do not intend to upgrade, in the *Hearing Instruments* tab.
- Access the *Fine Tuning* tab. Under *Automatic programs*, ensure *Speech in loud noise* is not enabled (this program requires a compatible hearing instrument on the contralateral ear).



When upgrading the second side to Marvel CI:

- Simply repeat the migration of the recipient's SoundWave 3.2 file into Target CI.
- When connecting to the hearing instruments, select *Use fitting from hearing instrument* on the side that was previously upgraded. Select *Continue* to proceed with the fitting.



Phonak CROS-13
QUICK START GUIDE

MARVEL FROM EAR TO EAR!

Advanced Bionics and Phonak work together to provide every recipient with a two-ear hearing solution. Phonak CROS P-13 is available for Marvel CI recipients with unaidable hearing in the non-implanted ear.

1 CROS 2 MARVEL CI

1. CROS wirelessly transmits the microphone input signal from the non-implanted ear to the Marvel CI sound processor.
2. Marvel CI receives the signal and delivers it to the implanted ear.

Marvel CI + CROS provides recipients with access to sound from both sides and allows them to hear their best in all environments.

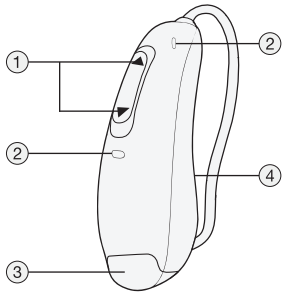
COMPATIBILITY

CROS is compatible with the Naída CI M90/30 and Sky CI M90. CROS can be programmed with Target CI v1.5 or later, and Noahlink Wireless.

OVERVIEW

PRODUCT COMPONENTS

1. Multifunction Button
2. Microphones
3. Battery Compartment
4. Right or Left Indicator

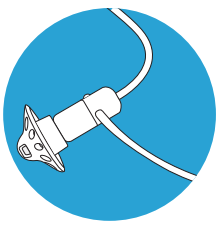


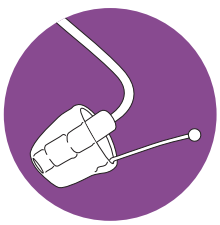
EARPIECE OPTIONS

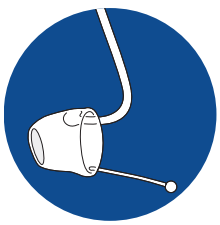
Standard Dome (CROS Tube)
- Dome available in three sizes (S, M, L)
- Right and Left
- Available in four lengths (0, 1, 2, 3)

SlimTip (CROS Tube)
- Custom-made earpiece
- Right and Left
- Available in four lengths (0, 1, 2, 3)

CROS Tip
- Fully custom-made earpiece
- Available in four lengths (0, 1, 2, 3)







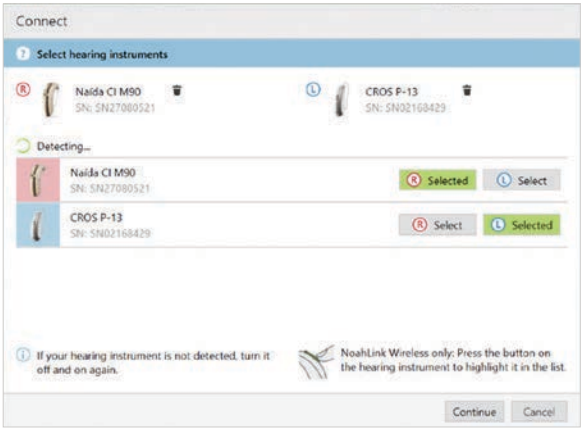
WIRELESS COMMUNICATION

When using wireless accessories or smartphones, both will stream directly to Marvel CI. When the signal from a wireless accessory or smartphone is present, the CROS signal will pause. When the signal from the wireless accessory or smartphone has stopped, the CROS signal will resume.

FITTING GUIDE

PROGRAMMING PHONAK CROS P-13

- Connect hearing instruments.
  - Open Target CI v1.5 or later.
  - Select the orange Connect button at the top of the screen.
  - Assign sides for each hearing instrument, select Continue.
    NOTE: Target CI will identify if a firmware update is required. Follow steps to perform update as indicated in Target CI.
- Proceed with programming.
- Complete the programming session.
  - Select Save & Close at the top right corner of the screen.
    NOTE: During the saving process, CROS cannot be unchecked.
    NOTE: The wireless connection between CROS transmitter and Marvel CI starts automatically once both instruments are disconnected from the software and turned on.

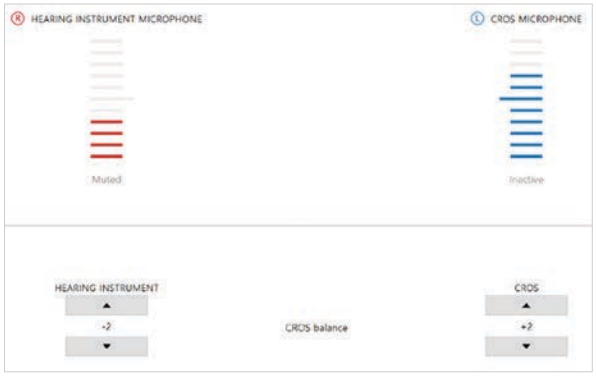


OPTIONAL CROS PROGRAMMING CONSIDERATIONS

- Select Acoustic Parameters in the Instruments tab to choose an earpiece, as needed.
- Choose Program Options within the Fitting tab to adjust or confirm CROS microphone mode, as needed.
- Adjust CROS Balance within the Fitting tab, as needed, per the directions below.

CROS BALANCE

- Select *CROS Balance*.
  NOTE: Adjustment to CROS balance is applied across all programs.
- Confirm CROS has been unmuted at the top of the dashboard.
  NOTE: When CROS is initially unmuted, a notification to enable Binaural VoiceStream Technology™ will appear.
- Adjust the loudness balance between CROS and Marvel CI sound processor by manipulating the up and down arrow keys beneath the hearing instruments.
  NOTE: A change to one hearing instrument will result in a change to both sides simultaneously.



REMOTE PROGRAMMING CONSIDERATIONS FOR CROS

PROGRAMMING PHONAK CROS P-13

- Open Target CI and select *Start Remote Support*.
  NOTE: During Remote Programming, CROS is not connected but remains active throughout the session. A new CROS instrument cannot be added during a Remote Programming session.
- Connect Marvel CI sound processor.
- Proceed with programming.
  NOTE: All adjustments made to CROS programming during a Remote Programming session will save to the Marvel CI sound processor.
- Select *Save and Close* before ending the remote session.

If you require more information about programming CROS, please contact your local AB support.

Marvel CI Bimodal Solution
PROGRAMMING GUIDE

Target CI is designed for easier, faster, and smarter fitting. Target CI is the first hearing care software to allow the fitting of a sound processor and compatible hearing aid at the same time in one fitting software. It provides a streamlined workflow for an efficient bimodal fitting experience.

COMPATIBILITY

- The Naída Link M hearing aid is compatible with the Naída CI M90 sound processor.
- The Sky Link M hearing aid is compatible with the Sky CI M90 sound processor.

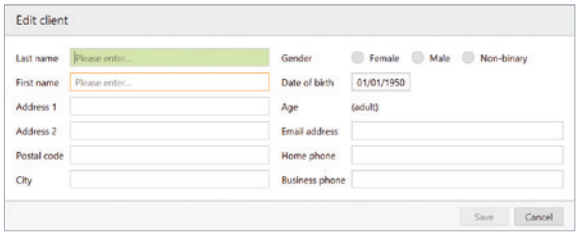
FITTING HARDWARE

Marvel CI sound processors and hearing aids can be programmed in the Target CI fitting software, using the Noahlink Wireless.

FITTING GUIDE

Open Target CI and follow the steps below to navigate the fitting of both Marvel devices in one session. Work through the tabs from left to right to complete the required fitting steps.

1. CREATE THE CLIENT FILE



For a New client:

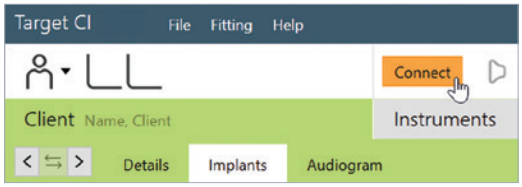
- Select *New client*. Enter the client details[1] and *Save*.
- Select *New session* to open a new fitting session.

For an Existing client:

- Search and select the client's file; then, select *Open Session*[2].

2. CONNECT TO THE HEARING INSTRUMENTS

- Connect to both hearing instruments via Noahlink Wireless or Remote Programming.
- When programming wirelessly, ensure that fully charged batteries are used for both devices. Remove and re-attach the battery to put the devices into pairing mode. Click the *Connect* button within the 3-minute pairing window.
- Verify the sides for which each device is intended to be used.
- Once the device connections are successful, *Close* to proceed.

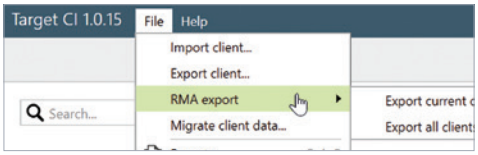


3. CONNECT TO THE INTERNAL DEVICE

- Place the headpiece on the recipient's head to achieve lock with the implant.
- For a new client, create a new implant record by clicking on the implant icon and follow the prompts to add a new implant.
- Add the required implant information; then, select *Save*.

4. MEASURE IMPEDANCES AND NEURAL RESPONSE IMAGING (NRI)

- Under *Client* access the *Impedance* tab to run impedances and conditioning.
- Access the *NRI* tab to measure NRI, if desired.



5. ENTER THE AUDIOGRAM

- Access the *Audiogram* tab to enter the client's latest audiogram[3]. Select the transducer type used.
- Optional: AudiogramDirect allows the measurement of an audiogram via the hearing aid and acoustic coupling. To access it, click *AudiogramDirect* > *Start* and follow the prompts.

6. SELECT THE APPROPRIATE ATTACHMENTS

- Under the *Instruments* tab, access the *Acoustic Parameters*, select the *Attachment* for the sound processor.
- For the hearing aid, select the appropriate earpiece option.

1. Always enter the client's Date of birth so that the appropriate default settings can be applied.
2. Open session should be used at all follow-up visits to allow access to past impedance and NRI data.
3. If using Noah, enter client details and audiogram in Noah, prior to accessing Target CI.

7. PERFORM THE FEEDBACK AND REAL EAR TEST

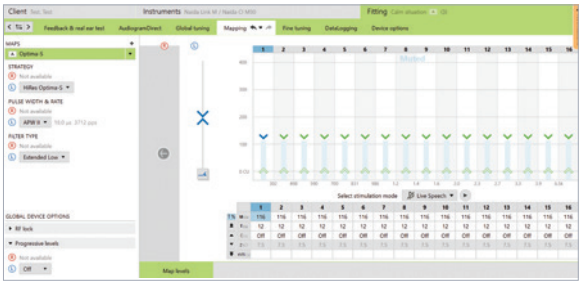
- Under the *Fitting* tab, access *Feedback & real ear test*.
- Instruct the patient to remain quiet for the duration of the measurement.
- Select *Start* to run the feedback management test.

8. PERFORM GLOBAL TUNING AND SELECT FITTING FORMULA

- Access the *Global tuning* tab to confirm the fitting formula and to view acoustic gain[4].
- Consider using the *Adaptive Phonak Digital Bimodal fitting formula*, as appropriate.

9. CREATE A MAP AND VERIFY SOUND QUALITY OF THE SOUND PROCESSOR

- Under *Fitting*, access the *Mapping* tab to set the appropriate map parameters (i.e. stimulation strategy, pulse width, etc.).
- Select the *Stimulation mode* type to measure M-Levels. T-Levels will default to 10% of the set M-Levels.
- To start and stop stimulation, click the play button, or the "unmute" and "mute" control in the dashboard, or press the F-key on the keyboard.
- Verify comfort using *Live Speech stimulation*.
- If desired, create progressively louder levels under *Global device options*.
- If desired, create additional Maps under *Mapping*.



10. FINE TUNE THE HEARING AID SETTINGS

- Access the *Fine tuning* tab. Then, select the *Gain & MPO* tab to manage acoustic settings for the hearing aid.

11. FINE TUNE BOTH DEVICES IN PROGRAM OPTIONS

- Access the *Program options* tab to fine tune individual programs further, if desired[5].
- Microphone mode and comfort features can be adjusted for each individual program, if desired.
- Add any *Additional programs [+]*, if needed, based on the client's unique listening needs.

12. MANAGE DEVICE OPTIONS

- Access the *Device options* tab to manage Manual controls, Bluetooth®, Signals & alerts, Indicator light, Startup and Datalogging, as needed, based on each recipient's unique preferences.
- For ease of discovering the device during Bluetooth pairing, access the *Bluetooth* tab and label each side with the recipient's name.
- Consider assigning the Bluetooth Side to the side with better hearing and/or longer battery life.

13. SAVE & CLOSE THE SESSION

- Select *Save & close* to finalize the fitting session.
- Run and review the sound processor *Battery estimation*, if desired.
- Add any notes to the fitting session, if desired.
- Follow the prompts to *Save* the fitting session to the Hearing instruments and/or the Database.
- Select *Close* to complete the fitting session.

If further support or information regarding product availability is required, please contact your local AB representative.

4. The gain level and compression settings are based on the user's experience.
5. By default, the settings are applied to both the CI and HA; however, settings for each device can be customized by unlinking the devices.

M Acoustic Earhook
QUICK REFERENCE GUIDE

The M Acoustic Earhook coupled with the Marvel CI sound processor is designed for CI candidates and recipients who have aidable low frequency hearing in the implanted ear. This solution provides acoustic amplification of the low frequencies via hearing aid technology, in combination with electrical stimulation of the high frequencies in the same ear via cochlear implant technology. M Acoustic Earhook takes advantage of natural acoustic hearing to provide the benefits of combined stimulation to recipients with unilateral or bilateral Marvel CI(s).

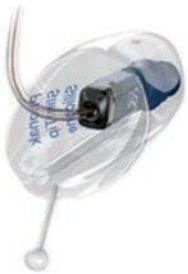
COMPATIBILITY

The M Acoustic Earhook is compatible with the Naída™ CI M90 and Sky CI™ M90 sound processors.

COMPONENTS

1. M Acoustic Earhook
2. Receiver
3. Sound processor
4. M Battery
5. Front microphone
6. Back microphone
7. Multi-function button with status LED
8. CeruShield™ Disk
9. Pin removal tool
10. Connector pin

EARPIECE OPTIONS



Custom SlimTip[1]

Custom fit recommended for moderate or greater hearing loss for better retention, comfort and protection of the receiver.

Power dome

Suitable for moderate hearing loss. Offers a tighter fit than the Vented dome.

Vented dome

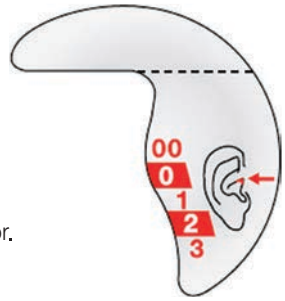
Suitable for mild-to-moderate hearing loss. Beneficial if occlusion is a concern.

1. Ordered from Phonak. Availability varies by region.

ASSEMBLING THE M ACOUSTIC EARHOOK

Follow the steps below to setup the device appropriately:

- The M Acoustic Earhook is available in 5 different lengths (00, 0, 1, 2, 3) for either the left or right ear.
- The Measurement Tool helps to determine the appropriate length of the Acoustic Earhook to accommodate different ear shapes and sizes.
- The Pin Removal Tool is used for attaching the M Acoustic Earhook to and from the sound processor.
- Confirm that a CeruShield wax filter is inside the receiver. The receiver ships with a wax filter already inserted.
- Select a suitable earpiece option to attach to the receiver of the M Acoustic Earhook. Ensure a comfortable fit and seal in the ear canal for good retention. When mounting the earpiece on to the receiver, there is a tactile click upon attachment.



Measurement Tool

CARE AND MAINTENANCE

Earwax Protection

- The M Acoustic Earhook is equipped with a CeruShield wax filter to protect the receiver from earwax damage.
- Check the earwax protection regularly and exchange it if it looks dirty or if sound quality is reduced.
- The CeruShield earwax filter should be replaced at least every four to eight weeks.

CeruShield Disk

General Care

- When not in use, store the sound processor and M Acoustic Earhook in the equipment case provided.
- Ensure the M Acoustic Earhook is not placed within proximity of the headpiece magnet, as the magnet may damage the receiver.
- Visually inspect the device daily for earwax and moisture deposits in the M Acoustic Earhook.
- Wipe the earpiece daily with a dry tissue.
- If a dome is used, it should be replaced every three months, or when it becomes brittle.
- To clean the M Acoustic Earhook:
  - Remove the dome from the receiver.
  - Using a lint-free cloth or moist cleansing wipe, gently clean the dome and receiver unit. Never use cleaning agents such as household detergents.
  - Prior to reattaching the dome to the receiver, ensure that all parts are completely dry.

FOR MORE INFORMATION

Refer to the M Acoustic Earhook Instruction For Use. If further support is required, please contact your local AB representative. They will provide information regarding regulatory approval and product availability in your region.

M Acoustic Earhook
PROGRAMMING GUIDE

The M Acoustic Earhook allows recipients to take advantage of any usable acoustic hearing in the implanted ear.

FITTING HARDWARE

Marvel CI sound processors with M Acoustic Earhook are programmed in the Target CI fitting software, using either the Noahlink Wireless or CPI-3 programming interface.

FITTING GUIDE

Open Target CI and follow the steps below to navigate fitting of Naída™ CI M90 or Sky CI™ M90 sound processors with the M Acoustic Earhook. Work through the tabs from left to right to complete the required fitting steps.

1. CREATE THE CLIENT FILE

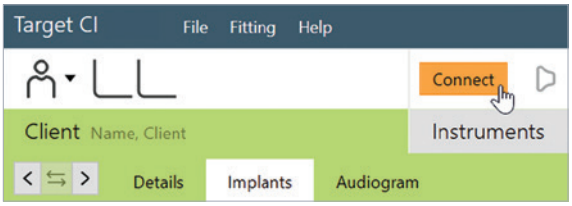
For a New client:

- Select *New client*. Enter the client's details[1] and *Save*.
- Select *New session* to open a new fitting session.

For an Existing client:

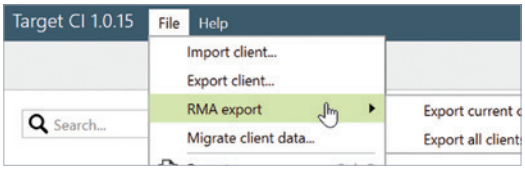
- Search and select the client's file; then, select *Open Session*[2].

2. CONNECT TO THE HEARING INSTRUMENTS



- Connect to the hearing instrument(s) via Noahlink Wireless, CPI-3, or Remote Programming.
- When programming wirelessly, ensure that a fully charged rechargeable battery is used. Remove and reattach the battery to put the sound processor into pairing mode. Click the *Connect* button within the 3-minute pairing window.
- Verify the sides for which each device is intended to be used.
- Once the device connection is successful, *Close* to proceed.

3. CONNECT TO THE INTERNAL DEVICE



- Place the headpiece on the recipient's head to achieve lock with the implant.
- For a new client, create a new implant record by clicking on the implant icon and follow the prompts to add a new implant.
- Add the required implant information; then, select *Save*.

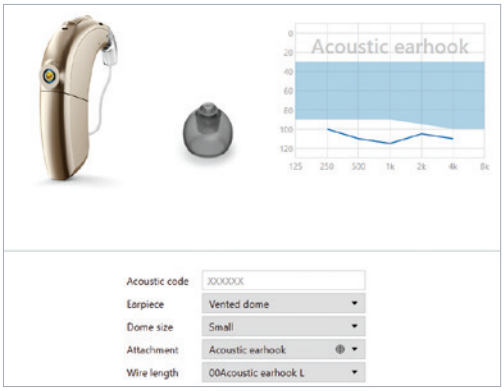
4. MEASURE IMPEDANCES AND NEURAL RESPONSE IMAGING (NRI)

- Under *Client*, access the *Impedance* tab to run impedances and conditioning.
- Access the *NRI* tab to measure NRI, if desired.

5. ENTER THE RECIPIENT'S LATEST AUDIOGRAM

- Access the *Audiogram* tab to enter the client's latest audiogram[3]. Select the transducer type used.
- AudiogramDirect allows the measurement of an audiogram via the M Acoustic Earhook. To access it, click *AudiogramDirect > Start* and follow the prompts.

6. SELECT THE APPROPRIATE ATTACHMENTS



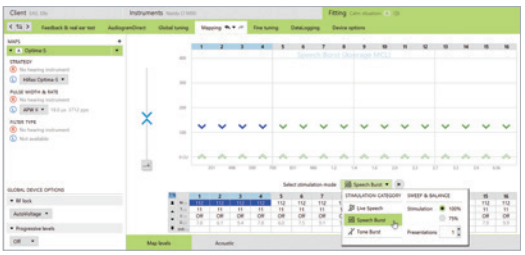
- Under the *Instruments* tab, access the *Acoustic Parameters*, select *Acoustic Earhook,* the appropriate earpiece, dome size, and wire length.
- For optimal fitting, *SlimTip* is recommended (order from Phonak).

7. PERFORM THE FEEDBACK AND REAL EAR TEST

- Under the *Fitting* tab, access *Feedback & real ear test*.
- Instruct the patient to remain quiet for the duration of the measurement.
- Select *Start* to run the feedback management test.

1. Always enter the client's Date of birth so that the appropriate default settings can be applied.
2. Open session should be used at all follow-up visits to allow access to past impedance and NRI data.
3. If using Noah, enter the client's details and audiogram in Noah, prior to accessing Target CI.

8. PERFORM GLOBAL TUNING AND SELECT FITTING FORMULA



- Access the *Global tuning* tab to confirm the fitting formula and to view acoustic gain.
- Consider using the *Adaptive Phonak Digital Bimodal fitting formula*, as appropriate.

9. CREATE A MAP FOR THE ELECTRIC MODE

- Under *Fitting*, access the *Mapping* tab, set the appropriate electric parameters (i.e. stimulation strategy, pulse width, etc.).
- Select the *Stimulation mode* type to measure M-Levels. T-Levels will default to 10% of the set M-Levels.

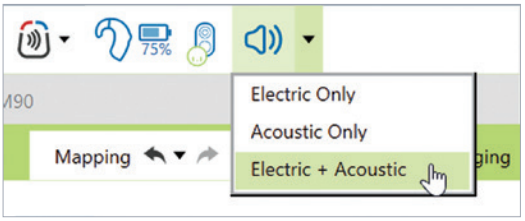
If electrodes are extra-cochlear:

- Disable electrodes which are suspected to be located outside the cochlea.
- Disable the first electrode located inside the cochlea (e.g. if electrodes 15 and 16 are outside the cochlea, disable electrodes 14 -16 in the map).
- Check M-Level on remaining active electrodes using tone burst stimulation. If the recipient reports sound as uncomfortably loud or unpleasant (e.g. tinny, shrill), reduce M-Level to a comfortable level[4].

10. SET ACOUSTIC AND ELECTRIC CUTOFF FREQUENCIES

- Select the *Acoustic* tab to access acoustic and electric cutoffs.
- The electric cutoff will default to the point at which recipient's unaided threshold exceeds 70 dB HL. The acoustic cutoff will default to the point at which the unaided threshold exceeds 90 dB HL.

11. VERIFY SOUND QUALITY AND COMFORT



- Click the dropdown next to the *Mute/Unmute* icon, to stimulate *Electric only*, *Acoustic only*, or *Electric + Acoustic* together.
- Verify sound quality and comfort using live speech stimulation.

12. FINE TUNING

- Access *Fine tuning* to confirm settings, as desired.
- Access the *Gain & MPO tab* to set acoustic gains and maximum acoustic earhook output.

13. MANAGE DEVICE OPTIONS

- Access the *Device options* tab to set controls and alerts according to the recipient's preference.
- For ease of discovering the device during Bluetooth® pairing, access the *Bluetooth* tab and label each side with the recipient's name.

14. SAVE & CLOSE THE SESSION

- Select *Save & close* to complete the fitting session.
- Run and review the sound processor *Battery estimation*, if desired.
- Add any notes to the fitting session, if desired.
- Follow the prompts to *Save* the fitting session to the Hearing instruments and the Database.
- Select *Close* to complete the fitting session.

FOR MORE INFORMATION

If further support or information regarding product availability is required, please contact your local AB representative.

4. Additional electrodes should be disabled if any of the following are noted with individual electrode stimulation: non-auditory percept, abnormal or absent loudness growth, or atonal or abnormal stimulus sound quality.

AutoSense OS 3.0
QUICK START GUIDE

Marvel CI sound processors (Naída CI M90, Naída CI M30 and Sky CI M90) are designed to help you stay connected with your family and friends, by providing a powerful hearing experience in any listening situation. This guide provides the basic information needed to help build confidence with your new device.

WHAT IS AUTOSENSE OS?

AutoSense OS™ 3.0 operating system is a sophisticated, **easy to use automatic program** in the Marvel CI sound processors and Phonak Link M hearing aids. It automatically senses your surroundings and adapts to provide optimum clarity and comfort in the different listening situations, without requiring manual program changes.

TIPS FOR SUCCESS

STARTUP PROGRAM

When your device is powered on, you will hear a melody[1] as the device goes into the automatic startup program.

AUTOMATICALLY ADAPTS TO CHANGING ENVIRONMENTS

The device will seamlessly adapt to your surroundings and adjust automatically from quiet, to noise and while streaming music or media.

BE PATIENT

It may take a few days or weeks to get used to the new sound quality, just like with all new technologies. Allow the brain time to adapt to the new sound. Try out the following listening exercises to build your confidence.

ALWAYS FACE THE PERSON YOU WISH TO HEAR

When in noisy environments, the directional microphones will activate. It is designed to focus to the front, while making sounds from the back and sides to be perceived as softer. Hence, it is important to always face the person you wish to hear, especially in group conversations.

AB REMOTE APP

You can adjust the volume on the device or the AB Remote app, if desired. You can customize the balance of the streamed signal versus the environmental sounds also.

WIRELESS SOLUTIONS

If you are still struggling to hear in noise, consider using a wireless solution like Roger devices to improve hearing in challenging listening situations like meetings and restaurants.

1. The startup melody will only be audible if enabled in the fitting software by the hearing care professional.

EXPERIENCE THE BENEFIT

Try the following activities with a family member or friend to help you adjust to the sound quality.

Listening Activity	Rate your experience and add a comment regarding the experience 1 = Poor ; 2 = Fair ; 3 = Good ; 4 = Very Good ; 5 = Excellent
Conversation with one person in a quiet situation. E.g. in the clinic or at home. Observe the speakers voice and the sounds around you.	1 2 3 4 5
Group conversation in a quiet situation. Always face the person you wish to hear.	1 2 3 4 5
Conversation with one person in a noisy restaurant. When in noise, the directional microphones will activate. It is designed to focus to the front, while making sounds from the back and sides to be perceived as softer. Always face the person you wish to hear.	1 2 3 4 5
Group conversation in a noisy situation. When in noise, the directional microphones will activate and focus to the front while reducing background noise. Always face the person you wish to hear in the group.	1 2 3 4 5
Go for a walk outdoors. Observe the environmental sounds around you like birds, traffic, etc.	1 2 3 4 5
Conversation in the car. Listen to the driver or other passengers.	1 2 3 4 5
Listen to music via speaker and/or Bluetooth® streaming. Start with your favorite songs, and follow the lyrics.	1 2 3 4 5
Listen to a podcast via Bluetooth streaming. Find an interesting podcast or audio book to stream directly to your device using Bluetooth.	1 2 3 4 5

We want you to get the most out of your Marvel CI device and enjoy a powerful hearing experience in any listening situation. If you are still struggling to adapt to the new sound quality after a few weeks, please inform your audiologist. You may require additional programming. You can rate the listening activities in the table above and take it along to the clinic, so the hearing care professional is informed about your experiences in the various listening situations.

For more information, please visit AdvancedBionics.com/MarvelCI

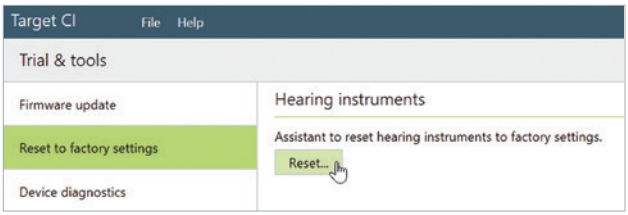
Target CI
PROGRAMMING REPLACEMENT MARVEL DEVICES

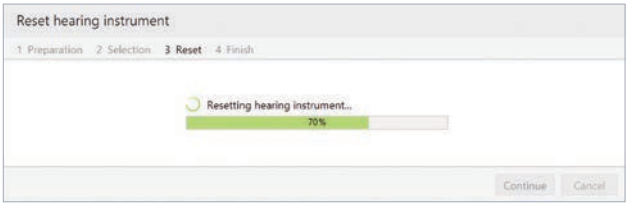
This guide provides the hearing care professional with the steps to program a replacement Marvel CI sound processor or hearing aid in Target CI.

RESET TO FACTORY SETTINGS IF USING A LOANER MARVEL DEVICE

If using a Marvel device that was previously programmed for a different recipient, it is advisable to reset to factory settings first. This step will clear all patient and program information previously stored on the device. Reset one hearing instrument at a time. If you are using a new hearing instrument, you can skip this step.

- Open Target CI and select *Trial & tools*.
- Select *Reset to factory settings > Reset* under Hearing instruments.
- Select the preferred programming interface – *Noahlink Wireless* or *CPI-3*.
- Turn the hearing instrument off and on again (i.e. remove and re-attach the battery to the device). Click *Continue*.
  Note: Any data previously saved on the device will be lost. However, selecting *Reset to factory settings* will not remove any previous Roger license installations.
- Select the detected hearing instrument, click *Continue*.
- The reset may take several minutes. Be patient and do not disconnect the device or close the software. The progress bar is a visual indicator to monitor progress. Click *Continue*.
- Once the Hearing instrument is successfully reset, click *Close*. The device has now been reset to factory settings.





PROGRAMMING THE REPLACEMENT MARVEL DEVICE

OPEN TARGET CI AND SELECT THE CLIENT FILE

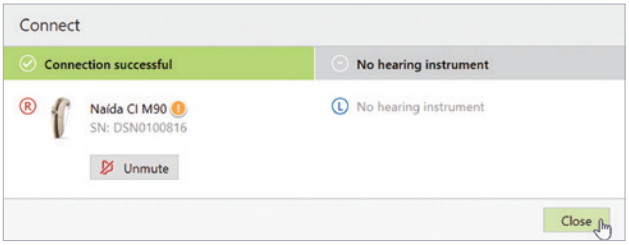
- Open the most recent fitting session.
  Note: If the *Apply Junior mode* message pops up when programming a replacement Sky CI M, select *Keep current mapping parameters and match "Junior mode" defaults* to maintain the recipient's current map parameters.

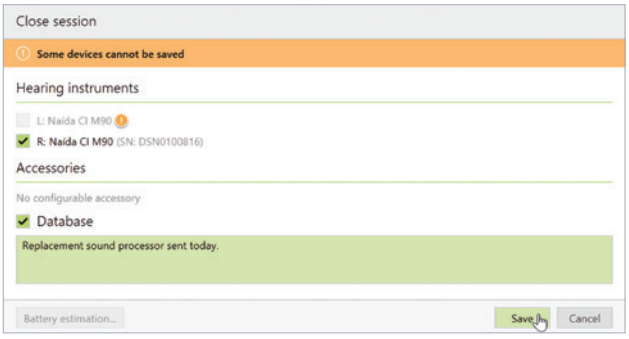
CONNECT TO THE HEARING INSTRUMENT

- Connect to the hearing instrument via Noahlink Wireless, CPI-3, or Remote Programming.
- When programming wirelessly, ensure that a fully charged rechargeable battery is used. Remove and re-attach the battery to put the sound processor into pairing mode. Select the *Connect* button within the 3-minute pairing window.
- Verify the side for which the device is intended to be used.
- Once device connection is successful, *Close* to proceed.

SAVE AND CLOSE THE SESSION

- Select *Save & close* to finalize the fitting session.
- Add any notes to the fitting session, if desired.
- *Save* the fitting session to the Hearing instruments and/or the Database.
- Select *Close* to complete the fitting session.

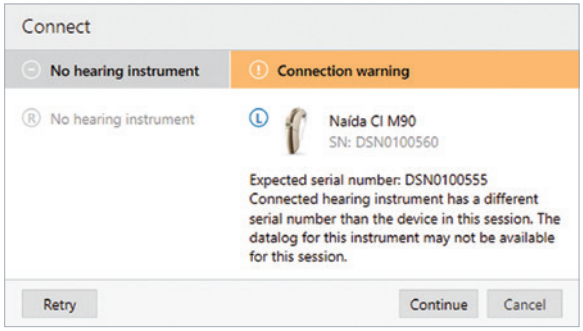




PROGRAMMING A BACK-UP MARVEL CI SOUND PROCESSOR DURING IN-PERSON CLINIC VISIT

Follow the steps below to program a back-up Marvel CI sound processor.

- Program the primary Marvel CI sound processor; then, *Save & close* session.
- Open the session that was just created with the primary Marvel CI.
- Put the back-up Marvel CI into pairing mode by attaching a fully charged rechargeable battery to this back-up device.
- Connect to the hearing instrument via Noahlink Wireless, CPI-3, or Remote Programming.
- Verify the side for which the device is intended to be programmed.
- A *Connection warning* notification will pop-up indicating that the connected device has a different serial number than the device in this session (see below for more details). Select *Continue* to proceed.
- Be sure to select *Use fitting from session*; then, follow the prompts to proceed.
- Once device connection is successful, select *Close* to proceed
- Select *Save & close session* to save the same settings and programs to the back-up Marvel CI sound processor and database.



Target CI Connection Warning Notification

If the serial number of the device connected to the session does not match the serial number of the device stored in the session, the datalog report in Target CI will not be available.

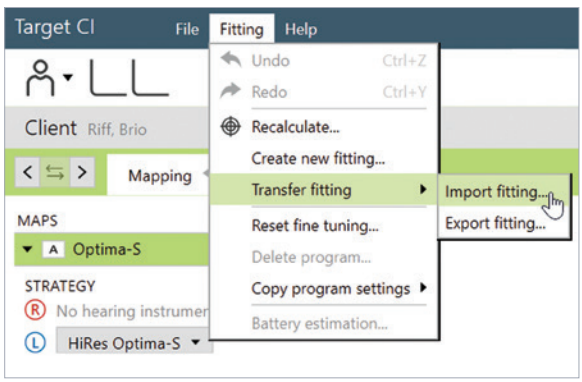
- In the case of programming the back-up Marvel CI device, the hearing care professional can ignore this message and proceed with the fitting session to program the back-up device.
- This notification will also be displayed at return visits when a Marvel CI device that has a different serial number than the one used in the previous fitting session is connected. In this case, there are two resolutions:
  a. Disconnect the device and connect the device with matching serial number to session, if available.
  b. Instead of starting by opening the existing session, rather start a new session and choose to read settings from the hearing instrument.

  Note: The most recent impedance data, but no historical impedance or NRI data, will be available when starting a new session.

IF THE REPLACEMENT MARVEL CI DEVICE IS A DIFFERENT TYPE

If programming a replacement Marvel CI sound processor that is different from the original device type issued to the recipient (e.g. programming Naída CI M90 to replace the Sky CI M90, or vice versa), use the *Transfer fitting* function within Target CI.

- Open Target CI, select the client whose device is to be programmed from the client list.
- Select *Open session* to open the client's most recent fitting session.
- Connect to the device via Noahlink Wireless or CPI-3.
- Go to the *Fitting* menu. Select *Transfer fitting > Import fitting*.
- The transfer fitting assistant transfers fitting data between different hearing instrument types. Select *Continue* to proceed.
- Import the fitting session that should be loaded onto the replacement processor. Select the fitting session from the list; then, select *Continue* to proceed.
- Confirm transferable programs and settings; select *Continue* to proceed.
- Select *Close* to complete the transfer fitting process.



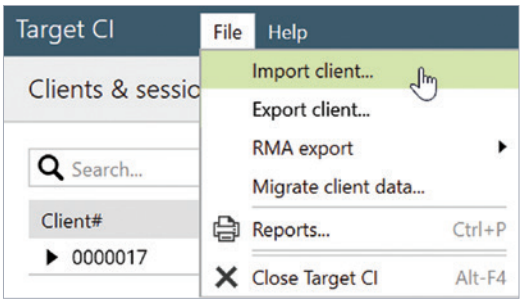
If further support is required, please contact your local AB representative.

Target CI
IMPORTING AND EXPORTING CLIENT FILES

This guide provides the hearing care professional with the steps to import and export the client file from Target CI.

HOW TO IMPORT THE CLIENT FILE INTO TARGET CI

If a Marvel CI user transfers from one clinic to another, the hearing care professional can obtain and import the client's Target CI file into their own Target CI database. The imported file will provide the client's full fitting history.

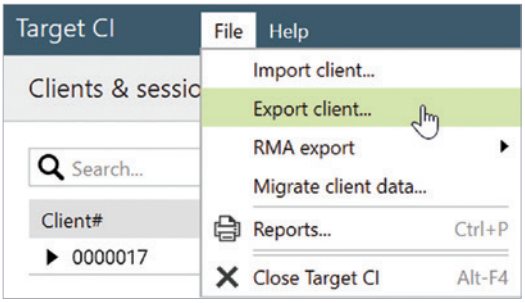


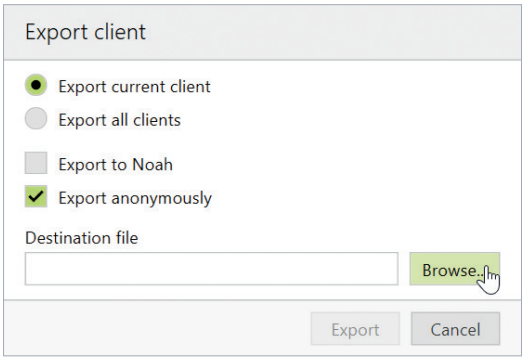
- Go to *File > Import clients*.
- Click *Browse*, select the file you wish to import; then, click *Import Client*.
- If the client file was anonymized, it will appear in Target CI as an anonymized number. For example: *Anonymized19600101*. The client name may be edited after the anonymized file is imported into Target CI.

Note: If the Target CI client file is not available to import when seeing a transfer client, then the current device settings can still be accessed by connecting to the patient's hearing instrument and selecting *Use fitting from hearing instrument*.

HOW TO EXPORT A CLIENT FILE FROM TARGET CI

If a Marvel CI user transfers from one clinic to another, the hearing care professional can export the client's Target CI file and send it to the new clinic. **It is recommended that client data be exported from within Target CI, rather than Noah, in order to maintain data privacy.**





- Select the *Client file* to be exported. Do not open the client file.
- Go to *File > Export client*.
- Select the preferred export client file option:
  - Export current client (default) to only export the individual client file.
  - Export all clients if you want to move all clients to another installation (and don't want to use a database back-up). This option only appears in stand-alone mode.
  - Export to Noah to make this file a .nha file, in order to import into Noah. It can be used together with the above Export all option if you wish to move the stand-alone patients to Noah.
  - Export anonymously (default) will remove the client's name from the file and replace it with an anonymized number. Consider whether the person receiving the file will need the name within the file or not.
- Click *Browse* to select the *Destination file* location to be saved; then, click *Export*.
- Once the export is complete, simply open the folder to locate the file to be sent.

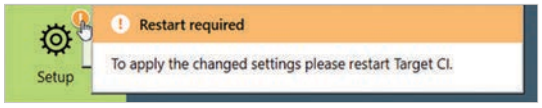
Note: Consider creating a shortcut from the desktop to the *C:\ProgramData\Advanced Bionics\Target CI\Target CI\RMAExports* file for easy file location in future.

HOW TO IMPORT A CLIENT FILE FROM THE AIM SYSTEM

Data from the AIM™ System can be imported into Target CI v1.5 or later. Data that can be imported from AIM includes IntelliLink ID, Implant type, Electrode type, Impedance measurements, and NRI measurements.

Enable the AIM system data transfer feature in Target CI by conducting the following steps:

- Open Target CI; then, select *Setup > Support*.
- Type *A1miable* into the *Support number* text box to enable AIM imports.
- Restart Target CI to apply the change.



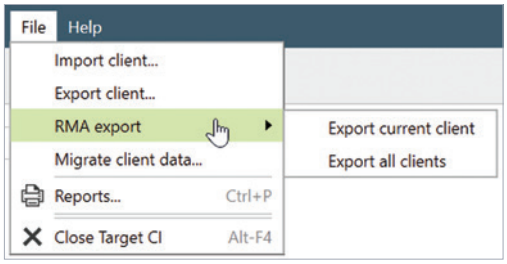
To import a file from AIM

- Open Target CI.
- Access the client file in one of the following ways:
  - If the recipient is in the Target CI database, select the client file; then, select Open session.
  - If the recipient is not in the Target CI database, create the client file; then, select New session.
- Select *Fitting > Import AIM*.
- Select *Browse*; then, select the .json file to be imported from the saved location.
- Select *Import*.

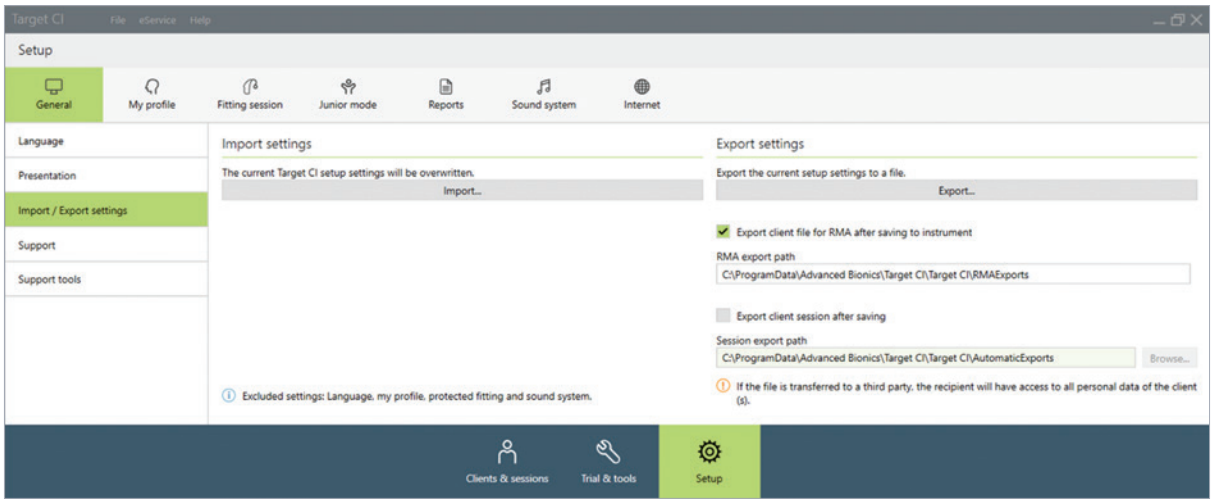
Measurements imported from AIM are identified with this symbol:

FOR REGIONS WITH AB EXPRESS AND AB PRO PORTAL RMA SERVICES

AB Express and the AB Pro Portal allow health care professionals to send fitting information to AB to support repairs and exchanges. These services may not be available in all regions. Check with your local AB representative.



- Select the *Client file* to be exported. Do not open the client file.
- Go to *File > RMA export*.
- Select the appropriate export option and follow the prompts:
  - Export current client (default) to only export the individual client file when using the Processor Direct Service.
  - Export all clients if you want to export all clients.
- The files are exported to the file path in *Setup* (Note: this file path is fixed).
- To access the RMA export file, go to *Setup*; then, under *General* select *Import/Export settings*.
- In *Setup*, the checkbox indicates that a file is exported automatically after saving to the hearing instrument.
- Once in the RMAExports folder, the hearing care professional can either upload the selected client file manually to AB (in Europe this may be called **AB4You**, in North America it is called **Processor Direct**) or the AB Express will automatically pull the file from this RMAExports folder.



- This data export is fully encrypted and saved to the following location:
  C:\ProgramData\Advanced Bionics\Target CI\Target CI\RMAExports
  - No identifying information will be available in the file name, so it will be important to retrieve the file immediately after exporting it.
  - Important: Although the file can be renamed as long as the .rma extension is preserved, renaming the file may breach cybersecurity compliance of anonymizing patient data.
- For AB Express users, all files in the RMAExports folder will be automatically sent to AB. You will be able to select the latest programming file while completing an RMA on the ProPortal. For AB ProPortal users, you can start your RMA on the ProPortal and upload the RMA export file directly on the web during the RMA process.

Target CI Remote Programming
QUICK START GUIDE

Remote Programming[1], available in Target CI, is designed to support the care of Marvel CI recipients by providing complete programming sessions with greater convenience. For follow-up appointments, a programming session can be conducted in real time in the recipient's own environment, rather than traveling to the clinic.

This guide provides information on how to successfully conduct a follow-up programming session using Remote Programming in Target CI for all AB recipients with Marvel CI, including bimodal recipients.

REMOTE PROGRAMMING REQUIREMENTS

Remote Programming is available for follow-up programming sessions for all Marvel CI recipients, including those with Link M, M Acoustic Earhook, and CROS. To activate Remote Programming, the programming computer must be connected to the internet and the hearing instrument(s) must be connected to Target CI v1.5 or later in the clinic. The recipient must pair to their hearing instrument(s) in the AB Remote Support app.

Additional requirements include:

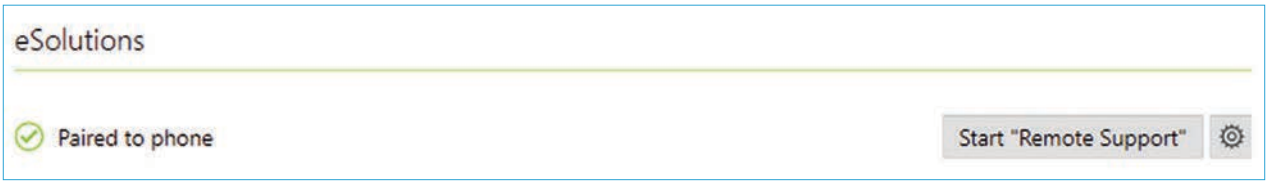
- Computer with an integrated webcam or microphone, or an external webcam and microphone connected to the computer.
  NOTE: For better sound quality, use headphones with a microphone connection for the Remote Programming session.
- Stable internet connection (Wi-Fi, LAN or 4G) with at least 5 Mbit/s of data transfer connection for uploads and downloads. Internet connection can be checked within Target CI.

REMOTE PROGRAMMING STEPS

OPEN TARGET CI V1.5 OR LATER

SELECT THE CLIENT FILE AND CHOOSE START REMOTE SUPPORT

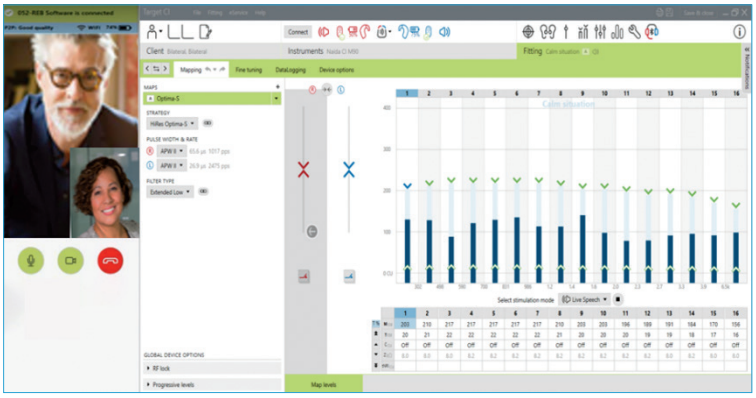
- Confirm the programming computer is connected to the internet.
- The hearing care professional (HCP) can select *Start Remote Support* to begin the Remote Programming session.
  NOTE: *Start Remote Support* is available after the recipient pairs to their phone and the recipient joins the programming session in the AB Remote Support app. *Paired to phone* will display in Target CI after the recipient's hearing instruments have been paired to their phone and will remain visible for subsequent programming sessions.



1. For adults and children aged 13 years and older

SELECT THE DESIRED VISIT HISTORY AND CHOOSE *OPEN SESSION* TO BEGIN PROGRAMMING

- The Remote Support window will appear on the left side of the Target CI screen.



- Conduct the Remote Programming. The same cochlear implant programming steps that can be performed during in-person programming sessions are available during the Remote Programming session.

SELECT *SAVE AND CLOSE* TO COMPLETE PROGRAMMING

NOTE: Target CI will not allow the hearing care professional to close the Remote Support video call before saving and closing the session.

END THE REMOTE PROGRAMMING SESSION

- Selecting will end the video call for the hearing care professional and the recipient.
- Close the Remote Support video window to end the Remote Programming session in Target CI.

PRO TIPS

During the in-person fitting session, assist the recipient with downloading the AB Remote Support app and pairing their hearing instrument(s). Going through these simple steps prepares the recipient for future remote programming sessions.

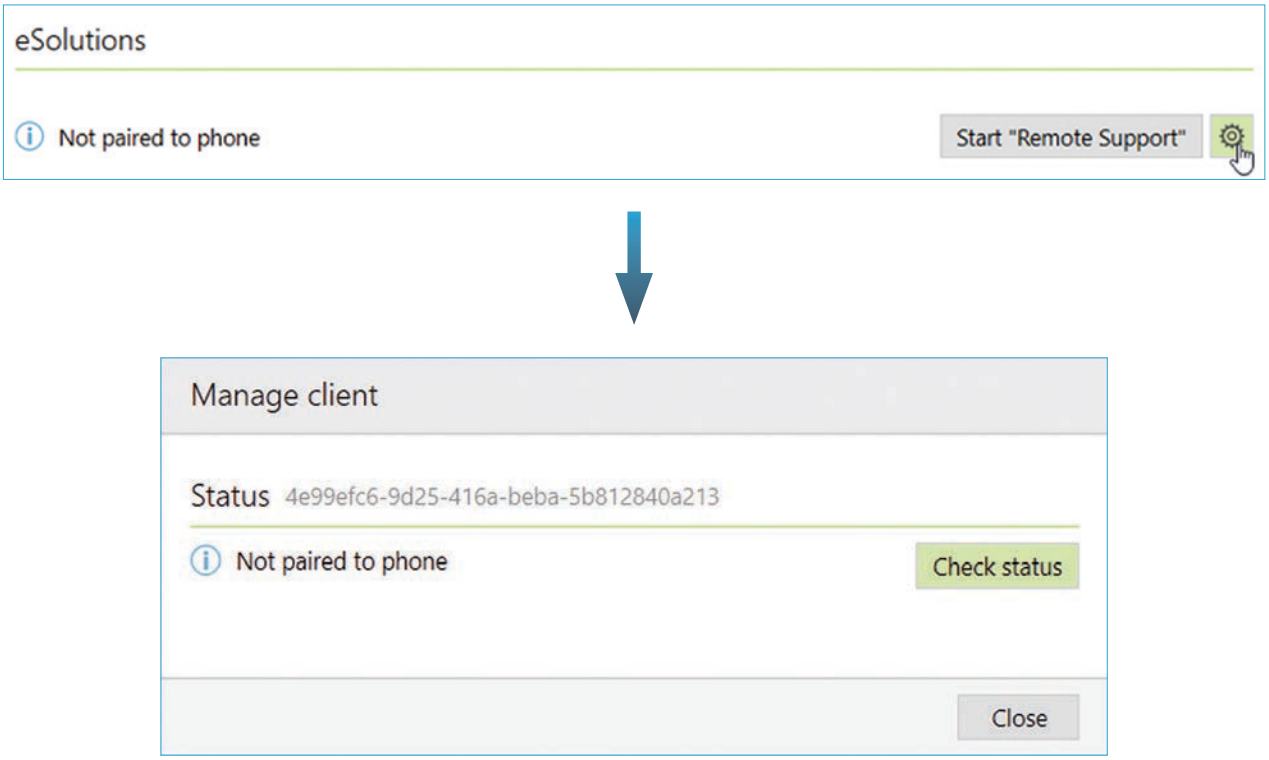
During a Remote Programming session:

- When a recipient joins the Remote Programming session, ensure good visibility in the Remote Support video window for the hearing care provider and the recipient. Adjust camera angle or body position as needed.
- Ensure audio quality is adequate. Adjust the microphone or volume settings, if needed.
- To ensure good visibility within Target CI during Remote Programming, undock the Remote Support window (option found in menu in top left of the Remote Support window) and move to another location on the screen, if needed.
- Encourage recipients to set their phone to *Do not disturb* prior to the remote programming session.
- Encourage recipients to remain in the AB Remote Support app for the entire programming session and communicate with their HCP if they must navigate away from the app (e.g., changing phone settings) to minimize disruptions during programming and prevent ending the session prematurely.
- Notify the recipient when sound will be muted (e.g., when connecting, saving, etc.) so they do not think the wireless connection has been lost.
- Provide access to a loudness scaling chart for the recipients to utilize during the remote programming session.

TROUBLESHOOTING

Not paired to the phone displayed in Target CI after the recipient has paired to the AB Remote Support app and initiated a Remote Programming session by selecting *Join waiting room*.

- Select *Manage client* and then select *Check status*.



- Select *Close* after pairing has been recognized in Target CI.

If sound quality is poor, try the following:

- Adjust the microphone and/or volume settings
- End the call and establish a new video connection

If video quality is poor, check that:

- There is a high quality internet connection
- Computer manufacturer updates have been installed

Recipient loses connection during the programming session.

The Remote Programming session is still open for the hearing care professional. To reconnect, the recipient needs to:

- Reopen the AB Remote Support app.
- Join the Remote Programming session.
- Resume participation in the Remote Programming session.

No Remote Support ID available is displayed under eSolutions in Target CI

Remote Programming is not available because the initial fitting in Target CI v1.5 or later has not been saved or because the client file was imported from Target CI v1.0 and the recipient has not been programmed in Target CI v1.5 or later. To enable Remote Programming, the recipient needs to be programmed in-person in Target CI v1.5 or later. on a programming computer that is connected to the internet.

Supporting the Recipient with Connection or Pairing Issues in the AB Remote Support app

- Ensure Bluetooth® is enabled and that all pairing requests are accepted when pairing devices within the AB Remote Support app.
- Forget Bluetooth® pairings on the phone/tablet and in the AB Remote Support app for devices no longer in use (e.g., sound processors that have been replaced).
- Ensure that the hearing instrument battery is fully engaged and adequately charged.
- Forget Bluetooth® pairing on the phone/tablet for the current instrument(s) and re-pair instrument(s) to the AB Remote Support app.
  - This will require re-pairing device with phone for Bluetooth® streaming function and potentially connection with other apps in use on phone (e.g., AB Remote app).

    NOTE: If the wireless network connection status is poor, encourage recipient to see whether a better connection may be established (e.g., move to another location, turn off video camera or power down/remove possible interfering devices).
- If the recipient is using more than one set of hearing instruments with the AB Remote Mobile app, the recipient may need to switch between devices. The recipient can go to *Settings > Manage Devices* to see which hearing instrument is paired. If the incorrect hearing instrument is paired, the recipient can go to *Settings > Pair hearing devices* to connect to a different hearing instrument.

If you require more information about Remote Programming in Target CI, please contact your local AB support.

AB Remote Support app
QUICK START GUIDE

The AB Remote Support app[1] allows you to virtually meet with your hearing care professional in a video appointment and to conveniently program your Marvel devices. First, contact your clinic to arrange a virtual appointment. Then, follow the simple steps below to prepare for the remote session.

STEP 1: DOWNLOAD THE AB REMOTE SUPPORT APP

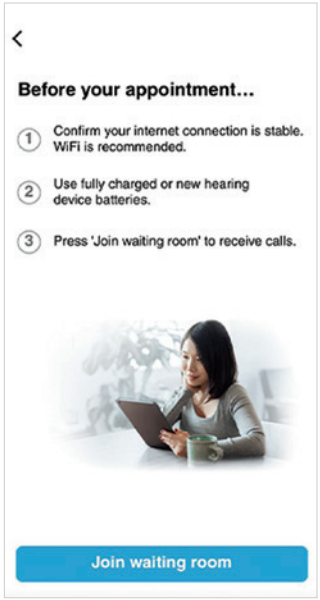
- From the app store, download the AB Remote Support app.
  Note: The AB Remote Support app is compatible with Apple iOS 14 and Android OS 6 or higher.

STEP 2: PAIR MARVEL DEVICE(S) TO AB REMOTE SUPPORT APP

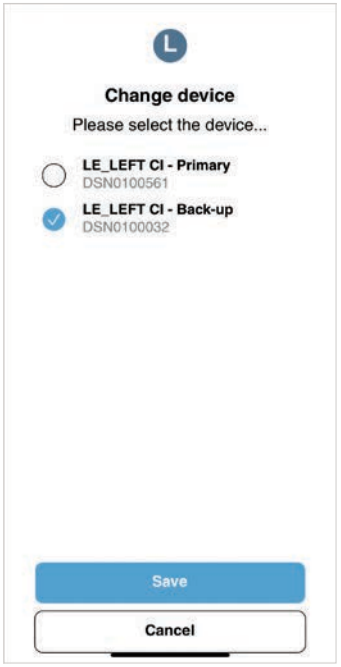
- Turn on Bluetooth® on your phone.
- Open the AB Remote Support app, and tap *Let's Get Started*.
- Remove and reattach the battery for each hearing device to enable Bluetooth pairing mode. Then, tap *Continue* in the AB Remote Support app.
- Select the device(s) found in the app; then, select *Done*.
  Note: Navigate to *Settings > Pair new devices*; then follow the above instructions to pair any back-up devices.
  Note: The CROS device does not pair to the Remote Support app for Remote Programming.
- Once pairing is complete, you are ready for the Remote Programming session.

STEP 3: PARTICIPATE IN THE REMOTE PROGRAMMING SESSION

- When joining the remote session at the pre-determined appointment time, select the *Appointment* icon, then select *Continue* > *Join waiting room*.
  NOTE: The first time you join, the AB Remote Support app will prompt you to allow access to your phone's camera and microphone. Select *OK*, when prompted; then allow access to your camera in the phone settings.
- When your hearing care professional joins, select *Join* to start the session.
- You and your hearing care professional will be able to see each other through the video. You will hear your hearing care professional through the phone speaker.
- Participate in the remote session to program and adjust your device settings, just as you would in an in-person programming session.
  NOTE: When loudness measurements are conducted, you will not hear sounds in the environment. Use the AB Loudness Rating Chart to provide feedback about the loudness levels.
- Select *Done* after your hearing care professional ends the session.



REMOTE PROGRAMMING FOR BACK-UP DEVICES



Complete the following steps after your hearing care professional indicates that it is time to program your back-up processor.

- Select to end the video call.
- Select *Leave* appointment; then, select *Done*.
- Select the < at the top of the screen.
- Select *Devices* at the bottom of the screen.
- Remove the battery from the primary processor and place the battery on the back-up processor.
- Select the blue *Change* button beneath the processor(s).
  NOTE: All devices must be paired in order to see the blue *Change* button. See Step 2 above.
- From the menu, select the back-up device.
- Select *Save*; then, rejoin the appointment by navigating to the Appointment tab and selecting *Continue*.
- Follow the steps in the AB Remote Support app to rejoin the Remote Programming session.
- The hearing care professional may proceed with programming at this time.

Considerations for a successful remote programming session

- Choose a quiet room to reduce distractions and background noise.
- Ensure that your cell phone connection is stable. Wi-Fi is recommended.
- Use a fully-charged battery for your hearing device(s).
- Charge your cell phone before the appointment.
- Turn on the *Do Not Disturb* function on your phone prior to the appointment. Accepting an incoming call or clicking on a notification will put the virtual appointment on hold.
- For Troubleshooting Tips, select *See device instructions* in the app.

Scan the QR code to watch a short video on the AB Remote Support app. If you require more information about the AB Remote Support app, please contact your hearing care professional or local AB support.

DOWNLOAD THE AB REMOTE SUPPORT APP

The AB Remote Support app is available for free for both iOS and Android devices.

Download on the App Store

GET IT ON Google Play

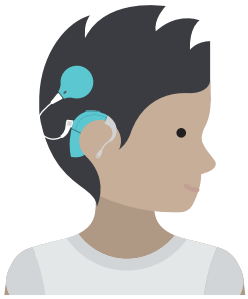
Marvel CI Connectivity
QUICK REFERENCE GUIDE

Marvel CI provides numerous ways for recipients to stream audio from their favorite devices and connect with the ones they love. With Marvel CI, recipients can stream using Bluetooth®, Roger™, and AirStream technologies. This clinical resource is designed to identify which streaming options are available for the recipient based on which hearing instrument the recipient is using with Marvel CI.

NAÍDA CI M90 on one side

		BLUETOOTH	ROGER	AIRSTREAM
RECOMMENDED ON OTHER SIDE	Naída CI M90 Phonak Naída Link M	**Bilateral/Bimodal streaming** via integrated Bluetooth	**Bilateral/Bimodal streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into each device via Roger iN microphone or via Roger X + Roger installer	**Bilateral/Bimodal streaming** with Phonak TV Connector and Phonak PartnerMic
OTHER HEARING INSTRUMENTS	Sky CI M90 Phonak Paradise or Phonak Marvel HI	**Unilateral streaming** to the selected hearing instrument via integrated Bluetooth	**Bilateral/Bimodal streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into each device via Roger iN microphone or via Roger X + Roger installer	**Bilateral/Bimodal streaming** with Phonak TV Connector. **Unilateral streaming** to the paired hearing instrument with Phonak PartnerMic
	Naída CI Q90	**Unilateral streaming** to Naída CI M90 via integrated Bluetooth **OR** to Naída CI Q90 via Naída CI Connect, Roger 17[2], or Phonak ComPilot	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Naída CI M90 via Roger iN microphone or via Roger X + Roger installer and Roger 17 for Naída CI Q90	**Bilateral streaming** with Phonak TV Connector when Naída CI Connect is attached to Naída CI Q90. **Unilateral streaming** to Naída CI M90 with Phonak PartnerMic
	Phonak Naída Link Q	**Unilateral streaming** to Naída CI M90 via integrated Bluetooth **OR** to Phonak Naída Link Q via Roger 10 (Link UP)[2], Roger 15 (Link RIC)[2] or Phonak ComPilot	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Naída CI M90 via Roger iN microphone or via Roger X + Roger installer and Roger 10 (Link UP), Roger 15 (Link RIC) attached to Naída Link Q	**Unilateral streaming** to Naída CI M90 via Phonak TV Connector and Phonak PartnerMic
	Chorus	**Unilateral streaming** to Naída CI M90 via integrated Bluetooth **OR** to Chorus via integrated Roger[2]	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Naída CI M90 via Roger iN microphone or via Roger X + Roger Installer. Roger 02 is integrated into Chorus.	**Unilateral streaming** to Naída CI M90 via Phonak TV Connector and Phonak PartnerMic

1. Bluetooth on Roger microphone should be disabled because Phonak Marvel and Phonak Paradise technologies have integrated Bluetooth.
2. Requires a Roger microphone with Bluetooth



SKY CI M90 on one side

		BLUETOOTH	ROGER	AIRSTREAM
RECOMMENDED ON OTHER SIDE	Sky CI M90 Phonak Sky Link M	**Bilateral/Bimodal streaming** via integrated Bluetooth	**Bilateral/Bimodal streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into each device via Roger iN microphone or via Roger X + Roger installer	**Bilateral/Bimodal streaming** with Phonak TV Connector and Phonak PartnerMic
OTHER HEARING INSTRUMENTS	Naída CI M90 Phonak Paradise or Phonak Marvel HI	**Unilateral streaming** to the selected hearing instrument via integrated Bluetooth	**Bilateral/Bimodal streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into each device via Roger iN microphone or via Roger X + Roger installer	**Bilateral/Bimodal streaming** with Phonak TV Connector. **Unilateral streaming** to the paired hearing instrument with Phonak PartnerMic
	Naída CI Q90	**Unilateral streaming** to Sky CI M90 via integrated Bluetooth **OR** To Naída CI Q90 via Naída CI Connect, Roger 17[2], or Phonak ComPilot	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Sky CI M90 via Roger iN microphone or via Roger X + Roger installer and Roger 17 for Naída CI Q90	**Bilateral streaming** with Phonak TV Connector when Naída CI Connect is attached to Naída CI Q90. **Unilateral streaming** to Sky CI M90 with Phonak PartnerMic
	Phonak Naída Link Q	**Unilateral streaming** to Sky CI M90 via integrated Bluetooth **OR** To Phonak Naída Link Q via Roger 10 (Link UP)[2], Roger 15 (Link RIC)[2] or Phonak ComPilot	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Sky CI M90 via Roger iN microphone or via Roger X + Roger installer and Roger 10 (Link UP), or Roger 15 (Link RIC) attached to Naída Link Q	**Unilateral streaming** to Sky CI M90 via Phonak TV Connector and Phonak PartnerMic
	Chorus	**Unilateral streaming** to Sky CI M90 via integrated Bluetooth **OR** To Chorus via integrated Roger[2]	**Bilateral streaming** (Roger mic input only)[1] Microphones: any Roger iN or Roger microphone[1] Receivers: Roger installed into Sky CI M90. Roger 02 is integrated into Chorus.	**Unilateral streaming** to Sky CI M90 via Phonak TV Connector and Phonak PartnerMic

1. Bluetooth on Roger microphone should be disabled because Phonak Marvel and Phonak Paradise technologies have integrated Bluetooth.
2. Requires a Roger microphone with Bluetooth

Target CI
KEYBOARD SHORTCUTS

MAPPING KEYBOARD BINDINGS

KEY	ACTION
F	Stop All Stimulation
Page Down	Adjust All Markers Down
Page Up	Adjust All Markers Up
Down Arrow	Adjust Selected Markers Down (M, T, Clipping)
Up Arrow	Adjust Selected Markers Up (M, T, Clipping)
L or Ctrl + Left Arrow	Bilateral Window: Focus Left Side
R or Ctrl + Right Arrow	Bilateral Window: Focus Right Side
0-9	Data Entry
Alt + Left Arrow	Move Entire Channel Selection to the Left
Alt + Right Arrow	Move Entire Channel Selection to the Right
Left Arrow	Move Selection Left
Right Arrow	Move Selection Right
Ctrl + A	Select All Markers
C	Select Clipping Marker
G (goes to Map Input Gain tab)	Select Gain Marker
M	Select M Marker
T	Select T Marker
Shift + Left Arrow	Select Multiple Channels to the Left
Shift + Right Arrow	Select Multiple Channels to the Right
S	Toggle Stimulation On/Off
Ctrl + Z	Undo
Ctrl + Y	Redo
Shift + Tab *(must press Enter to confirm electrode selection)*	Move Numerical Data Entry Selection Left
Tab *(must press Enter to confirm electrode selection)*	Move Numerical Data Entry Selection Left

NRI KEYBOARD BINDINGS

KEY	ACTION
F	Stop All Stimulation
Page Down	Adjust All Markers Down
Page Up	Adjust All Markers Up
Down Arrow	Adjust Selected Markers Down
Up Arrow	Adjust Selected Markers Up
0-9	Data Entry
Alt + Left Arrow	Move Entire Channel Selection to the Left
Alt + Right Arrow	Move Entire Channel Selection to the Right
Left Arrow	Move Selection Left
Right Arrow	Move Selection Right
Ctrl + A	Select All Markers
H	Select High Marker
L	Select Low Marker
Shift + Left Arrow	Select Multiple Channels to the Left
Shift + Right Arrow	Select Multiple Channels to the Right
S	Toggle Measurement On/Off

Notes

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ADVANCED BIONICS
POWERFUL CONNECTIONS

028-Q069-02 Rev D

CLINICAL RESEARCH

Optimizing Hearing for Listeners with a Cochlear Implant and Contralateral Hearing Aid

Adaptive Phonak Digital Bimodal Fitting Formula

With the introduction of the Phonak Naída™ Link hearing aid, a new era in bimodal hearing has begun. Unilateral Advanced Bionics (AB) Naída cochlear implant recipients who can use a contralateral hearing aid will have access to (1) technologies that have been designed specifically to work together across the two devices and (2) the listening advantages of Binaural VoiceStream Technology™.

A new Phonak prescriptive fitting formula has been developed for the Naida Link to align the frequency response, loudness growth functions, and automatic gain control (AGC) characteristics between the Naída CI processor and the hearing aid. The objective is to provide the best hearing experience for AB bimodal listeners while at the same time making it easy for audiologists to program the Naída Link.

Why a new prescriptive fitting formula?

First, combined electric and contralateral acoustic stimulation provides substantial benefits to bimodal listeners, including better speech understanding in noise and voice pitch perception, enhanced localization abilities, and improved music perception.[1-3] However, conventional hearing aid prescriptions (e.g., NAL-NL2, DSL v5) do not align acoustic and electric processing, which is required for optimal bimodal hearing. For example, traditional fitting prescriptions focus amplification in frequency regions that are important for speech understanding (1 – 4 kHz), whereas low frequencies (250 – 750 Hz) may be most important for maximizing bimodal benefit.[4] Moreover, low compression kneepoints (CK < 50 dB SPL) and moderate compression ratios (CR ~ 2:1) are usually prescribed for hearing aids, while cochlear implants use very different input/output functions (e.g., Naída CI: CK = 63 dB, CR = 12:1). Finally, the dynamic behavior of AGC systems differs substantially between devices. Hearing aids typically implement syllabic compression (attack/release time < 50 ms), whereas cochlear implants use slow-acting automatic gain control (attack/release > 1 sec). Thus, using traditional fitting prescriptions for a hearing aid may cause misaligned frequency response, loudness growth, and dynamic behavior for bimodal listeners.

Second, fitting a hearing aid to work with a cochlear implant can be a time-consuming iterative procedure.[5] Thus, the audiologist must have expertise with both hearing aid and cochlear implant fitting software, and may spend considerable time fitting both devices.

Therefore, a prescriptive hearing aid fitting formula has been developed to:

- Optimize hearing for AB bimodal listeners.
- Make it easy and efficient for audiologists to fit the Naída Link.

How does the new fitting formula work?

Because the cochlear implant is the dominant provider of sound information to most bimodal listeners, the overall design goal was to align the hearing aid parameters with the cochlear implant. Specifically, modifications to a standard hearing aid prescription were implemented to align frequency response,

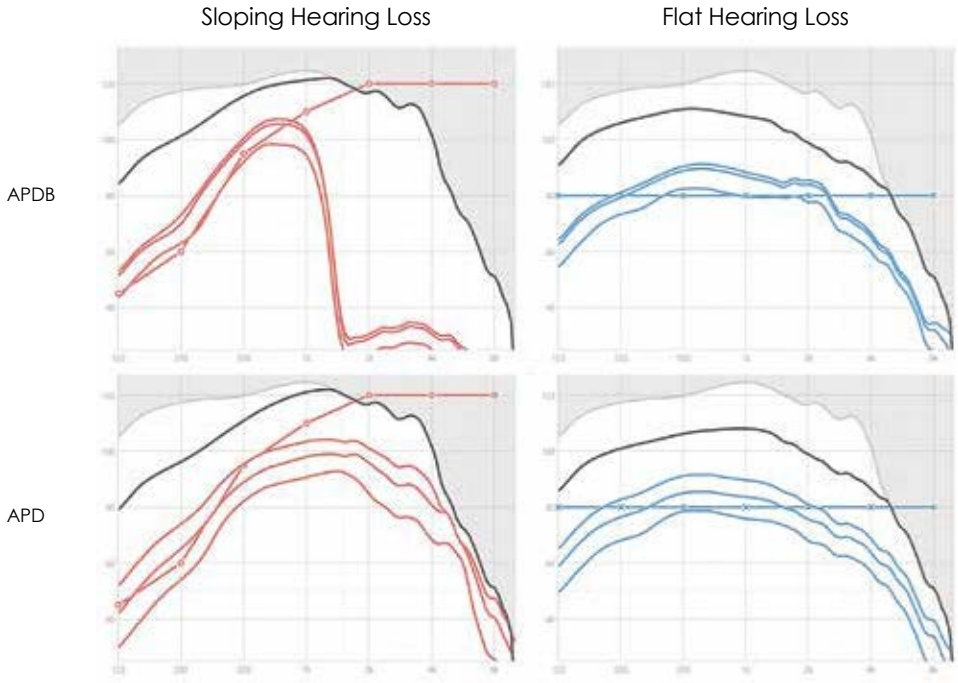

Figure. *Adaptive Phonak Digital Bimodal (APDB) and Adaptive Phonak Digital (APD) prescribed output for speech at 50, 65, and 80 dB SPL (thin lines) for a sloping and a flat hearing loss. Broken lines indicate audiometric thresholds.*

loudness growth, and dynamic behavior between the two devices. The resulting fitting formula is termed Adaptive Phonak Digital Bimodal (APDB).

The Adaptive Phonak Digital fitting formula is used as a starting point because this formula is used commonly in clinical practice for severe and profound hearing losses.[6] Three modifications are made.

First, the frequency response is adjusted to optimize low-frequency gain and bandwidth. Low-frequency gain optimization uses the model of effective audibility to ensure audibility of cues that contribute to speech understanding even in relatively quiet environments (55 dB SPL).[7] Depending upon the configuration of the audiogram, this step often results in a gain increase below 1 kHz. This gain increase is limited to make sure that speech at 65 dB SPL does not exceed the most comfortable level. Note that for certain hearing loss configurations (reversed, mild-to-moderate sloping, and flat losses), this gain increase will not be applied. Bandwidth is optimized by ensuring that (1) bandwidth is as wide as possible[8], (2) frequencies between 250 and 750 are audible[4], and (3) amplification does not extend into dead regions[9].

Second, loudness growth is aligned by implementing the input-output function of the cochlear implant in the hearing aid (CK = 63 dB SPL, CR = 12:1). And third, the dynamic compression behavior is aligned by porting the Naída CI dual-loop AGC into the hearing aid.[10] All three modifications were verified and optimized in a series of experiments with bimodal listeners (see Call Out box).

Comparisons of the Adaptive Phonak Digital (APD) and Adaptive Phonak Digital Bimodal (APDB) fitting results are shown in the figure above for a flat and a sloping hearing loss. There are almost no differences in frequency response between the two formulae for the flat audiogram. In contrast, the bandwidth is limited by APDB for the sloping audiogram because a dead region was identified. Alignment of loudness growth is reflected in the fact that output curves for speech with 65 dB SPL and 80 dB are very close for APDB, whereas APD prescribes clearly different output.

What steps are required to program the Naída Link?

Programming a Naída™ Link with Phonak Target programming software is easy. To take advantage of the optimized frequency response, loudness growth, and dynamic behavior, the fitter only needs to connect a Naida Link to Target. By default APDB is selected and will offer these benefits to bimodal listeners.

Conclusion

A new prescriptive Adaptive Phonak Digital Bimodal (APDB) fitting formula optimizes hearing for AB bimodal listeners by (1) adjusting the frequency response of the Naída™ Link in the acoustic-hearing ear, (2) aligning the loudness growth between the Naída CI processor and the Naída Link, and (3) synchronizing the dynamic behavior between the two devices. In most cases, optimum bandwidth and balanced loudness is achieved automatically when using the APDB fitting formula. APDB now is implemented in the Phonak Target software so that the Naída Link can be programmed using simple, easy-to-execute steps.

VERIFICATION AND OPTIMIZATION OF THE APDB FITTING FORMULA

Because bimodal listeners are not homogeneous, a series of studies was conducted to determine which hearing aid program modifications should be applied depending upon hearing loss and hearing aid configuration. Experiments were conducted at seven research sites in Belgium, Germany, the Netherlands, and the United States. Participant audiograms ranged from profound hearing loss (little aidable hearing at 125 and 250 Hz) to flat and sloping moderate losses (aidable hearing up to 4 kHz). Outcome measures included speech understanding in noise, sound quality ratings, and subjective preference. A randomized crossover design was applied whenever possible to evaluate the effect of bimodal fitting modifications both acutely and chronically. Results from two of these studies are summarized here.

Frequency Response Adjustment
(Advanced Bionics LLC, Valencia, USA, Chalupper et al. 2013[10])

Seven experienced bimodal subjects (aidable hearing < 750 Hz) were tested in noise (AzBio sentences at signal-to-noise ratios that resulted in scores 50% of their scores in quiet using the implant alone) using their own hearing aid program, and a hearing aid programmed with APD, NAL-RP, a bimodal formula with aligned frequency response based on the audiogram configuration, and a bimodal formula with aligned frequency response using the result of the TEN–Test to identify dead regions. Best sentence scores in noise were seen with the bimodal formula without the TEN-Test (Figure 1). The bimodal formula outperformed both APD and NAL-RP. Administering the TEN-Test to assess dead regions did not further improve bimodal benefit because the APDB correctly identified dead regions based on the audiogram.

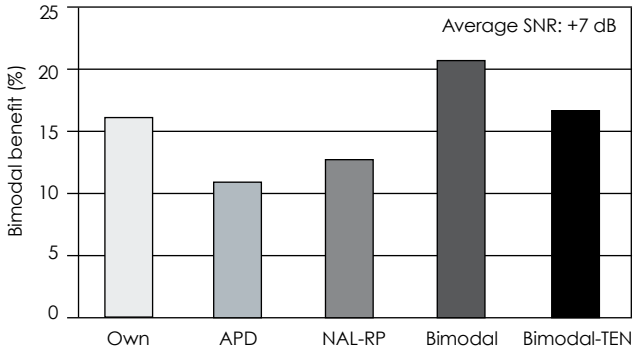

Figure 1. *Bimodal benefit (bimodal sentence score minus sentence score with cochlear implant alone) for five hearing aid fitting programs: subject's own, Phonak APD, NAL-RP, bimodal formula based on audiogram configuration, and bimodal formula based on the TEN-Test.*

AGC Alignment *(Radboud University Nijmegen, the Netherlands, Veugen et al. 2016[11])*

Fifteen experienced bimodal subjects were tested bimodally in noise (adaptive LIST test) using a hearing aid programmed with a standard Phonak AGC (syllabic) and an AGC aligned with the Naída CI processor. With target speech from the front, the aligned AGC improved speech understanding by 1.6–2.9 dB (median) compared to the standard Phonak AGC depending upon where the competing talker noise originated. When noise was presented on the hearing aid side (S0NHA), a larger improvement was achieved compared to noise presented on the CI side (S0NCI) or from both sides (S0N+/-90) (Figure 2). The vast majority of subjects preferred the aligned AGC over the standard AGC (only one patient preferred standard AGC). Take-home questionnaires did not show any changes over time, suggesting no effect of acclimatization. Questionnaires also indicated that the AGC-matched hearing aid was ranked significantly better for understanding one person in quiet, understanding one person in noise, and hearing the timbre of sounds.

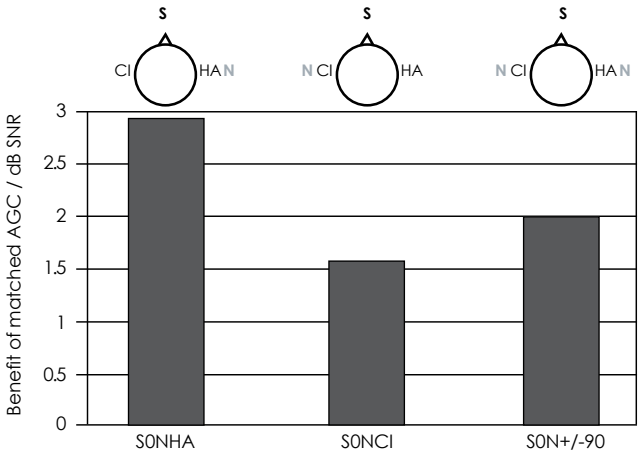

Figure 2. *Benefit of aligned AGC compared to Phonak AGC for understanding speech in noise in three listening configurations.*

REFERENCES

1. Dorman MF, Gifford RH, Spahr AJ, McKarns SA. (2008) The benefits of combining acoustic and electric stimulation for the recognition of speech, voice and melodies. Audiology and Neurotology 13:105-112.

2. Straatman LV, Rietveld AC, Beijen J, Mylanus EA, Mens LH. (2010) Advantage of bimodal fitting in prosody perception for children using a cochlear implant and a hearing aid. Journal of the Acoustical Society of America 128:1884-1895.

3. Tyler RS, Parkinson AJ, Wilson BS, Witt S, Preece JP, Noble W. (2002) Patients utilizing a hearing aid and a cochlear implant: Speech perception and localization. Ear and Hearing 23:98-105.

4. Sheffield SW, Gifford RH. (2014) The benefits of bimodal hearing: effect of frequency region and acoustic bandwidth. Audiology and Neurotology 19(3):151-163.

5. Ching TY, van Wanrooy E, Dillon H. (2007) Binaural-bimodal fitting or bilateral implantation for managing severe to profound deafness: a review. Trends in Amplification 11:161–192.

6. Scherf F, Arnold LP. (2014) Exploring the clinical approach to the bimodal fitting of hearing aids and cochlear implants: results of an international survey. Acta Otolaryngologica 134(11):1151-1157.

7. Ching TY, Dillon H, Katsch R, Byrne D. (2001) Maximizing effective audibility in hearing aid fitting. Ear and Hearing 22(3): 212-224.

8. Neuman AC, Svirsky MA. (2013) Effect of hearing aid bandwidth on speech recognition performance of listeners using a cochlear implant and contralateral hearing aid (bimodal hearing). Ear and Hearing 34(5):553-561.

9. Zhang T, Dorman MF, Gifford R, Moore BCJ. (2014) Cochlear dead regions constrain the benefit of combining acoustic stimulation with electric stimulation. Ear and Hearing 35: 410–417.

10. Chalupper J, Agrawal S, Fredelake S, Spahr T. Rationale and implementation of a bimodal fitting formula. Presented at the Conference on Implantable Auditory Prostheses, Lake Tahoe, CA, 14-19 July 2013. Figshare: http://dxdoiorg/106084/m9figshare1340020 2015.

11. Veugen LC, Chalupper J, Snik AF, van Opstal AJ, Mens LH. (2016) Matching automatic gain control across devices in bimodal cochlear implant users. Ear and Hearing 37: 260-270.

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Real-Ear Verification of the Phonak Naída™ Link
WITH AUDIOSCAN VERIFIT2

Understanding the use of the Adaptive Phonak Digital Bimodal fitting formula:

THE ADAPTIVE PHONAK DIGITAL BIMODAL FITTING FORMULA (APDBFF)

The Adaptive Phonak Digital Bimodal fitting formula (APDBFF) is specifically designed to meet the needs of bimodal cochlear implant (CI) recipients (individuals with a cochlear implant in one ear and a hearing aid in the other). The APDBFF differs from traditional fitting formulas, allowing bimodal recipients to take full advantage aligned signal processing between the Naída™ Link hearing aid (HA) and Advanced Bionics CI sound processors. For the bimodal listener, low frequencies (250-750 Hz) may be the most important to maximize bimodal benefit. The APDBFF focuses on more gain in this range, unlike traditional formulas that attempt to apply a significant amount of amplification in the high frequencies (1-4 kHz). Using traditional prescriptions for a bimodal fitting may cause misaligned frequency response, loudness growth, and dynamic behavior and is therefore not recommended.

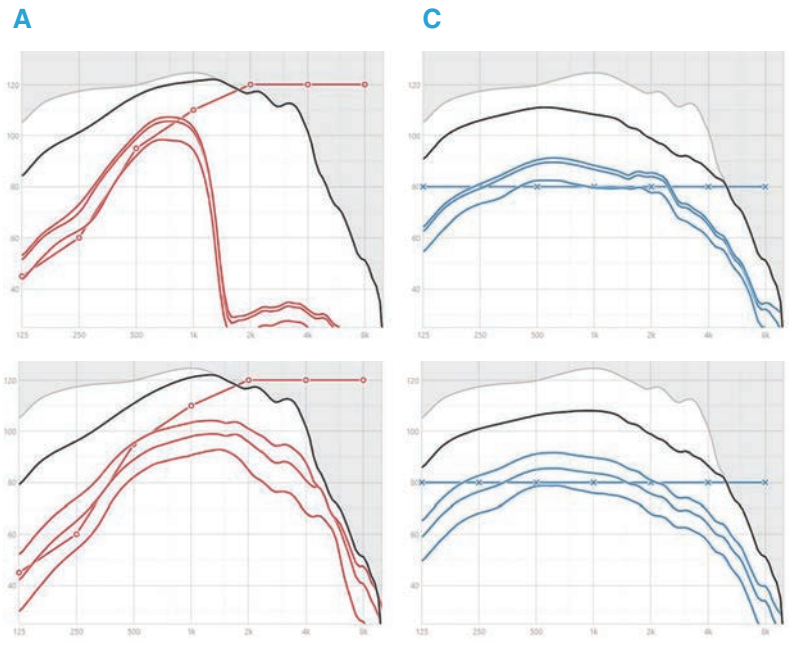
PROVEN BENEFIT

A study involving eleven unilateral CI users (6 adults, 5 children) with aidable hearing in the contralateral ear demonstrated the superiority of the APDBFF. Speech intelligibility was evaluated in quiet and noise using participants' own HAs fitted with NAL-NL1 and then with the Naída Link HA fitted with APDBFF and NAL-NL1 formulas. The results were clear: the APDBFF significantly improved speech intelligibility in quiet and noise, outperforming participants' HAs*. Furthermore, speech intelligibility with the APDBFF was significantly better than NAL-NL1 in noisy environments. At the conclusion of the study, ten out of eleven participants chose to continue using the APDBFF.

REAL-EAR VERIFICATION

The output of the Naída Link HA using the APDBFF is different from that obtained with traditional formulas such as DSL and NAL-NL1. Real-ear verification equipment does not account for these expected differences in output and should not be used to adjust the fitting of the Naída Link HA.

If a clinic is considering real-ear verification with the Naída Link HA and the APDBFF, it is important to understand the process of conducting real-ear verification with a proprietary fitting formula. The guidelines that follow are slightly different from those of a traditional fitting formula, as there are no defined "targets" for APDBFF in real-ear verification equipment. This distinction is crucial to ensure accurate and effective use of the APDBFF.



Prescribed output for speech of 50, 65 and 80 dB SPL for:

A. Sloping loss with Adaptive Phonak Digital Bimodal

B. Sloping loss with Adaptive Phonak Digital

C. Flat loss with Adaptive Phonak Digital Bimodal

D. Flat loss with Adaptive Phonak Digital

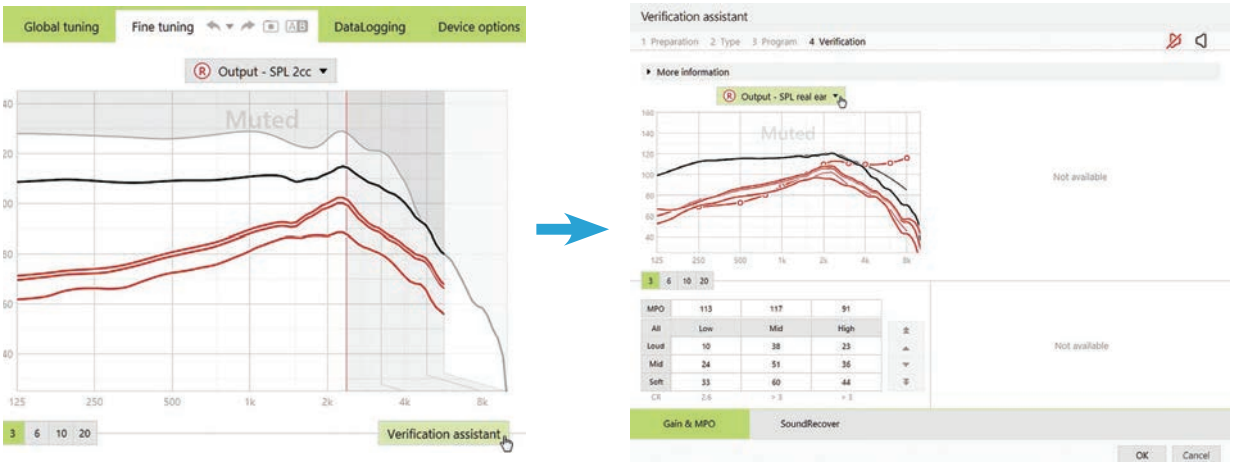
*Auletta, G., Franzè, A., Laria, C., Piccolo, C., Papa, C., Riccardi, P., Pisani, D., Sarnelli, A., Del Vecchio, V., Malesci, R., & Marciano, E. (2021). Integrated Bimodal Fitting for Unilateral CI Users with Residual Contralateral Hearing. Audiology research, 11(2), 200–206. https://doi.org/10.3390/audiolres11020018

Real-Ear Verification of the Phonak Naída™ Link
WITH AUDIOSCAN VERIFIT2

General Steps for performing Speechmapping with the Adaptive Phonak Digital Bimodal fitting formula:

1. Enter the relevant patient details into the verification system. Indicate the fit is “Binaural”. Do not select a target (i.e. NAL-NL2). Prepare the recipient for real-ear verification.

2. Enter the Verification Assistant in the Phonak Target software from the Fine Tuning tab to turn off adaptive features in the Phonak Naída Link during verification. Follow the on-screen instructions to prepare the hearing aid for verification.



Make sure the displays are set to your preferred view (Gain or Output; real-ear or 2cc coupler).

3. Obtain the Long Term Average Speech Spectrum (LTASS) curves for speech input at soft (50 dB) and moderate (65 dB) levels. Present the signal for a minimum of five seconds before recording the measurement in order to allow for signal processing parameters like attack time to fully engage.

4. Run the MPO test (loud input) to ensure UCL is not exceeded.

5. If SoundRecover is being utilized, consider using the 4000 Hz and/or 6300 Hz input for verification.

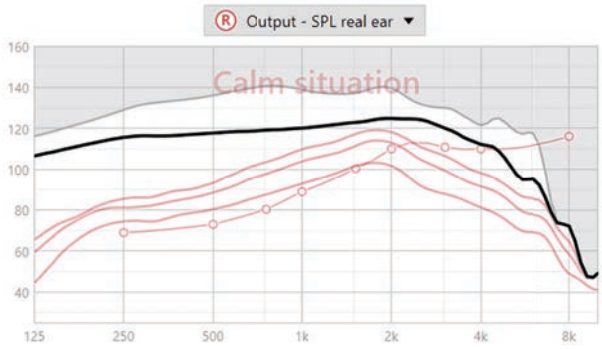
6. Depending on the results of steps 3-5, make gain adjustments in Target as appropriate (see next section for additional considerations). Repeat steps 3 – 5 as needed.

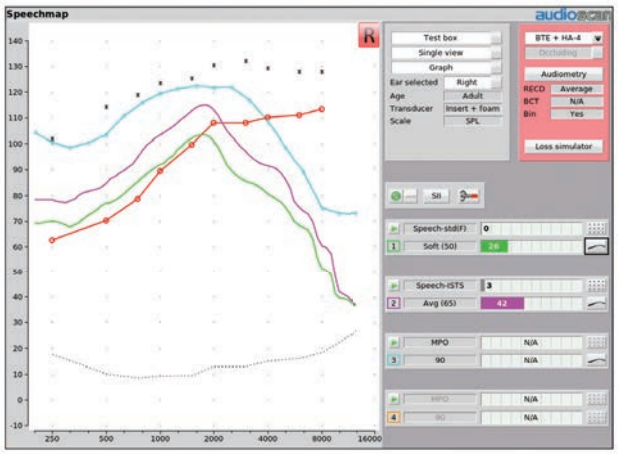
Real-Ear Verification of the Phonak Naída™ Link
WITH AUDIOSCAN VERIFIT2

Interpretation of Speechmapping results
(specific to Phonak Naída Link with the Adaptive Phonak Digital Bimodal fitting formula):

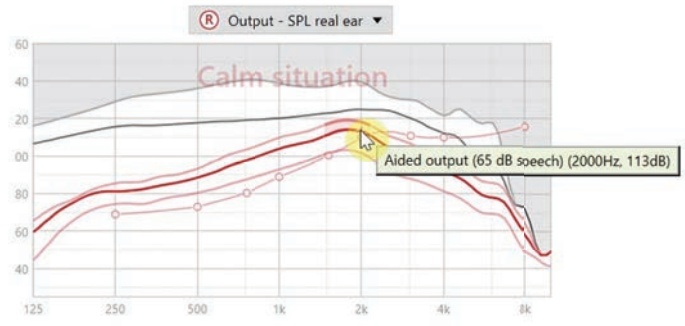
1. Expected vs. measured output or gain (for any level of hearing loss)

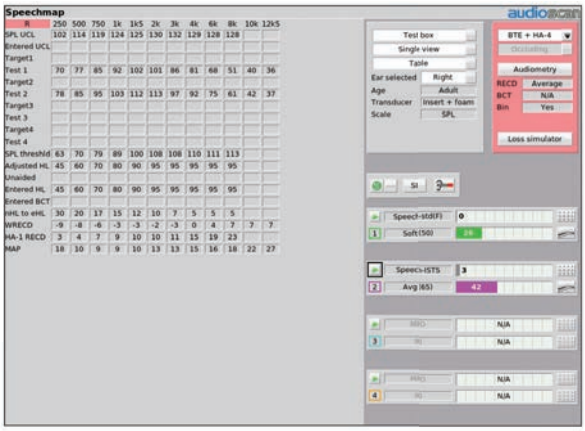
Compare prescribed hearing aid output/gain curves from Target to the hearing aid output or gain curves obtained in the ear. In the image below, you will observe that the curves obtained in the ear for soft, medium and loud input are similar to the predicted results from Target, as expected.





Or, compare predicted versus measured output/gain at specific frequencies. For example, in the image below, you see that predicted aided output for a 65 dB input at 2000 Hz is within 1 dB of the response obtained in the ear (though deviations within +/- 3 dB are acceptable).





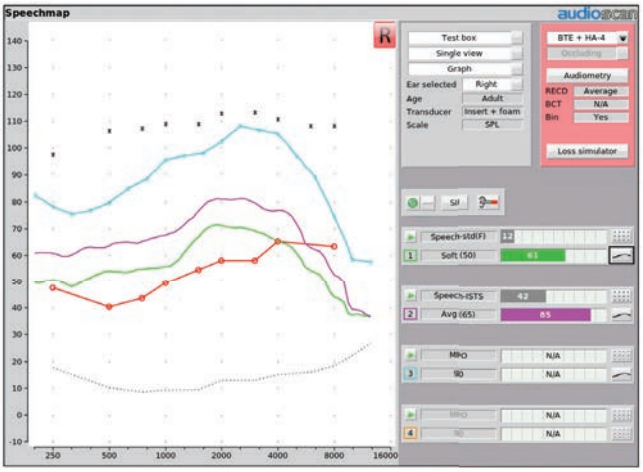
Determining that the hearing aid is performing in the ear as predicted by Target, based on the programming parameters, serves as a verification of appropriate function.

Real-Ear Verification of the Phonak Naída™ Link
WITH AUDIOSCAN VERIFIT2

Interpretation of Speechmapping results
(specific to Phonak Naída Link with the Adaptive Phonak Digital Bimodal fitting formula):

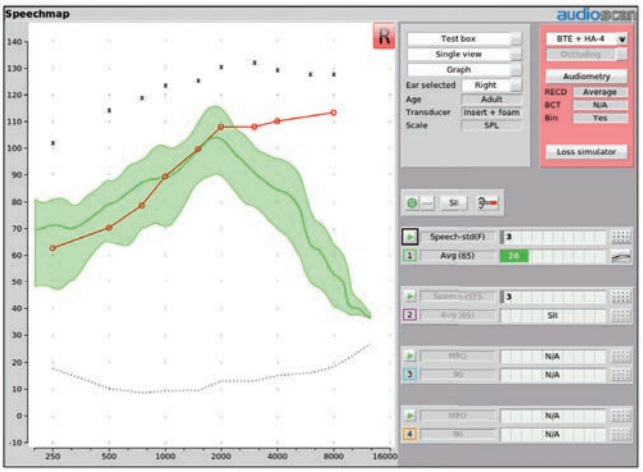
2. Assess audibility with the Speech Intelligibility Index (SII) (for mild-moderate flat losses)

- Soft speech (50 dB) LTASS should be at or slightly above (~3 dB) threshold (green line to the right).
- Moderate speech (65 dB) LTASS should generally be above threshold with an SII of approximately 70 (magenta line to the right).
- MPO should remain comfortably below UCL (blue line to the right).



Special considerations for steeply sloping losses:

When using the Adaptive Phonak Digital Bimodal fitting formula (APDBFF), specifically with individuals whose audiograms indicate cochlear dead regions, you may observe increased gain in the low frequencies and very little gain in the areas of suspected cochlear dead regions. This is expected and appropriate with the Naída bimodal hearing solution. Audibility in the high-frequencies is not the goal when fitting with the APDBFF, and in fact may be counter-productive in the case of cochlear dead regions. Verify your fitting using the first method above to ensure the hearing aid output is as predicted in Target, but do not adjust the high frequency output of the Naída Link. The APDBFF is intended to deliver the optimal gain for bimodal users with the Naída Link hearing aid.



ADVANCED BIONICS
POWERFUL CONNECTIONS

The Right Solution
AT THE RIGHT TIME

Marvel CI + Any Hearing Aid Any hearing aid can be worn with Marvel CI	Marvel CI + Phonak Hearing Aid Matching a Marvel CI with a Phonak HA adds extra benefits	Marvel CI + Link M Marvel CI with Link M is a Balanced Bimodal Solution
		Premium level technology plus the AB Advantage: Instantaneous broadband transfer of data between both devices ensures they are always balanced.
		Speech in 360° to detect where sounds are coming from and stream it to the other ear.
		One app controls both devices: balance volume and programs with one-touch control
	AutoSense AI in both devices	AutoSense AI in both devices: sounds are always classified the same in both ears
	Remote Programming of both devices	Simultaneous Remote Programming of both devices
	Hands-Free calling with either ear	Hands-Free calling with both ears, Acoustic Phones are heard in both ears
	Share accessories like TV Connector and Roger microphones	Share accessories such as: Partner Mic, TV Connector, & Roger microphones
Stream calls and entertainment to preferred ear	Universal connectivity from any Bluetooth® device to preferred ear	Universal connectivity from any Bluetooth® device to both ears
Timing: aligned by default	Timing: aligned by default	Synced Timing, compression and volume for Inter-Aural Comparison
Hearing with both ears may improve hearing	AB & Phonak devices utilize AI technology to hear better in noise	Excellent hearing – even in noise

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Integrated bimodal fitting and binaural streaming technology outcomes for unilateral cochlear implant users

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ORIGINAL ARTICLE

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Integrated bimodal fitting and binaural streaming technology outcomes for unilateral cochlear implant users

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ABSTRACT

Objective: Adults typically receive only one cochlear implant (CI) due to cost constraints, with a contralateral hearing aid recommended when there is aidable hearing. Standard hearing aids differ from a CI in terms of processing strategy and function as a separate entity, requiring the user to integrate the disparate signals. Integrated bimodal technology has recently been introduced to address this challenge. The aim of the study was to investigate the performance of unilateral CI users with and without an integrated bimodal fitting and determine whether binaural streaming technology offers additional benefit.

Study sample: Twenty-six CI users using integrated bimodal technology.

Design: Repeated measures where outcomes and user experience were assessed using a functional test battery more representative of real life listening (speech perception in noise tests, localisation test, tracking test) and the speech, spatial and qualities-of-hearing scale (SSQ).

Results: Bimodal outcomes were significantly better than for CI alone. Speech perception in noise improvements ranged from 1.4 dB to 3.5 dB depending on the location of speech and noise. The localisation and tracking tests, and the SSQ also showed significant improvements. Binaural streaming offered additional improvement (1.2 dB to 6.1 dB on the different speech tests).

Conclusions: Integrated bimodal and binaural streaming technology improved the performance of unilateral CI users.

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KEYWORDS
Cochlear implant; hearing aid; integrated bimodal technology; real-life tests

Introduction

Hearing with both ears (binaural hearing) is important for spatial hearing in real-life listening environments, e.g. hearing in background noise and sound localisation. Providing the appropriate intervention for listeners with bilateral hearing loss can help restore some of the binaural functions of normal hearing. Research has shown that hearing-impaired listeners with bilateral hearing aid (HA) fittings have better binaural summation, binaural squelch, and head-shadow effects for speech understanding in noise (Bronkhorst and Plomp 1989) and superior localisation performance compared to those who have unilateral fittings (Byrne, Noble, and LePage 1992).

Adults with bilateral severe to profound hearing loss typically receive a single cochlear implant (CI) due to cost constraints. Bimodal hearing has become the standard care for adult unilateral CI users having residual hearing in their non-implanted ear, with the intention to restore some of the binaural hearing functions. Binaural summation, head-shadow effect and access to acoustic low-frequency information via the HA are primary underlying mechanisms for the bimodal hearing benefits (Ching et al. 2006; Berrettini et al. 2010; Veugen et al. 2016). However, research comparing bimodal and CI-alone performance has shown mixed outcomes and user benefit reports (Ching, Incerti, and Hill 2004; Dunn, Tyler, and Witt 2005; Berrettini et al. 2010; Bouccara et al. 2016; Devocht et al. 2020). Factors influencing bimodal benefit include loudness mismatch, differences in the signal-processing strategies used by CI and HA, and separate fitting of devices by different professionals at CI services and audiology departments.

Standard HAs are not specifically designed to work together with a CI. Consequently, bimodal technology users may experience temporal synchronisation difficulties and mismatch in stimulation place between the two cochleae (van Hoesel 2012; Francart and McDermott 2013). The HAs typically use multichannel fast-acting automatic gain control (AGC) whereas, the CI processors typically employ a single-channel dual-loop AGC system that incorporates both slow and fast-syllabic time-constant circuits (Vaerenberg et al. 2014; Spirrov et al. 2020). Veugen et al. (2016) assessed the effect of using a similar design of AGC in both the CI sound processor and HA to improve bimodal benefit. The parameters of CI AGC circuits were unmodified. However, the HA was programmed to have dual-action time constants approximating the dynamic properties of the CI processor and compression channels were coupled to mimic the signal-channel broadband compression in the CI

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processor. The results showed an improvement of speech perception in noise when the noise and speech were spatially separated, particularly when the noise was presented on the HA side.

Integrated bimodal technology

Sonova has developed an integrated bimodal system known as the Naida Link Bimodal system, which consists of the Advanced Bionics' Naida Q90 speech processor and Phonak Link UP HA. The two devices provide matched compression algorithms and time constants. This technology also uses a dedicated fitting formula, adaptive Phonak digital bimodal (APDB), which aligns the frequency response, loudness growth functions and AGC characteristics between the two devices. The alignment of frequency response is achieved by optimising low-frequency gain and bandwidth. Low-frequency gain is optimised by applying the model of effective audibility to ensure audibility of speech (55 dB SPL) in quiet environments (Advanced Bionics 2016). According to the audiometric profile, the gain is increased for frequencies below 1000 Hz compared to traditional HA fitting formulae, where the amplification is applied across the entire spectrum particularly in the frequency region required for speech understanding (1000–4000 Hz) (Cuda et al. 2019). Frequency bandwidth is optimised by making bandwidth as wide as possible for aidable frequencies (Neuman and Svirsky 2013), enhancing audibility of frequencies between 250 and 750 Hz, while ensuring that amplification does not extend into dead regions (Auletta et al. 2021). The loudness growth between the two devices is aligned by implementing the input-output function of the CI sound processors (compression knee point of 63 dB SPL and ratio of 12:1) in the HA. The AGC system is further aligned, in a dynamic sense, by porting the Naida CI dual loop AGC into the HA (Advanced Bionics 2016). The Naida CI processor has a single-channel dual-loop AGC system which includes both slow and fast attack-and-release time constants. To implement the latter compression system in the AGC of the HA, (1) the compression channels in the HA are coupled to mimic the single-channel compression, and (2) slow and fast time constants are applied in the HA (Vroegop et al. 2019).

Several studies (Vroegop et al. 2018; Cuda et al. 2019; Ernst et al. 2019; Vroegop et al. 2019; Holtmann et al. 2020; Warren et al. 2020; Auletta et al. 2021) assessed the benefits of integrated bimodal technology (Naida Link Bimodal system) for speech perception. Vroegop et al. (2018) measured the speech-reception threshold (SRT) in noise in both static and dynamic settings. The speech sentences were presented from the front loudspeaker placed at 0° azimuth for static conditions and randomly from either a loudspeaker at −45° or 45° for the dynamic condition. Four uncorrelated babble-noise maskers were presented from the loudspeakers placed at −45°, 45°, −135°, and 135°. There was no significant difference between using the CI only and using the CI with the Naida Link HA in static conditions. In contrast, there was a significant improvement in the SRT of 3.1 dB with integrated bimodal listening compared to the CI only in dynamic conditions. In a later study, Vroegop et al. (2019) found bimodal benefits of 1.6 dB and 2.5 dB when the noise was presented from the front, or the CI side respectively. There was no bimodal benefit when the noise was presented from the HA side. Similarly, Cuda et al. (2019) found a bimodal benefit of 3.9 dB for speech perception in noise when both the speech and noise were presented from the front speaker. Warren et al. (2020) also found a significant bimodal benefit of integrated fitting (approximately 19.2%) compared to using the CI only. However, the amount of bimodal benefit was highly variable (inter-subject variability), ranging from 1.5% to 61.4%. The results from these studies indicated that integrated bimodal technology could improve speech intelligibility in noise compared to using a CI only. However, the amount of benefit seems highly dependent on the location of the target speech and the noise masker.

Only one study has assessed the benefit of the integrated bimodal technology on localisation tasks as well as self-reported benefits using a subjective hearing-quality questionnaire (Holtmann et al. 2020). Four loudspeakers were placed at 0, 90, 180, and 270 degrees to assess the localisation performance using the Naida Link HA over the standard HA. There was no significant difference between the two HAs in localisation tests. The hearing implant sound quality index (HISQUI 19) showed a significant improvement of sound quality only at the end of the study (at 8-12 weeks after the Naida HA fitting). The Oldenburg inventory did not show any statistically significant change arising from use of the Naida Link HA.

Binaural streaming technology

Advanced Bionics' Binaural VoiceStream Technology allows the CI and HA to be linked wirelessly to stream full bandwidth audio signals for both ears in real time with short transmission delays. Different directional patterns and features are available with this technology that aim to improve speech understanding in different challenging listening situations, such as restaurants, classrooms, or when using a phone in noisy situations. This paper focuses on the most common features used for speech perception in noise, namely StereoZoom and ZoomControl.

StereoZoom

StereoZoom is a directional beamforming system (binaural beamformer) produced by wirelessly connecting the four omnidirectional microphones (two dual-microphone systems at each side, a Naida CI processor and a Naida Link HA). This feature can produce a much narrower fixed-target beam (± 45°) than is provided by a monoaural two-microphone first-order beamformer. StereoZoom allows listeners to focus on a single speaker standing directly in front of them while reducing interfering noise from the sides and back, as well as from near to the front (Advanced Bionics 2014).

Vroegop et al. (2018) assessed the benefit of using StereoZoom on the SRTs for 18 bimodal participants. A significant improvement of 4.7 dB on the SRT was found by using the StereoZoom compared to using the general set-up of the integrated bimodal technology (everyday map) in the static condition. However, the StereoZoom did not provide any significant benefit in the dynamic condition. This result indicated that the benefit of using StereoZoom is relevant only when the target speech is presented from the front. It also indicated that using the StereoZoom beamformer reduces the localisation performance as there was no improvement in the SRT in the dynamic listening condition. Therefore, activating StereoZoom for the more dynamic listening situations, such as in real-life listening environments, would be a disadvantage.

Ernst et al. (2019) measured the benefit of using StereoZoom over UltraZoom (monaural directional beamformer) and T-Mic setting (omnidirectional microphone) for bimodal CI users. They used two loudspeaker set-ups: (1) set-up A: speech fixed from front loudspeaker (0°) and the noise from loudspeakers placed at ± 60°, ± 120°, & 180°, (2) set-up B: speech fixed from front loudspeaker (0°) and the noise from loudspeakers placed at ±

30° and ± 60°. StereoZoom provided a significant benefit over the T-Mic of 4.6 dB and 2.6 dB in test set-ups A and B respectively. In addition, the StereoZoom provided an advantage of 1.3 dB (set-up A) dB and 1.2 dB (set up B) over UltraZoom. The amount of benefit seems largely dependent on the direction of the noise and the degree of separation between the target speech and the noise masker. A larger benefit can be obtained when the noise and speech are well separated.

ZoomControl

The ZoomControl feature allows the listeners to select a preferred direction that they want to listen to. They can select to focus to the right, left or back, in situations where they cannot see the speaker's face, for example when in a car. ZoomControl can switch the maximum sensitivity to the back when the listeners want to focus on speech from behind them. If the listeners want to focus on the right or left, the signal will be transmitted from one side to the other side where 75% of the direct microphone input in the non-attended side is suppressed to accommodate the transmitted signal (Advanced Bionics 2014). Holtmann et al. (2020) assessed the benefits of using the ZoomControl over the standard settings of the Naida Link HA when the speech was presented at the HA and the noise on the CI side. A significant improvement of 2.8 dB was found when enabling ZoomControl. Additionally, a considerable significant benefit (3.9 dB) was obtained when using ZoomControl compared to using a standard HA in the same test set-up. This finding indicates that ZoomControl can enhance speech understanding when the signal of interest is on the poorer hearing side and can help to overcome the effect of head shadow.

Rationale for present study

The benefits of integrated bimodal technology have been mainly assessed for speech perception with fixed speech presented from the front. There is a need to assess the benefits of this technology with test set-ups that are more representative for real-life listening situations, including roving speech in noise and speech and noise from opposite sides. Further research is also needed to determine the benefit of integrated bimodal technology for localisation and tracking. Finally, the potential benefit of using binaural streaming technology compared to the standard settings of the integrated bimodal technology has not been widely assessed and warrants further investigation.

Method

Ethics approval was granted by the University of Southampton Ethics Board (ERGO: 45969).

Participants

26 unilateral CI users with a Naida Q90 speech processor and Naida Link UP hearing aid in the non-implanted ear were recruited from University of Southampton Auditory Implant Service (see supplement for demographic information). The APDB fitting prescription was used to fit the Naida Link UP hearing aids and settings were checked ahead, within three weeks of the data collection. Participants ranged in age from 19 to 87 years (group mean age = 62 years, $SD = 20$ years). The inclusion criteria were: (1) ≥ 18 years, (2) > 6 months CI use, (3) > three months of integrated bimodal user experience with StereoZoom and ZoomControl, (4) BKB score in quiet of ≥ 50%, and (5) no cognitive or learning difficulties (as documented in the participant/CI user's records at the multi-disciplinary CI service). The participants' hearing thresholds in the non-implanted ears (tested ahead, within three weeks of the data collection) are presented in Figure 1.

Test protocol

1. Speech-in-noise tests:
   - SrN ± 60° (roving speech that was randomly presented from one of nine different loudspeakers arranged in a 180-degree arc to the front of the listener while uncorrelated multi-talker babble noise was played simultaneously from two of the loudspeakers placed at 60° to the left and right sides). This test simulates a group conversation in a noisy background.
   - S0°N ± 60° (fixed speech presented from the front in the presence of uncorrelated multi-talker babble presented simultaneously from two loudspeakers placed at 60° to the left and right sides). This test simulates a one-to-one conversation in a noisy background.
   - SHANCI (fixed speech at HA side at 90° and multi-talker babble noise at the CI side at 90°). This test simulates having a conversation with a person sat on the HA side of the CI user while there is competing noise on the CI side.
2. Spatial listening tests:
   - Localisation test using five loudspeakers with 30° separation. The stimulus is a phrase: *"Hello, what's this?"*, spoken by one of five different talkers presented at levels between 65 and 75 dB SPL with 11 roving intensity levels, and 0–10 dB of attenuation applied in 1 dB steps. Attenuation was chosen at random from trial to trial.
   - Tracking of moving sound test. Six movement trajectories of a horse galloping sound presented in a stepped manner at 65 dB SPL from an array of nine loudspeakers arranged in a 180-degree arc in front of the

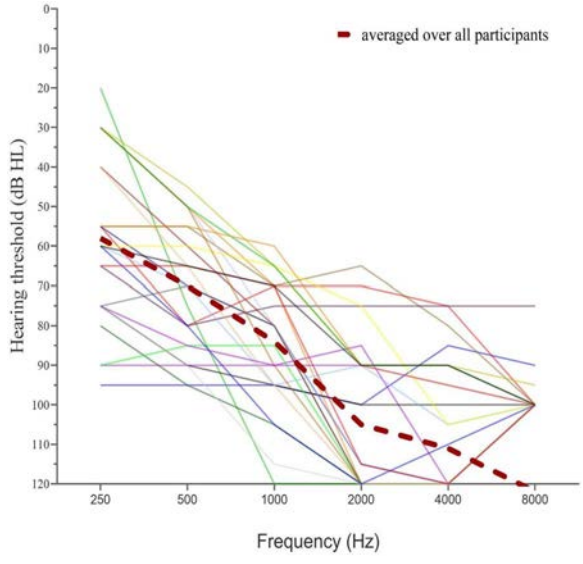

Figure 1. The unaided hearing thresholds of the individual participants for the non-implanted ear. The dashed red line displays the group mean threshold. For calculating the average, in case of "no response," the reading was given a value of 130 dB HL based on (BSA (British Society of Audiology) 2018).

listener: left-centre-right, right-centre-left, left-centre-left, right-centre-right, centre-right-centre and centre-left-centre. Each trajectory was repeated twice in a pseudo-random order.

3. The speech, spatial and qualities-of-hearing scale (SSQ) version 3.1.1 (Gatehouse and Noble 2004, Noble and Gatehouse 2004).

Apparatus

The AB-York Crescent of Sound which was developed by Kitterick et al. (2011) was used to administer the speech in noise, localisation and tracking tests. The AB-York Crescent of Sound consists of nine audio-visual stands (Plus XS.2, Canton loudspeakers) arranged in a semi-circular array with a radius of 1.45 m. Loudspeakers are placed at ± 90°, ± 60°, ± 30°, ± 15°, and 0° azimuth, where 0° is straight ahead of the listener. The axis of each loudspeaker is suspended at the height of 1.1 m. A 15" visual display unit (VDU) is placed below each loudspeaker from − 60° through to + 60°. The VDU was used to show the number of corresponding loudspeakers in the localisation test. Figure 2 shows the AB-York Crescent of Sound at the University of Southampton Auditory Implant Service.

Procedure

The testing was completed in a single session that lasted on average three hours, including short breaks of 10 min. The SSQ questionnaire was sent ahead of the time to allow participants time to think about the questions. The participants were seated on a chair in the centre of the Crescent of Sound loudspeaker array, one metre away from and facing the frontal loudspeaker which was placed at 0 degrees azimuth. A summary of listening conditions and main procedure for each test is given in Table 1. To minimise any possible order effects, the following steps were taken:

1. The order of the first two test categories (Table 1; speech-in-noise tests and spatial-listening tests) were firstly counterbalanced across participants with the SSQ always completed as the final category. In other words, the test session for half of the participants started with speech-in-noise tests, then spatial-listening tests. For other half of the participants, the test session started with spatial-listening tests followed by speech-in-noise tests
2. Within these two categories, the order of the listening conditions (device configuration) was counterbalanced using either a 3×3 or 2×2 Latin square design depending on the number of device configurations. For instance, the test session for some participants started testing them in the listening condition of using the CI only, while others started testing them when they use the CI with Naida HA or use the CI with Naida HA and binaural streaming technology (StereoZoom/ZoomControl)
3. Then the order of the sub-tests was also counterbalanced across participant for each device configuration using either a 3×3 or 2×2 Latin square design depending on the number of sub-tests (Table 1)

For the SSQ questionnaire, participants were asked to answer each question based on their experience when using: (1) the CI only, (2) the CI + their old (standard) HA, and (3) the CI + their Naida Link HA. For the latter listening condition, the

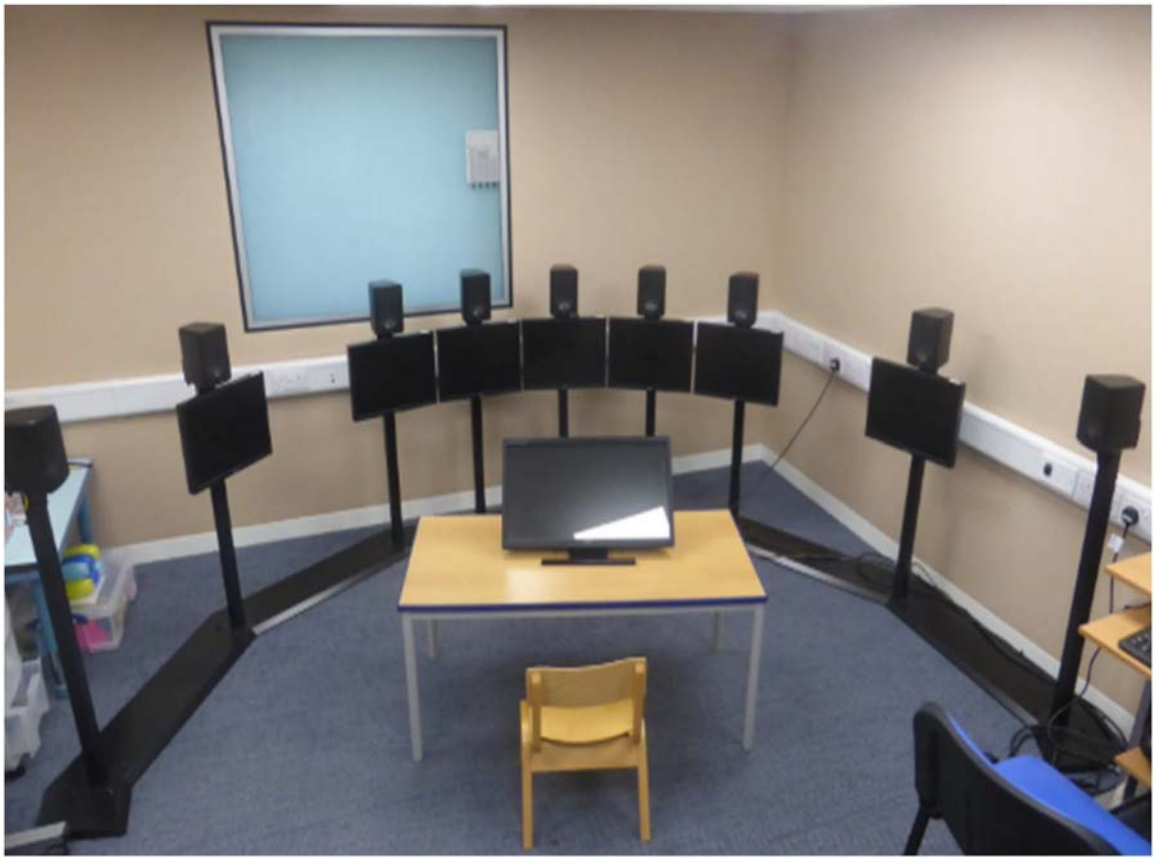

Figure 2. The AB-York Crescent of Sound at the University of Southampton Auditory Implant Service.

Table 1. Summary of the main procedures and the listening conditions for CI participants using the Naida Link HA.

Test category	Sub-test	Listening conditions	Head movement
Speech-in-noise tests	SrN ± 60°	1. CI only 2. CI + Naida Link HA	Allowed
	S0°N ± 60°	1. CI only 2. CI + Naida Link HA 3. CI + Naida Link HA + StereoZoom	Fixed facing the front loudspeaker
	SHANCI	1. CI only 2. CI + Naida Link HA 3. CI + Naida Link HA + ZoomControl	Fixed facing the front loudspeaker
Spatial-listening tests	Localisation	1. CI only 2. CI + Naida Link HA	Fixed facing the front loudspeaker
	Tracking	1. CI only 2. CI + Naida Link HA	Allowed
CI user experience	SSQ questionnaire	1. CI only 2. CI + standard HA 3. CI + Naida Link HA	–

CI: cochlear implant; HA: hearing aid; N: noise; r: roving; S: speech; SSQ: speech; spatial and qualities-of-hearing scale.

participants were asked to answer the questions based on their overall experience with the integrated bimodal technology, without any relation to specific settings or features (i.e. ZoomControl, StereoZoom, etc).

Results

Speech in noise tests

Figure 3 shows the SRTs of the integrated bimodal participants in the three speech in noise tests for different listening conditions (Cl alone, CI + Naida Link HA, and CI + Naida Link HA + binaural streaming feature).

A paired-samples *t*-test was used (no Bonferroni correction was applied) to determine whether there was a statistically significant mean difference between the two listening conditions (CI only vs. CI + Naida Link HA) in the SrN ± 60° test. The SRT was lower (better) in the listening condition of using CI + Naida HA (8.1 dB SNR ± 2.9) as opposed to when using the CI only (9.4 dB SNR ± 3.1). The results showed a statistically significantly difference: $t(25)=2.7$, $p < 0.05$, $d = 0.5$.

For the S0°N ± 60° and SHANCI tests, a one-way repeated measures ANOVA test was carried out for each test separately to determine whether there was an overall effect of listening conditions: (1) Cl only, (2) CI + Naida Link HA, and (3) CI + Naida Link HA + binaural Streaming technology (StereoZoom/ZoomControl). For all ANOVAs undertaken, Greenhouse-Geisser corrections were applied where assumptions of sphericity were violated.

In the S0°N ± 60° test, there was a significant overall effect of listening condition: $F(2, 50)=17.1$, $p < 0.01$. *Post hoc* analysis indicated that all three conditions were statistically significantly different from each other. For the SHANCI test, there was an overall effect of listening condition, $F(1.6,40.8)=62.6$, $p < 0.001$. Post hoc analysis indicated that all three conditions were statistically significantly different from each other. The mean difference and the 95% confidence intervals between the different listening conditions for each test are shown in Table 2, which shows an improvement with the integrated bimodal and binaural streaming technology.

Spatial-listening tests

The mean performance on the sound-localisation test (30° separation) for the integrated bimodal participants in the two listening conditions, (1) CI only and (2) CI + Naida Link HA, is shown in Figure 4 (left panel). The chance range for randomly guessing

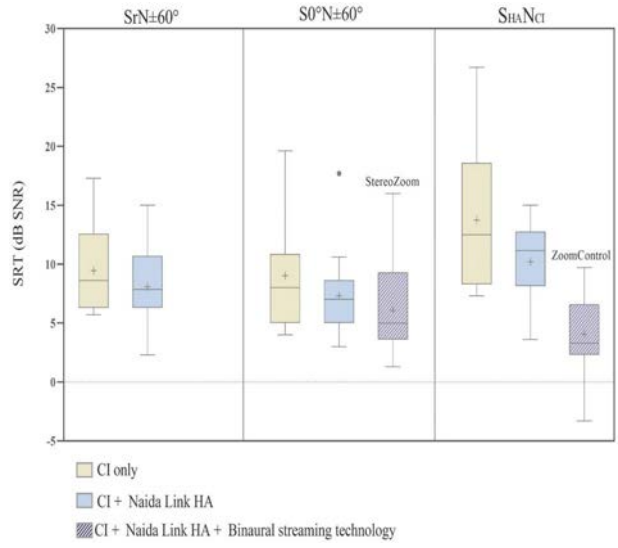

Figure 3. Box plots representing the SRTs in dB SNR for the three listening conditions: (1) Cl only, (2) CI + Naida Link HA + binaural streaming technology OFF, and (3) CI + Naida Link HA + binaural streaming technology ON in SrN ± 60° (left), S0°N ± 60° (middle), and SHANCI (right) tests. The boxes represent the two middle quartiles. The solid horizontal lines within each box indicate the median; the cross inside the box shows the mean. The outliers are plotted as solid circles. Lower SRTs indicate better performance could add. $N = 26$.

was calculated using the "Monte-Carlo" simulation method in the MATLAB (version R2019a) software indicating the mean percentage correct of the chance range of random guessing is 20%. Performance when using the CI only was close to chance (mean = 21.4%, $SD = 7.8$). However, the performance was higher than chance in the integrated bimodal condition (mean = 33.7%, $SD = 10.1$). Paired-sample *t*-tests showed that localisation accuracy was significantly higher in the bimodal condition by 12.3% (95% confidence interval, 7.6–17) compared to using the CI-only condition ($t(25)=5.4$, $p < 0.001$).

The right panel in Figure 4 shows mean performance on tracking moving sounds in the two listening conditions, (1) CI only and (2) CI + Naida Link HA. The chance range was calculated using binomial distribution with $n = 12$ trials, each with a chance success rate of 0.167 indicating the mean percentage correct of the chance range of random guessing is 16%. Mean performance when using the CI only was within the chance range (mean = 17.9%, $SD = 15.4$). Although there was considerable variability in the performance among the participants when using the Naida

Table 2. Mean difference (95% confidence intervals) between the listening conditions for the SrN ± 60°, S0°N ± 60° and SHANCI tests.

Test	Mean difference (95 % confidence interval)
SrN ± 60°	(CI + Naida Link HA) - CI only = −1.4 db (−2.4 to 0.3)
S0°N ± 60°	(CI + Naida Link HA) - CI only= − 1.7 dB (−2.8 to −0.6)
	(CI + Naida Link HA + StereoZoom) – (CI + Naida Link HA) = −1.2 dB (−2.3 to −0.2)
SHANCI	(CI + Naida Link HA) - CI only = −3.5 dB (−5.5 to −1.5)
	(CI + Naida Link HA + ZoomControl) – (CI + Naida Link HA) = − 6.1 dB (−7.5 to −4.8)

CI: cochlear implant; HA: hearing aid; N: noise; r: roving; S: speech.

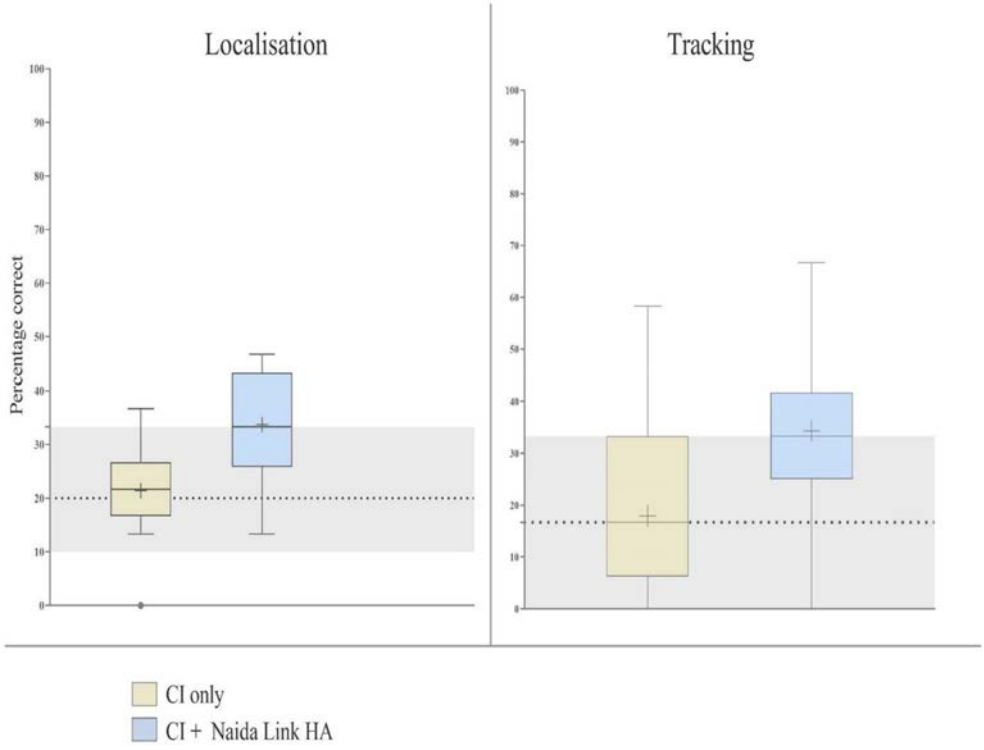

Figure 4. Results of the localisation (left-hand panel) and tracking test (right-hand panel) for the adult CI participants in the listening condition of using the CI only (yellow box plots) and in the listening condition of CI + Naida Link HA (blue box plots). The boxes represent the two middle quartiles. The solid horizontal lines within each box indicate the median; the cross inside the box shows the mean. The dashed horizontal line shows the level of performance expected by chance, with the grey shaded area showing the 5th and 95th percentiles of the chance range. The outliers are plotted as solid circles. $N = 26$.

Link HA with CI, the mean performance was higher than chance (mean = 34.3%, $SD = 15.6$). Paired-sample t-tests showed that the difference between the two listening conditions was statistically significantly different ($t(25) = 4.5$, $p < 0.001$). The tracking of moving sounds was better in the bimodal condition than when using one CI by 16.4% (95% confidence interval, 8.9–23.9).

SSQ

Only complete questionnaires for the three listening conditions were included in the analysis ($n = 20$; 77%). Figure 5 shows the self-rated scores on the overall SSQ and each of the three subscales for the integrated bimodal participants in the three listening conditions.

A two-way repeated measures ANOVA test was performed, with the listening condition and type of subscale as the independent variables. The main effect of listening condition was statistically significant ($F(2,38)=19.6$, $p < 0.001$). *Post hoc* tests revealed that scores were statistically significantly higher when using CI with a Naida Link HA compared to using CI alone ($p < 0.001$) and to CI with the standard HA ($p < 0.001$). The tests also showed that there was no statistically significant difference in the scores of the listening conditions of using CI with the standard HA and using CI alone ($p = 0.3$). The main effect of the type of subscale was statistically significant ($F(2,38)=22.4$, p<.001). *Post hoc* tests revealed that the scores for spatial subscales were significantly lower than that for the speech ($p = 0.001$) and qualities subscale ($p < 0.001$). The tests also showed that the scores for qualities of hearing were significantly higher than that for the speech ($p = 0.021$) and spatial subscale ($p < 0.001$) scores. The interaction between listening condition and subscale was not statistically significant, $F(2.9, 54.9)=1.2$, $p = 0.3$.

Correlation between unaided hearing thresholds of the non-implanted ear and integrated bimodal technology

The relationship between the unaided hearing thresholds of the non-implanted ear and the performance scores of the participants when using the Naida Link HA was examined, based on the hypothesis that residual hearing acuity might account for inter-subject variance in bimodal benefit. The data of all 26 participants were included in the correlation analysis, except for the

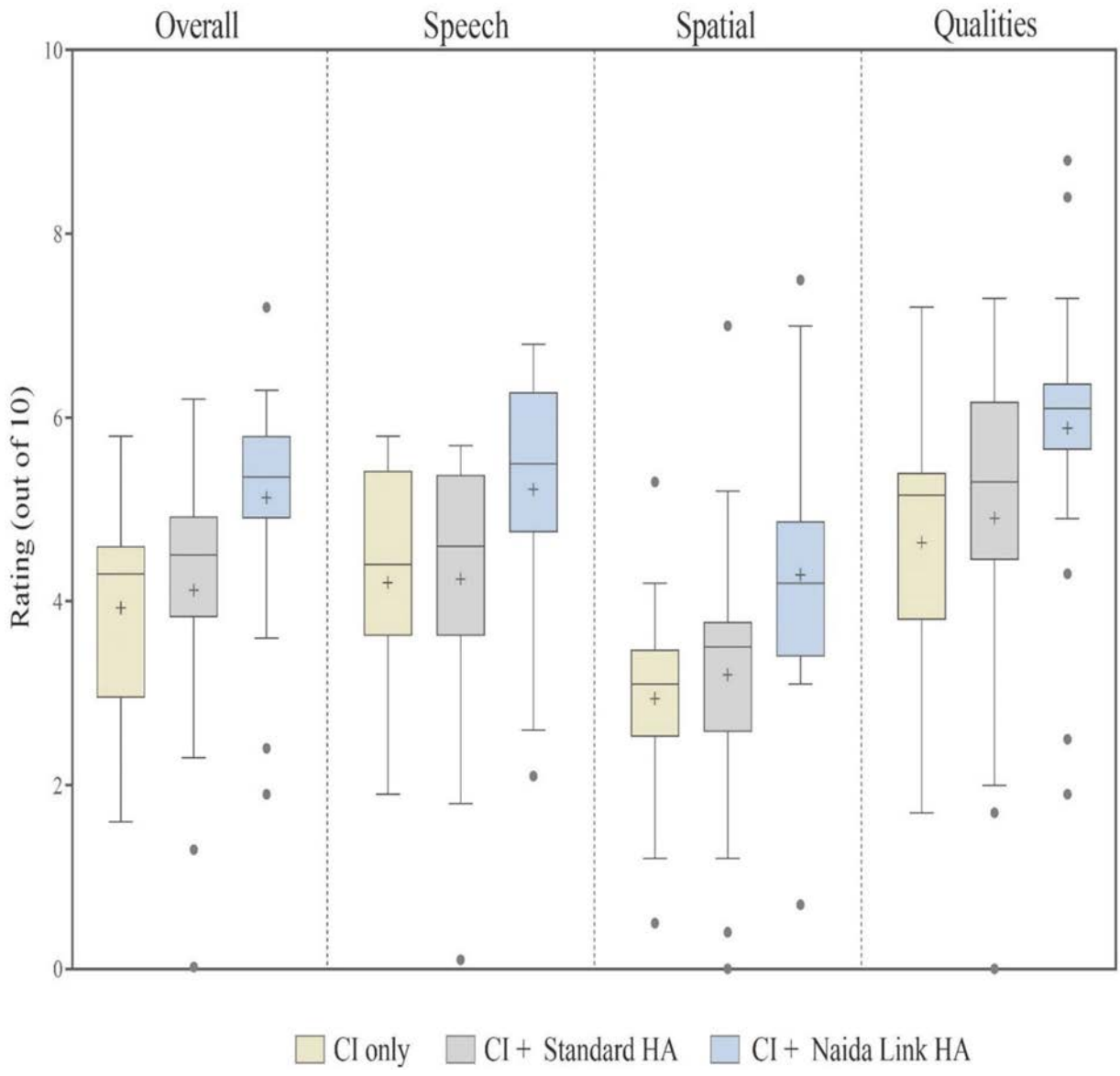

Figure 5. Scores on the overall SSQ and each of the three subscales: speech, spatial and qualities of the listening conditions: (1) the CI alone (yellow box plots), (2) CI + previous standard HA (grey box plots), and (3) CI + Naida Link HA (blue box plots). The boxes represent the two middle quartiles. The solid horizontal lines within each box indicate the median; the cross inside the box shows the mean. The outliers are plotted as solid circles. $N = 20$.

SSQ, where data on 24 participants who completed the questionnaire for the listening condition of CI + Naida Link HA were included. Pearson correlation analysis was used, with different combinations of hearing thresholds applied as predictor variables (250 Hz, 500 Hz, 1000 Hz, 250–500 Hz average, or 500–1000–2000 Hz average of the non-implanted ear); however, this failed to show any significant associations between hearing thresholds and results of any of the performance tests using the CI + Naida Link condition, or SSQ questionnaire (as shown in Table 3). It should be noted that the scores of the performance tests included in the analysis were presented as:

1. Average scores of the three speech-in-noise tests on the best-aided condition. The average scores of the speech-in-noise tests were calculated by taking the average scores of the three tests: (1) SrN ± 60° in CI + Naida Link HA condition, (2) S0°N ± 60° in CI + Naida Link HA + StereoZoom condition and (3) SHANCI in CI + Naida Link HA + ZoomControl condition.
2. Average performance scores of the spatial-hearing tests (localisation and tracking).
3. Rating scores of the overall SSQ.

Discussion

The first aim of this study was to compare the outcomes of the integrated bimodal technology (Naida Q90 CI processor and Phonak Link UP HA) to using the CI alone using a test battery with tests that are more representative for real-life listening situations as opposed to only using standard speech tests. The results showed a significant bimodal benefit on improving speech perception with the integrated bimodal technology. Mixed outcomes of the standard bimodal technology have been reported in the literature. Some studies reported a significant benefit with bimodal hearing (as in Flynn and Schmidtke 2004; Ching et al. 2006; Gifford et al. 2007; Dorman et al. 2008; Berrettini et al. 2010, Devocht et al. 2017), while other studies showed non-

Table 3. Results of correlation analyses, *r* values (95% confidence interval), between the unaided thresholds of non-implanted and the performances scores when using the CI with the Naida Link HA (*$n = 24$).

Performance test	PTA (500–1000–2000 Hz)	PTA (250–500 Hz)	1000 Hz	500 Hz	250 Hz
Average speech tests with best aided condition	−0.1 (−0.4 to 0.3)	−0.1 (−0.5 to 0.3)	−0.1 (−0.5 to 0.3)	−0.1 (−0.5 to 0.3)	−0.1 (−0.5 to 0.3)
Average spatial tests	−0.1 (−0.5 to 0.3)	0.2 (−0.2 to 0.5)	−0.2 (−0.5 to 0.2)	0.1 (−0.3 to 0.4)	0.3 (−0.1 to 0.6)
SSQ overall*	0.1 (−0.3 to 0.5)	0.4 (−0.1 to 0.7)	0.1 (−0.3 to 0.5)	0.4 (−0.01 to 0.7)	0.3 (−0.1 to 0.6)

CI: cochlear implant; HA: hearing aid; PTA: pure tone average; SSQ: speech, spatial and qualities-of-hearing scale.

significant benefits or a decrement in the performance compared to CI alone (as in Tyler et al. 2002; Dunn, Tyler, and Witt 2005; Morera et al. 2005; Mok et al. 2006; Pyschny et al. 2011; Bouccara et al. 2016).

The largest benefit of the integrated bimodal technology in the current study was 3.5 dB, found when the noise was presented on the CI side and the speech on the HA side. This is similar to the findings of Vroegop et al. (2019) who reported their largest bimodal benefit (2.5 dB) when using the Naida Link HA with the noise presented at the CI and the speech from the front compared to other test set-ups in their study. Likewise, Spirrov et al. (2020) found their largest bimodal benefit of 4.4 dB with the matched AGC between the CI and HA when the noise was on the CI side compared to when the noise was presented from the front, or on the HA side. It should be noted that Spirrov et al. (2020) used a Nucleus 6 processor from Cochlear (Sydney, Australia) and an Enzo 3D HA from GN hearing (Copenhagen, Denmark) in their study.

In the test condition using fixed speech from the front and diffuse noise from the two loudspeakers placed at ± 60°, the bimodal benefit was 1.7 dB which is comparable to the 1.6 dB benefit found by Vroegop et al. (2019), when the speech and noise were presented from the front. Cuda et al. (2019) also reported a significant bimodal benefit when the speech and noise were presented from the front; however the amount of the benefit (3.9 dB) was larger than those found in the current study and in the one by Vroegop et al. (2019). The finding in the current study is in line with Warren et al. (2020) who found a significant improvement in the speech perception with using the CI and Naida Link HA compared to using the CI only when the speech and noise were presented from the front.

The smallest significant bimodal benefit in the present study was 1.4 dB, found in the test of roving speech in uncorrelated multi-talker noise presented from the two loudspeakers at 60°. This study used roving speech that can be presented randomly from an array of nine loudspeakers placed at ± 90°, ± 60°, ± 30°, ± 15°, and 0° azimuth. This test set-up simulates one of the common listening situations in real life where the listener is sitting around a table with a group of people with background noise present. However, this set-up might have been challenging to the CI users as they needed first to locate where the speech was coming from and then spontaneously turn their heads and focus on the target sentence. Although the participants were not asked to identify the direction of the speech during the test trial, it was challenging for them to adapt to speech that was not presented from a fixed location. This could explain the smallest bimodal benefit found for this test set-up. Few studies have previously used roving target speech set-ups with adult CI users who were using the integrated bimodal technology. Vroegop et al. (2018) used speech randomly presented from two loudspeakers placed at + 45° and − 45°, with a babble noise presented from four loudspeakers placed at ± 45° and ± 135°. They found a bimodal benefit of 3.1 dB using the Naida Link HA, better than the benefit found with roving speech in the current study. The discrepancy might be related to the number of loudspeakers used to present the speech in the Vroegop et al. (2018) study with only two loudspeakers, as against nine loudspeakers been used in the current study.

The findings from the present study show that using integrated bimodal technology significantly improved the speech perception in noise. However, the amount of bimodal benefit seems largely dependent on the direction of the noise and speech as the improvement in the SRT in dB SNR ranged from 1.4 dB to 3.5 dB depending on the test set-up. This is likely to be as a result of the better-ear effect particularly when the speech target is at the CI side.

The localisation and tracking tests showed significant improvement when using integrated bimodal technology compared to using the CI only. Although the improvement was statistically significant, more than half of the participants still performed close to or within the chance range. The single published study assessed the performance of CI users when using a Naida Link HA compared to the standard HA (Holtmann et al. 2020). The test set-up consisted of four loudspeakers placed at 0°, ± 90°, and 180°. Their results did not show a significant difference between the Naida Link HA and the standard HA in the localisation test. These findings suggest that benefits of integrated bimodal technology in the domain of localisation have not been established as clearly as for speech perception in noise.

The self-rated scores on the SSQ were significantly higher when using the integrated bimodal technology compared to using the CI only and also to using the CI with the participants' previous standard HA. The mean rating of the overall SSQ score using the Naida Link HA was about 5.1 points which is at the mid-range scoring scale suggesting an improvement in the hearing skills needed for everyday functions; however, difficulties can remain. This finding was in line with Vroegop et al. (2018) who found an overall rating score of the SSQ of about 5.2 and 5.4 points for using the Naida Link HA when programmed with the APDB and NAL-NL2 formulae respectively. A similar finding was reported by Holtmann et al. (2020) where there was a significant improvement in the hearing implant sound quality index (HISQUI) − 19 at the 8–12 week assessment post-fitting when using the Naida Link HA over the standard HA. However, apparent benefit of integrated bimodal technology over the standard HA should be treated with caution as the validity of rated scores for the listening condition of using the standard HA might be affected by the participants' memory, e.g. some participants always use the Naida link HA which makes it hard for them to remember what the standard HA was like in the past.

The second aim of this study was to assess whether using binaural streaming technology would add a further improvement compared to the standard settings of integrated bimodal technology. Additional benefit of 1.2 and 6.1 dB were found by enabling

the StereoZoom and ZoomControl features respectively. The significant benefit of the StereoZoom in this study was smaller than the benefit found in previous studies. Vroegop et al. (2018) found a benefit of 4.7 dB when the speech was presented from the front and the noise from the loudspeakers was at ± 45° and ± 135°. Similarly, StereoZoom benefits of 4.6 and 2.6 dB over the standard settings (using T mic) were found by Ernst et al. (2019) in test set-ups A (S0° N ± 60°, ± 120°, & 180°) and B (S0°N ± 30° & ± 60°) respectively. These studies used similar and narrower degrees of separation between the noise and the target speech compared to the current study. The reason for this discrepancy is unclear. However, it could be attributed to a random error given the 95% confidence interval estimate reported in Table 2.

To the best of the researchers' knowledge, there is only one recent published study that assessed the benefit of ZoomControl for CI users with integrated bimodal technology (Holtmann et al. 2020). They found a significant improvement when first enabling ZoomControl. They also found a further improvement following 12 weeks of acclimatisation: median SRTs at + 0.97 dB with the standard settings of a Naida Link HA compared −1.8 dB with ZoomControl activated. Although they used a similar test set-up (SHANCI), the ZoomControl benefit found in the present study is relatively larger than the benefit found by Holtmann et al. (2020). The SRTs for all the participants in the current study improved by at least 1.3 dB, with the largest improvement being 12.3 dB. The benefit of ZoomControl for the participants in this study probably resulted from the head-shadow effect that results in a level difference between the two ears (Veugen et al. 2017) and the better ear effect, particularly when the speech is at the CI side as a result of the dominance of the CI in speech understanding. Another reason is the 12 dB reduction at the microphone of the CI sound processor when ZoomControl is activated.

For future work, it would be useful to compare the integrated bimodal technology to bilateral CI. Conducting such a comparison would provide a better understanding of whether the integrated bimodal technology can offer comparable benefits to bilateral CI, particularly in spatial listening as a result of matching signal processing between devices. Future research using a test battery that includes more representative real-life tests is advised. Lastly, it is recommended that this research be extended to look at CI user outcomes with the newer and recently launched Naida Link Marvel integrated bimodal and bilateral technology. The Marvel CI sound processor's technology, comprises an automated operating system that adapts to the listener's surroundings, blending multiple features to create distinct settings for the user's unique listening environment.

Conclusion

Integrated bimodal technology outcomes were significantly better than for the CI alone, as shown in improved performance on a test battery that integrated tasks that are more representative of real-life listening, particularly for speech understanding in noise where the target speech and noise masker were spatially separated. Improved performance was also found for localisation and tracking, despite considerable variation noted among the users. Finally, binaural streaming technology can provide an additional improvement for speech understanding in noise above that offered by integrated bimodal technology. Further research comparing integrated bimodal and bilateral CI fitting outcomes on a real-life test battery is recommended.

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Authors contributions

First author**:** Data collection, analysis of data and writing of first draft. Second author: Conceptualisation of study, oversaw data collection, contributed to analysis and writing. Third author: Oversaw analysis and contributed to writing. Fourth author: Contributed to writing.

Ethical approval

Ethics approval was granted by the University of Southampton Ethics Board (ERGO: 45969).

Disclosure statement

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References

Advanced Bionics. 2014. "*Binaural VoiceStream Technology: Improving speech understanding in challenging listening environments.*" (Advanced Bionics AG and affiliates).

Advanced Bionics. 2016. "*Optimizing Hearing for Listeners with a Cochlear Implant and Contralateral Hearing Aid: Adaptive Phonak Digital Bimodal Fitting Formula.*" (Advanced Bionics AG and affiliates).

Auletta, G., A. Franzè, C. Laria, C. Piccolo, C. Papa, P. Riccardi, D. Pisani, A. Sarnelli, V. Del Vecchio, R. Malesci, et al. 2021. "Integrated Bimodal Fitting for Unilateral CI Users with Residual Contralateral Hearing." *Audiology Research* 11 (2):200–206. https://doi.org/10.3390/audiolres11020018.

Berrettini, S., S. Passetti, M. Giannarelli, and F. Forli. 2010. "Benefit from Bimodal Hearing in a Group of Prelingually Deafened Adult Cochlear Implant Users." *American Journal of Otolaryngology* 31 (5):332–338. https://www.ncbi.nlm.nih.gov/pubmed/20015774. https://doi.org/10.1016/j.amjoto.2009.04.002.

Bouccara, D., E. Blanchet, P. E. Waterlot, M. Smadja, B. Frachet, B. Meyer, and O. Sterkers. 2016. "Benefit of Contralateral Hearing Aid in Adult Cochlear Implant Bearers." *European Annals of Otorhinolaryngology, Head and Neck Diseases* 133 (3):161–165. https://www.ncbi.nlm.nih.gov/pubmed/26679231. https://doi.org/10.1016/j.anorl.2015.11.002.

Bronkhorst, A. W., and R. Plomp. 1989. "Binaural Speech Intelligibility in Noise for Hearing-Impaired Listeners." *The Journal of the Acoustical Society of America* 86 (4):1374–1383. https://doi.org/10.1121/1.398697.

BSA (British Society of Audiology) Professional Practice Committee. 2018. "*Recommended Procedure: Pure-Tone Air-Conduction and Bone conduction Threshold Audiometry with and without Masking*". British Society of Audiology. https://www.thebsa.org.uk/wp-content/uploads/2023/10/OD10

4-32-Recommended-Procedure-Pure-Tone-Audiometry-August-2018-FINAL-1.pdf.
Byrne, D., W. Noble, and B. LePage. 1992. "Effects of Long-Term Bilateral and Unilateral Fitting of Different Hearing Aid Types on the Ability to Locate Sounds." *Journal of the American Academy of Audiology* 3 (6):369–382.
Ching, T. Y. C., P. Incerti, and M. Hill. 2004. "Binaural Benefits for Adults Who Use Hearing Aids and Cochlear Implants in Opposite Ears." *Ear and Hearing* 25 (1):9–21. https://doi.org/10.1097/01.aud.0000111261.84611.c8.
Ching, T. Y., P. Incerti, M. Hill, and E. van Wanrooy. 2006. "An Overview of Binaural Advantages for Children and Adults Who Use Binaural/Bimodal Hearing Devices." *Audiology & Neuro-Otology* 11 Suppl 1 (Suppl 1):6–11. https://www.ncbi.nlm.nih.gov/pubmed/17063004. https://www.karger.com/Article/Pdf/95607. https://doi.org/10.1159/000095607.
Cuda, D., A. Murri, A. Mainardi, and J. Chalupper. 2019. "Effectiveness and Efficiency of a Dedicated Bimodal Fitting Formula." *Audiology Research* 9 (1):219. https://doi.org/10.4081/audiores.2019.219.
Devocht, E. M. J., A. M. L. Janssen, J. Chalupper, R. J. Stokroos, and E. L. J. George. 2017. "The Benefits of Bimodal Aiding on Extended Dimensions of Speech Perception: Intelligibility, Listening Effort, and Sound Quality." *Trends in Hearing* 21:2331216517727900. https://doi.org/10.1177/2331216517727900.
Devocht, E. M. J., A. M. L. Janssen, J. Chalupper, R. J. Stokroos, H. Kingma, and E. L. J. George. 2020. "Self-assessment of Unilateral and Bimodal Cochlear Implant Experiences in Daily Life." *PloS One* 15 (12):e0242871. https://doi.org/10.1371/journal.pone.0242871.
Dorman, M. F., R. H. Gifford, A. J. Spahr, and S. A. McKarns. 2008. "The Benefits of Combining Acoustic and Electric Stimulation for the Recognition of Speech, Voice and Melodies." *Audiology & Neuro-Otology* 13 (2):105–112. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3559130/pdf/nihms338427.pdf. https://doi.org/10.1159/000111782.
Dunn, C. C., R. S. Tyler, and S. A. Witt. 2005. "Benefit of Wearing a Hearing Aid on the Unimplanted Ear in Adult Users of a Cochlear Implant." *Journal of Speech, Language, and Hearing Research: JSLHR* 48 (3):668–680. https://doi.org/10.1044/0192-4388(2005/046.
Ernst, A., K. Anton, M. Brendel, and R.-D. Battmer. 2019. "Benefit of Directional Microphones for Unilateral, Bilateral and Bimodal Cochlear Implant Users." *Cochlear Implants International* 20 (3):147–157. https://doi.org/10.1080/14670100.2019.1578911.
Flynn, M. C., and T. Schmidtke. 2004. "Benefits of Bimodal Stimulation for Adults with a Cochlear Implant". *International Congress Series* 1273:227–230. https://doi.org/10.1016/j.ics.2004.08.040.
Francart, T., and H. J. McDermott. 2013. "Psychophysics, Fitting, and Signal Processing for Combined Hearing Aid and Cochlear Implant Stimulation." *Ear and Hearing* 34 (6):685–700. https://doi.org/10.1097/AUD.0b013e31829d14cb.
Gatehouse, S., and W. Noble. 2004. "The Speech, Spatial and Qualities of Hearing Scale (SSQ)." *International Journal of Audiology* 43 (2):85–99. https://doi.org/10.1080/14992020400050014.
Gifford, R. H., M. F. Dorman, S. McKarns, and A. J. Spahr. 2007. "Combined Electric and Contralateral Acoustic Hearing: Word and Sentence Recognition with Bimodal Hearing." *Journal of Speech, Language, and Hearing Research: JSLHR* 50 (4):835–843. https://doi.org/10.1044/1092-4388(2007/058.
Holtmann, L. C., A. Janosi, H. Bagus, T. Scholz, S. Lang, D. Arweiler-Harbeck, and S. Hans. 2020. "Aligning Hearing Aid and Cochlear Implant Improves Hearing Outcome in Bimodal Cochlear Implant Users." *Otology & Neurotology: Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology* 41 (10):1350–1356. https://doi.org/10.1097/MAO.0000000000002796.
Kitterick, P. T., R. E. S. Lovett, A. M. Goman, and A. Q. Summerfield. 2011. "The AB-York Crescent of Sound: An Apparatus for Assessing Spatial-Listening Skills in Children and Adults." *Cochlear Implants International* 12 (3):164–169. https://doi.org/10.1179/146701011x13049348987832.
Mok, M., D. Grayden, R. C. Dowell, and D. Lawrence. 2006. "Speech Perception for Adults Who Use Hearing Aids in Conjunction With Cochlear Implants in Opposite Ears." *Journal of Speech, Language, and Hearing Research: JSLHR* 49 (2):338–351. https://doi.org/10.1044/1092-4388(2006/027).
Morera, C., M. Manrique, A. Ramos, L. Garcia-Ibanez, L. Cavalle, A. Huarte, C. Castillo, and E. Estrada. 2005. "Advantages of Binaural Hearing Provided Through Bimodal Stimulation Via a Cochlear Implant and a Conventional Hearing Aid: A 6-Month Comparative Study." *Acta Oto-Laryngologica* 125 (6):596–606. https://www.ncbi.nlm.nih.gov/pubmed/16076708. https://doi.org/10.1080/00016480510027493.
Neuman, A. C., and M. A. Svirsky. 2013. "Effect of Hearing Aid Bandwidth on Speech Recognition Performance of Listeners Using a Cochlear Implant and Contralateral Hearing Aid (Bimodal Hearing)." *Ear and Hearing* 34 (5):553–561. https://doi.org/10.1097/AUD.0b013e31828e86e8.
Noble, W., and S. Gatehouse. 2004. "Interaural Asymmetry of Hearing Loss, Speech, Spatial and Qualities of Hearing Scale (SSQ) Disabilities, and Handicap." *International Journal of Audiology* 43 (2):100–114. https://doi.org/10.1080/14992020400050015.
Pyschny, V., M. Landwehr, M. Hahn, M. Walger, H. von Wedel, and H. Meister. 2011. "Bimodal Hearing and Speech Perception with a Competing Talker." *Journal of Speech, Language, and Hearing Research: JSLHR* 54 (5):1400–1415. https://doi.org/10.1044/1092-4388(2011/10-0210).
Spirrov, D., E. Kludt, E. Verschueren, A. Büchner, and T. Francart. 2020. "Effect of (Mis)Matched Compression Speed on Speech Recognition in Bimodal Listeners." *Trends in Hearing* 24:2331216520948974. https://doi.org/10.1177/2331216520948974.
Tyler, R. S., A. J. Parkinson, B. S. Wilson, S. Witt, J. P. Preece, and W. Noble. 2002. "Patients Utilizing a Hearing Aid and a Cochlear Implant: Speech Perception and Localization." *Ear and Hearing* 23 (2):98–105. https://doi.org/10.1097/00003446-200204000-00003.
Vaerenberg, B., C. Smits, G. De Ceulaer, E. Zir, S. Harman, N. Jaspers, Y. Tam, M. Dillon, T. Wesarg, D. Martin-Bonniot, et al. 2014. "Cochlear Implant Programming: A Global Survey on the State of the Art." *The Scientific World Journal* 2014:1–12. https://doi.org/10.1155/2014/501738.
van Hoesel, R. J. M. 2012. "Contrasting Benefits from Contralateral Implants and Hearing Aids in Cochlear Implant Users." *Hearing Research* 288 (1–2):100–113. https://doi.org/10.1016/j.heares.2011.11.014.
Veugen, L. C., J. Chalupper, A. F. Snik, A. J. Opstal, and L. H. Mens. 2016. "Matching Automatic Gain Control Across Devices in Bimodal Cochlear Implant Users." *Ear and Hearing* 37 (3):260–270. https://www.ncbi.nlm.nih.gov/pubmed/26656192. https://doi.org/10.1097/AUD.0000000000000260.
Veugen, L. C. E., J. Chalupper, L. H. M. Mens, A. F. M. Snik, and A. J. van Opstal. 2017. "Effect of Extreme Adaptive Frequency Compression in Bimodal Listeners on Sound Localization and Speech Perception." *Cochlear Implants International* 18 (5):266–277. https://doi.org/10.1080/14670100.2017.1353762.
Vroegop, J. L., N. C. Homans, A. Goedegebure, J. G. Dingemanse, T. van Immerzeel, and M. P. van der Schroeff. 2018. "The Effect of Binaural Beamforming Technology on Speech Intelligibility in Bimodal Cochlear Implant Recipients." *Audiology & Neuro-Otology* 23 (1):32–38. https://doi.org/10.1159/000487749.
Vroegop, J. L., N. C. Homans, M. P. van der Schroeff, and A. Goedegebure. 2019. "Comparing Two Hearing Aid Fitting Algorithms for Bimodal Cochlear Implant Users." *Ear and Hearing* 40 (1):98–106. https://doi.org/10.1097/AUD.0000000000000597.
Warren, S. E., M. Noelle Dunbar, C. Bosworth, and S. Agrawal. 2020. "Evaluation of a Novel Bimodal Fitting Formula in Advanced Bionics Cochlear Implant Recipients." *Cochlear Implants International* 21 (6):323–337. https://doi.org/10.1080/14670100.2020.1787622.

ASHA American Speech-Language-Hearing Association

AJA

Research Note

The Effect of Contralateral Routing of Signal Devices on the Quality of Life of Unilateral Cochlear Implant Recipients and Their Frequent Communication Partners

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ABSTRACT

Purpose: Unilateral cochlear implant (CI) recipients with limited hearing in the contralateral ear are deprived of the advantages of binaural hearing. To address speech recognition challenges arising from the head shadow effect, a contralateral routing of signal (CROS) device can be used; however, less is known of the broader impact of a CROS device on an individual's quality of life (QoL) or that of their frequent communication partners (FCPs). This preliminary study aimed to evaluate the impact of CROS on speech recognition in noise and its influence on the QoL of unilateral CI recipients and their FCPs.

Method: This preliminary study enrolled seven adult unilateral CI recipients and their FCPs. All CI recipients were fitted with CROS devices during their initial appointments. Speech recognition testing was conducted in noise with and without the CROS device in a sound booth before a take-home trial. Participants used the CROS devices for approximately 1 year, with device fitting occurring before and continuing during the COVID-19 pandemic. Participants completed two QoL questionnaires, the Auditory Performance and Satisfaction Scale for Single-Sided Deafness (APS-SSD) and the Nijmegen Cochlear Implant Questionnaire (NCIQ), twice: once prior to CROS device use and once after the take-home trial. Additionally, the FCPs of each CI recipient completed the Significant Other Scale of Hearing Disability (SOS-HEAR) Questionnaire twice, once before and once after extended CROS device use.

Results: When noise was directed toward the CI ear and speech toward the non-CI ear, speech recognition improved by 32% with the CROS device ($p = .001$). CI recipients reported significant median improvement in the "general" domain of the APS-SSD after the take-home trial (Wilcoxon $Z = 12.0$, $p < .05$). FCPs reported a significant median reduction in concerns related to their partner's hearing when the CI recipient used the CROS device (Wilcoxon $Z = 2.0$, $p < .05$).

Conclusions: This preliminary study demonstrates the benefit of CROS devices for unilateral CI recipients in noisy environments. Additionally, it highlights the positive impact of CROS devices on the QoL of both CI recipients and their FCPs. These findings emphasize the importance of considering CROS devices as a valuable solution for unilateral CI recipients to enhance their hearing experience, overall well-being, and that of their FCPs.

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Cochlear implants (CIs) are the standard of care to rehabilitate the hearing of individuals with severe-to-profound hearing loss (Buchman et al., 2020). Bilateral CIs (BiCIs) offer various advantages related to binaural hearing, including improved speech recognition in noisy environments (primarily due to overcoming the head shadow effect), enhanced localization abilities, reduced stress and fatigue, and an overall improved quality of life (QoL; Agrawal, 2008; Dunn et al., 2012; Härkönen et al., 2015; Litovsky et al., 2012; Reeder et al., 2014). For individuals with aidable acoustic hearing in the nonimplanted ear, the use of a hearing aid (HA) in combination with the CI (i.e., bimodal hearing) has been shown to provide significant benefit over CI-alone listening (Ching et al., 2006; Dorman et al., 2015; Dorman & Gifford, 2010; Devocht et al., 2020; Dunn et al., 2005; Farinetti et al., 2015; Firszt et al., 2012; Illg et al., 2014). However, some CI recipients may be unable to undergo bilateral implantation or prefer not to for various reasons. These reasons could include medical conditions, such as contraindications to surgery, anatomical limitations, risks associated with anesthesia, concerns related to the status of the auditory nerve or retrocochlear pathway, and other personal choices to avoid additional surgery. Additionally, some unilateral CI users may choose not to use an HA in the contralateral ear due to limited or lack of perceived benefits from traditional amplification. In these listeners, a contralateral routing of signal (CROS) device can be used to overcome the deleterious effects of the head shadow and provide significant benefits (Dorman et al., 2018; Dwyer et al., 2018; Ernst et al., 2019; Kurien et al., 2019; Mosnier et al., 2019; Snapp et al., 2019; Taal et al., 2016).

CI success has traditionally been defined by the results of speech recognition testing. However, in recent years, the broader impact of CI on an individual's life has led to incorporating QoL assessments alongside traditional speech-based outcome measures. With an increased emphasis on recipient QoL as a reported outcome measure, questionnaires can be used preoperatively and postoperatively to evaluate the impact a CI has on QoL. These subjective measures can give insight to clinicians far beyond the traditional speech recognition testing. Several questionnaires have been developed to assess the QoL of CI recipients, including the Hearing Implant Sound Quality Index (Amann & Anderson, 2014), the Nijmegen Cochlear Implant Questionnaire (NCIQ; Hinderink et al., 2000), and the Auditory Performance and Satisfaction Scale for Single-Sided Deafness (APS-SSD; Schafer et al., 2013). Similarly, questionnaires like the Significant Other Scale for Hearing Disability (SOS-HEAR; Scarinci et al., 2009) have been developed to assess the QoL of frequent communication partners (FCPs).

While the subjective and speech recognition benefit of CROS in unilateral listeners has been well explored, evaluating the QoL of FCPs through questionnaires could provide additional insights into the benefits of CROS devices outside of standard outcome measures. The current study aims were (a) to explore the impact of long-term use of CROS devices on the QoL of both unilateral CI recipients and their FCPs and (b) to assess the effects of CROS devices on speech understanding in noisy environments among unilateral CI recipients. We hypothesized that (a) the use of CROS devices will have a positive influence on the QoL of both unilateral CI recipients and their FCPs, including communication abilities and social interaction, and (b) the use of CROS devices will enhance speech understanding in unilateral CI recipients, especially in situations where access to target speech is diminished due to the head shadow effect. The null hypothesis, in contrast, would indicate no significant effect of CROS devices on these measures.

Method

Participants

Participants were recruited from within a tertiary-care academic medical center CI program. All participants provided written informed consent to participate, and the study site's institutional review board provided ethical oversight and reviewed and approved all study procedures (IRB00110953).

Participants in the study met the following inclusion criteria at the time of enrollment: They had to be at least 18 years of age; have a unilateral Advanced Bionics (AB) CII/90 K/Ultra implant; have used a Naída CI Q70 or Q90 processor for at least 6 months; have no prior experience using a CROS device; have no perceived benefits from a traditional HA in the nonimplanted ear, as reported by the CI recipients; demonstrate fluency in spoken English; and be a consistent user of their CI technology as daily device use positively correlates with speech recognition outcomes (e.g., Holder & Gifford, 2021; Lindquist et al., 2023). Exclusion criteria for the study included aidable acoustic hearing in the nonimplanted ear that is perceived to be beneficial by the CI recipient, successfully using traditional amplification, having less than 6 months of CI use experience, and achieving less than 30% sentence recognition scores in quiet conditions with unilateral CI alone. Criteria for speech recognition were applied because the study aimed to evaluate the benefits of the CROS device in challenging, noisy environments.

Participant demographics are shown in Table 1. Seven adult unilateral CI recipients (four males, three females) were enrolled and compensated for taking part in this study. Their median age was 68.3 years, ranging from

Table 1. Participant demographics.

Subject	Age (years)	Gender	Age of HL onset (years)	Age of severe-to-profound hearing loss	CI ear	Date of implant	Age at cochlear implantation (years)	Date fit with current sound processor	Internal device	External device	Coding strategy	Relationship with FCP	Individual SNR (in dB) tested
S1	78	F	46	55	Right	3/2005	60	12/16/2015	HiRes 90 K	Naida Q90	Optima	Spouse	13
S2	81	M	40	40	Left	2/2015	73	2/17/2015	HiRes 90 K	Naida Q70	Optima	Spouse	14
S3	59	M	29	41	Right	2/2005	42	1/22/2019	HiRes 90 K	Naida Q90	Optima	Spouse	21
S4	88	M	Unknown	Unknown	Right	11/2001	67	11/4/2016	CII	Naida Q90	Optima	Spouse	20
S6	71	M	65	65	Left	4/2019	67	4/24/2019	HiRes Ultra	Naida Q90	Optima	Spouse	13
S7	70	F	46	52	Right	3/2012	59	7/13/2017	HiRes 90 K	Naida Q90	Optima	Spouse	15
S8	26	F	Birth	1	Left	10/2009	3	3/5/2014	HiRes 90 K	Naida Q70	Optima	Daughter	13

Note. HL = hearing loss; CI = cochlear implant; FCP = frequent communication partner; SNR = signal-to-noise ratio; F = female; M = male.

24 to 85 years. The median duration of hearing loss was 26.5 years, and the median duration of severe-to-profound hearing loss was approximately 4.5 years. Age at severe-to-profound hearing loss age was documented as the age the participant felt HAs were no longer beneficial, giving a perceived length of deafness prior to cochlear implantation. Additionally, the median CI experience was 14.9 years. Per the inclusion criteria for the study, all but one participant depended solely on unilateral CI use for their everyday listening. This lone participant had an HA in the contralateral ear but reported unsatisfactory experiences with bimodal stimulation. They reported minimal HA use in the past 10 years and were therefore included in the study.

In addition to the CI participants, their FCPs were recruited for the study. FCPs were individuals who had at least 2 hr of in-person interactions with the CI participant each week. Six of the FCPs were spouses, and one was the mother of a participant. Table 1 includes the relationship of the participants to their FCP. Note that although S5 was initially recruited for the study, they were later withdrawn due to their speech recognition dropping below 30%, which meant they no longer met the inclusion criteria. Therefore, they were not included in these analyses or discussions.

Figure 1 shows the hearing thresholds for each participant's nonimplanted ear. Unfortunately, the thresholds for Subject 1 were intended to be obtained on a separate day; however, the visit was canceled due to unforeseen circumstances arising from the COVID-19 pandemic. Subject 5 withdrew from the study prior to unaided testing being completed.

General Procedures

The study was initially designed to include two in-person visits separated by a 6-month take-home phase for CI recipients and their FCPs. However, due to the COVID-19 pandemic, modifications had to be made. The 6-month take-home phase was extended to 16 months, and poststudy questionnaires were collected via mail and e-mail. Figure 2 provides an overview of the study procedures and required modifications.

Materials for Speech Recognition Testing

Speech recognition testing was conducted in a sound booth by a licensed clinical audiologist using a clinical two-speaker setup with speakers at ± 90°. The target stimuli were AzBio sentences (Spahr et al., 2012) calibrated to 65 dBA at the location of the listener. For speech recognition in noise testing, the interferer was a multitalker babble, presented at an individualized level for each participant. This level was determined such that their performance in

Figure 1. Hearing thresholds in the nonimplanted ear for all cochlear implant participants. Individual (black) and mean (blue) unaided hearing thresholds (dB HL) as a function of frequency for six unilaterally implanted individuals who participated in this study. Error bars represent ±1 standard error. Note that the audiogram for Subject 1 was not included due to a canceled appointment caused by the COVID-19 pandemic. S = subject.

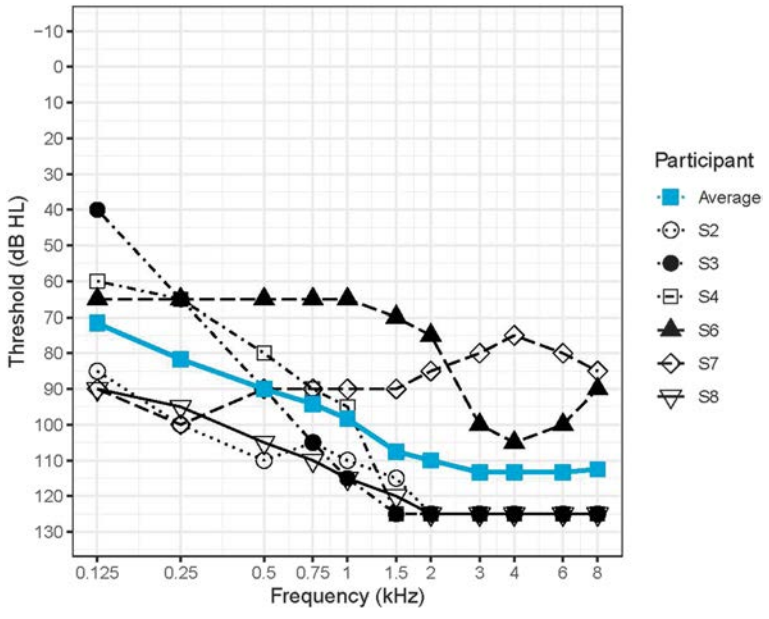
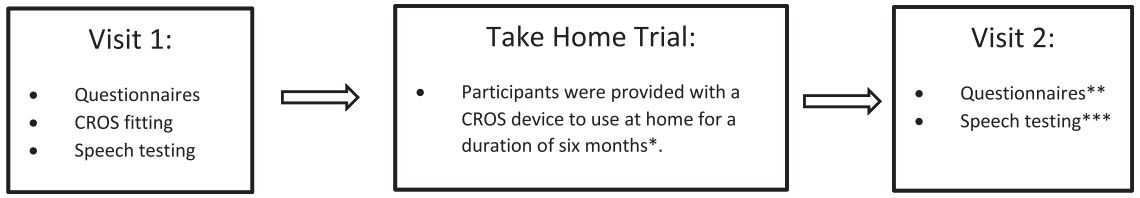


Figure 2. Study design and modifications due to the COVID-19 pandemic. The initial study procedures and the modifications made in response to challenges arising from the COVID-19 pandemic. During Visit 1, participants engaged in various activities, such as questionnaire completion, contralateral routing of signal (CROS) fitting, and speech recognition testing in a sound booth. However, due to the pandemic, adjustments were required. The planned 6-month home trial with the CROS device was extended to 16 months to accommodate pandemic-related limitations. Poststudy questionnaires were collected via mail and e-mail to ensure data collection and speech testing originally scheduled for Visit 2 could not be completed while adhering to social distancing measures. *The 6-month take-home trial of the CROS device was extended to 16 months to accommodate the limitations imposed by the pandemic. **Poststudy questionnaires were collected via mail and email to ensure data collection while adhering to social distancing measures. ***Speech testing in the sound booth could not be conducted due to the pandemic.



noise in the $S_{CROS(Off)}N_{CI}$ configuration was half of their performance in quiet in the $S_{CROS(Off)}$ configuration. The individual signal-to-noise ratio used ranged from 13 to 21 dB (see Table 1 for individual details). All speech testing in the sound booth was completed with a study-issued Naída CI Q90 sound processor. A study-issued Naída Link CROS was used for sound booth testing and during the take-home phase.

Materials for Questionnaires

For CI participants, two questionnaires were used: the APS-SSD and the NCIQ. The APS-SSD is a tool used to evaluate the impact of single-sided deafness on an individual's auditory performance and overall satisfaction with their hearing abilities. This scale was originally developed by Schafer et al. (2013). An adapted version of the APS-SSD, as introduced by Mosnier et al. (2019), was employed for the present study. This adapted version consists of 31 questions emphasizing specific, real-life situations where a CROS device may provide advantages. These questions are categorized into the following domains: hearing at home, at work or school, in social situations, and in general situations. Participants rate their experiences in each situation on a scale ranging from 0 (*can function well*) to 6 (*cannot function at all*). Additionally, the scale includes a section for assessing satisfaction with and usability of the CROS device.

The NCIQ, originally developed by Hinderink et al. (2000), enables a comprehensive assessment of auditory and psychosocial well-being across various contexts. CI recipients are asked to rate their experiences across distinct domains: activity limitations, advanced sound perception, basic sound perception, self-esteem, social interactions, and speech recognition. The NCIQ uses a 5-point Likert scale, ranging from 0 (*never* or *no*) to 100 (*always* or *quiet well*), with the additional option to select *not applicable* (N/A) when none of the provided options apply.

For FCP participants, a single questionnaire, the SOS-HEAR, was utilized. Developed by Scarinci et al. (2009), the SOS-HEAR is a tool designed to assess the impact of an individual's hearing disability on their significant other or family members. The results from the SOS-HEAR are categorized into six domains: communication changes, communicative burden, relationship changes, going out and socializing, emotional reaction, and concern for the partner. The questionnaire consists of 27 items; however, in this study, only 26 items were used, with one statement, "My partner's hearing difficulties have an effect on our intimate/physical relationship," excluded given that an FCP could be any person the subject frequently communicated with. The questionnaire uses a 5-point Likert scale, ranging from 0 (*no problem*) to 4 (*a complete problem*), and covers six subscales: communication changes, communicative burden, relationship changes, going out and socializing, emotional reaction, and concern for the partner. All participants completed these questionnaires twice: once before and once after using the CROS device during the extended home trial.

Procedures During Visit 1

During Visit 1, preintervention questionnaires were filled out and reviewed with the CI participants and their FCPs. Each CI participant's personal Naída CI sound processor was connected to the SoundWave programming software to import the participant's current everyday program and to confirm consistent device use via processor data logging. To maintain consistency in programming across participants, the same parameters were used and applied if needed: ClearVoice, an automatic noise reduction algorithm designed to enhance speech while reducing

background noise, was set to the "medium" setting; all participants used an omnidirectional microphone source (100% T-Mic); and upper stimulation levels (i.e., M-levels) were verified to a level where "most comfortable loudness was achieved, and loudness balanced to neighboring electrodes." After assessing these settings and adjusting them if needed, the CROS device was activated, and the CI program was saved to the study-issued Naída CI Q90 sound processor for testing in the sound booth.

Baseline speech recognition testing was completed under four listening conditions: (a) S_0, where speech in quiet is presented from 0° azimuth without the CROS device; (b) $Speech_{CROS(Off)}$, where speech in quiet is presented to the nonimplanted ear without the CROS device; (c) $Speech_{CROS(Off)}Noise_{CI}$, where speech presented to the nonimplanted ear without the CROS device and noise presented to the CI side; and (d) $Speech_{CROS(On)}Noise_{CI}$, where speech presented to the nonimplanted ear with the CROS device and noise to the CI side.

After baseline speech testing, the program from the study-issued sound processor was transferred to the participant's personal sound processor, and participants were instructed on how to use the CROS device. All participants exhibited proficient use of the CROS device and were authorized to take it home for everyday listening during an extended home trial period. In addition to the study program, an additional program, utilizing UltraZoom, an adaptive monaural beamformer for Q70 sound processors, and StereoZoom, an adaptive binaural beamformer for Q90 sound processors, was saved for use in more challenging listening situations during the home trial.

Procedures During Visit 2

Visit 2 was initially scheduled to last approximately 2 hr and to include the same questionnaire assessments and sound booth testing from Visit 1. Additionally, at this visit, a second program with directional microphones would evaluate the benefits of directional microphone technology (i.e., UltraZoom, StereoZoom). Due to COVID-19 restrictions, participation was limited to filling out the subjective questionnaires at home and mailing them to the clinic.

Procedures During Home Trial

During the take-home phase, participants used their personal Naída CI processor (Q70 or Q90) with the study-issued Naída Link CROS. The study participants' adherence to the protocol was consistently monitored through their preferred communication channels, such as e-mail and text messages. The research team initially maintained biweekly contact for the first 3 months and then transitioned to monthly check-ins to assess various aspects of device usage and communication patterns throughout the study duration. Additionally, CI participants were encouraged to ask any further questions or provide comments regarding their experiences with the CROS device in conjunction with their CI. The audiologist and research team promptly addressed any concerns about device use to ensure the timely resolution of any issues.

Statistical Analyses

All statistical analyses were conducted using R (Version 4.1.3) and the "stats" package. An alpha level of .05 was used for all statistical tests. All plots were facilitated by the "ggplot2" package in R (Version 3.4.2). To analyze the impact of CROS on subjective experience, responses from the pre- and post-CROS time points were compared using Wilcoxon signed-ranks tests with respect to each questionnaire's domains. Speech recognition scores in various listening conditions were analyzed utilizing a repeated-measures analysis of variance with Bonferroni correction to reduce the chance of Type 1 error.

Results

Speech Recognition

Figure 3 shows the distribution of speech recognition scores (in percent correct) without CROS (gray box plots) and with CROS (blue box plots) as a function of speech location. A "Q" indicates that the condition was conducted in quiet, and an "N" indicates that a condition was tested in noise. A statistically significant main effect was observed, $F(3, 18) = 56.02$, $p < .001$. Post hoc analysis revealed significantly worse speech recognition when speech was presented toward the non-CI ear in noise without a CROS device ($M = 30.4$, $SD = 10.3$) compared to when speech was presented from the front in quiet ($M = 70.0$, $SD = 13.0$, $p < .001$) and when speech was presented toward the non-CI ear in quiet ($M = 67.9$, $SD = 15.4$, $p < .001$). Speech recognition in noise was significantly improved with the CROS device ($M = 62.7$, $SD = 15.0$), compared to without the CROS device ($M = 30.4$, $SD = 10.3$, $p = .001$), and not statistically different than any condition evaluated in quiet ($p > .05$).

Questionnaire Results From CI Participants

Figure 4 displays the results of the adapted APS-SSD questionnaires completed by all CI recipients before the extended take-home trial with CROS (gray columns) and after (blue columns). A Wilcoxon signed-ranks test revealed a statistically significant median improvement of

Figure 3. Speech recognition with and without contralateral routing of signal (CROS) device in quiet and noise conditions. The distribution of speech recognition results during Visit 1 as a function of four test conditions: (a) speech presented from the front in quiet (Front [Q]), (b) speech presented toward the non-CI ear in quiet (non-CI ear [Q]), (c) speech presented toward the non-CI ear in noise (non-CI ear [N]), and (d) speech presented to the non-CI ear with a CROS device in noise (CROS [N]). Gray and blue box plots represent listening conditions without and with the CROS device, respectively. *The 6-month take-home trial of the CROS device was extended to 16 months to accommodate the limitations imposed by the pandemic. **Poststudy questionnaires were collected via mail and email to ensure data collection while adhering to social distancing measures. ***Speech testing in the sound booth could not be conducted due to the pandemic.

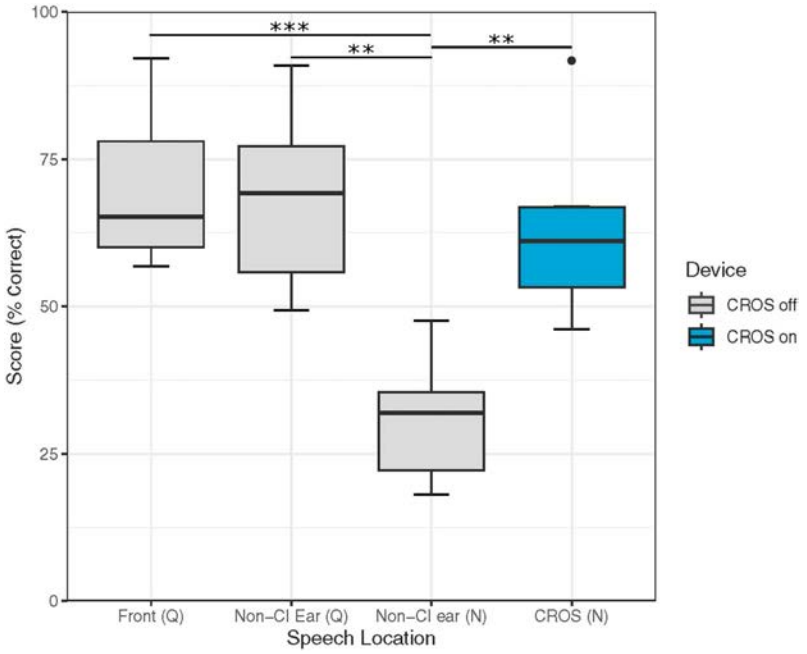
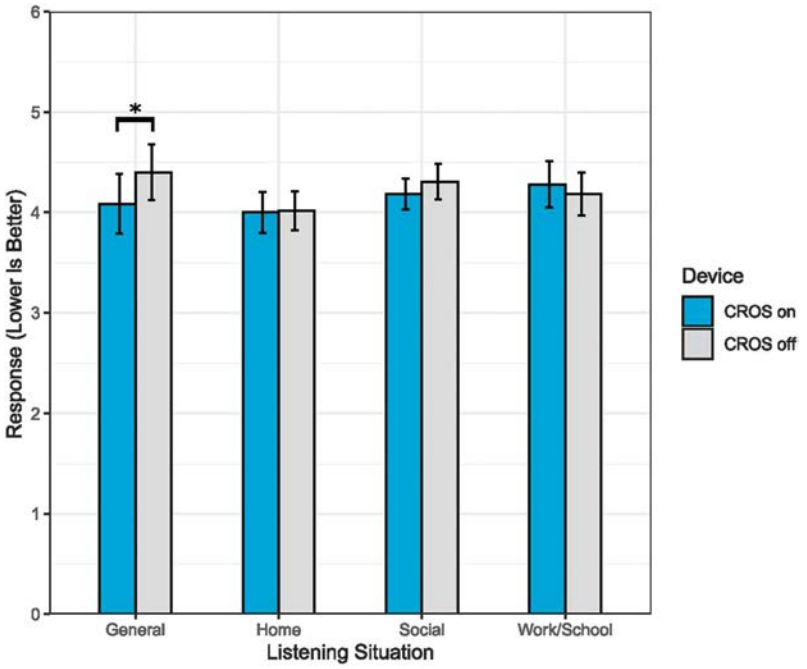


Figure 4. Auditory Performance and Satisfaction Scale for Single-Sided Deafness (APS-SSD) Questionnaire responses with contralateral routing of signal (CROS) device use. The results of the adapted APS-SSD Questionnaire completed by all cochlear implant recipients. Participants rated their experiences in each situation on a scale ranging from 0 (*can function well*) to 6 (*cannot function at all*). The figure displays the mean response obtained before the extended home trial with CROS (in gray) and after (in blue) in four specific environments (i.e., at home, work or school, social activities, or general conversations).



1.0 with CROS device use in the "general" domain (Z = 12.0, $p < .05$). No other statistically significant differences were observed.

Figure 5 displays the results of the NCIQ completed by the CI participants before the extended take-home trial with CROS (gray columns) and after (blue columns). A Wilcoxon signed-ranks test revealed no statistically significant differences between these time points across the six domains ($p > .05$).

Questionnaire Results From FCP Participants

Figure 6 shows the mean results of the SOS-HEAR completed by all FCPs before the extended take-home trial with CROS (gray columns) and after (blue columns). Statistically significant median improvement of 1.0 in the "concern for partner" domain ($Z = 2.0$, $p < .05$), indicating that FCP's concerns for their communication partners were reduced after the CI recipient's extended take-home trial with the CROS device. No other statistically significant differences were observed across any other domain ($p > .05$).

Discussion

This preliminary study aimed to investigate the impact of CROS on speech recognition and the QoL for unilateral CI recipients and their FCPs. The findings from this study demonstrated the potential benefits of CROS devices for this population outside of traditional speech recognition measures, providing insights into the improvement of their hearing experience and overall well-being. This impact extends not only to unilateral CI users but also to their FCPs.

Speech Recognition and CROS Device Use

In quiet conditions, there were no statistically significant differences in speech recognition between speech presented from the front and speech directed toward the non-CI ear without the CROS device. Speech recognition was significantly poorer in noise, where speech was presented to the non-CI ear without the CROS device. With the addition of the CROS device, average speech recognition significantly improved.

We observed a 32% improvement in mean speech recognition in noise with the CROS device. Additionally, we observed no statistically significant difference between the results of CI + CROS in noise and the conditions in quiet without the CROS device. This result is consistent with the findings of CROS benefit in the literature that range from 13.4% to 32.5% (Bergeron et al., 2022; Dorman et al., 2018; Dwyer et al., 2018; Hoshino et al., 2022; Kurien et al., 2019; Núñez-Batalla et al., 2020) and 4.23–10.4 dB (Ernst et al., 2019; Mosnier et al., 2019; Snapp et al., 2019; Stronks et al., 2022; Taal et al., 2016). Differences are likely due to differences in test setup, such as noise source

Figure 5. Nijmegen Cochlear Implant Questionnaire (NCIQ) responses with CROS device use. The results of the NCIQ completed by all cochlear implant recipients. Participants gave their responses on a 5-point Likert scale, ranging from 0 (*never* or *no*) to 100 (*always* or *quiet well*), with the additional option to select *not applicable* (N/A) when none of the provided options apply. The figure displays the mean response obtained before the extended home trial with CROS (in gray) and after (in blue) in six specific subdomains (i.e., activity limitations, advanced sound perception, basic sound perception, self-esteem, social interactions, speech recognition). CROS = contralateral routing of signal.

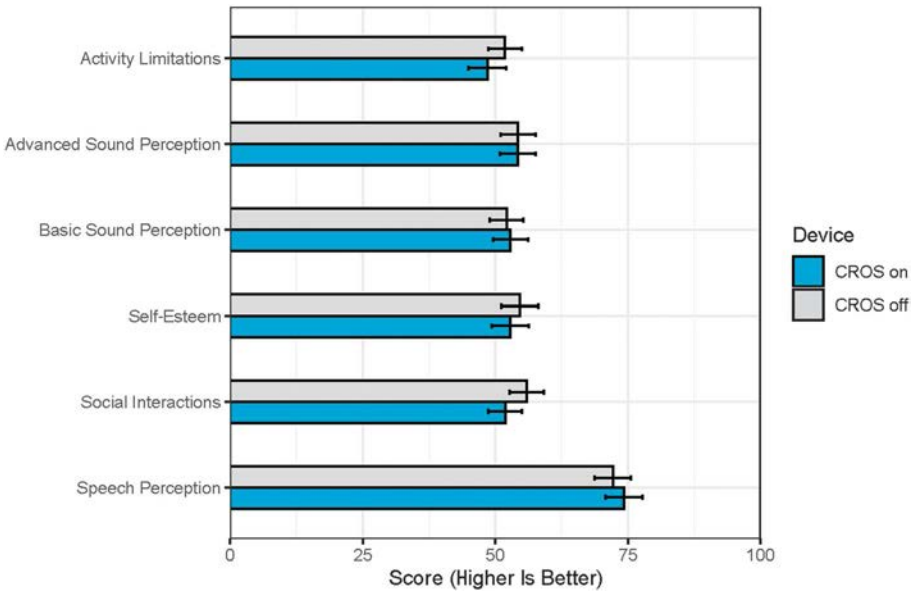
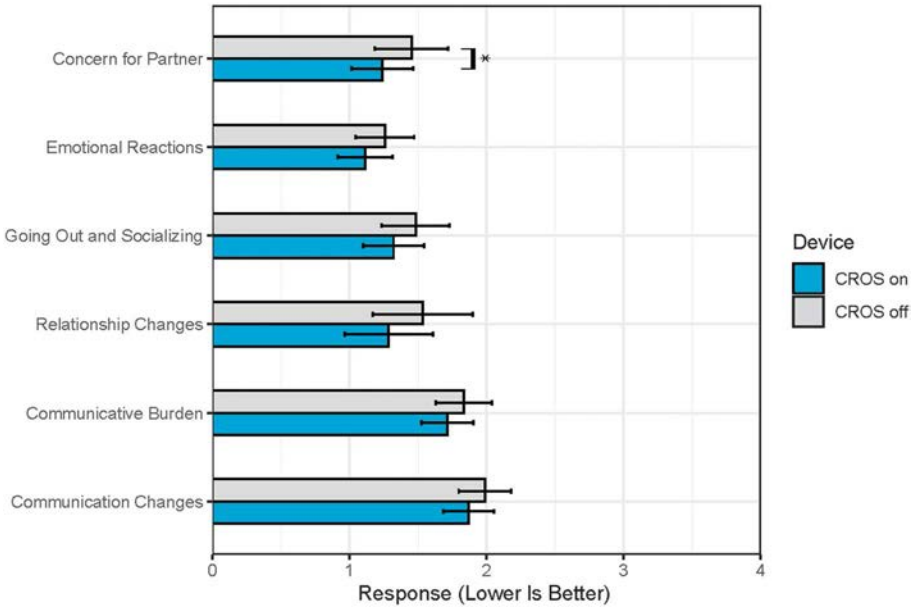


Figure 6. Significant Other Scale of Hearing Disability (SOS-HEAR) Questionnaire responses with CROS device use. The results of the SOS-HEAR Questionnaire administered to all FCPs of the cochlear implant recipients. Participants used a 5-point Likert scale, ranging from 0 (*no problem*) to 4 (*a complete problem*). The figure displays the mean response obtained before the extended home trial with CROS (in gray) and after (in blue) in six specific subdomains (i.e., concern for partner, emotional reactions, going out and socializing, relationship changes, communicative burden, communication changes). CROS = contralateral routing of signal.



azimuth, number of noise sources, and noise type. Although the current study did not investigate the impact of CROS when speech is presented in front of the listener, Dorman et al. (2018), utilizing a similar test environment as Dwyer et al. (2018), observed that when data from two studies were combined, 14 of 17 listeners benefitted from the CROS device. The benefit of improved speech understanding in noise when speech is presented from the front of the listener with CROS has since been observed in findings from studies of Snapp et al. (2019), Bergeron et al., (2022), and Ernst et al. (2019). These results suggest that CROS listeners derive significant benefit when the signal of interest is coming from the CROS side and a modest benefit when the signal is coming from the front. Although it was not tested in this study, for transparency, device counseling on situations where CROS benefit can be expected, as discussed above, and where CROS use can be detrimental (e.g., when the signal of interest is directed to the CI side and interference on the CROS side) should be part of the educational process for individuals considering a CROS device and is the motivation for the mute button, which can be used to reduce or completely silence input from the CROS device on most recent generation CROS devices from AB.

QoL of the CROS User and Their FCP

The current study assessed the impact of CROS device use on the QoL of CI recipients and their FCPs through questionnaires. Tavora-Vieira et al. (2015) showed that patient-reported outcome measures can provide clinicians with relevant information regarding the impact of hearing loss on candidates and recipients. The value of utilizing patient-reported outcome measures can be an invaluable assessment of a patient's real-world hearing experiences, thus evaluating a patient's perceived QoL. In addition to providing clinicians with insightful data, QoL measures are also of increased value to insurance carriers. Neubert et al. (2020) showed that health insurers in the United States often use outcomes and satisfaction measures for procurement and purchasing of services; for quality assurance, improvement, and reporting; and for strengthening the involvement of beneficiaries. In the current study, the results of the adapted APS-SSD showed a significant improvement in the general domain after the take-home period with the CROS device, suggesting that CI recipients experienced enhanced auditory performance and satisfaction in everyday situations. These findings are congruent with previous work by Mosnier et al. (2019), who observed a significant improvement with CROS in social and general domains after chronic device use. It is no surprise that no differences were observed in the other more social domains in the current work (e.g., "work/school" and "social"), particularly as the COVID-19 restrictions kept people home and out of more complex listening situations where we might expect to see CROS benefit. Neither the current study nor the study of Mosnier et al.

(2019) saw a significant change in the "home" or "work" domains after a home trial with CROS.

The NCIQ did not show significant differences in QoL scores after the home trial with CROS across any of the six domains (i.e., activity limitations, advanced sound perception, basic sound perception, self-esteem, social interactions, and speech recognition). The authors hypothesize that the lack of more significant findings via the subjective assessments might be attributable to two mechanisms: (a) CROS benefit being the largest in complex listening situations, which exposure was limited to during COVID-19 shutdown protocols, meant a lack of perceived benefit in more social situations, and (b) perhaps these assessments are not sensitive enough to capture CROS benefit in those domains.

Despite some lack of statistical improvement that could be quantified by the subjective assessments used in this study, statistical improvement in perceived CROS benefit have been described elsewhere (e.g., Dwyer et al., 2018; Ernst et al., 2019). In the current study, the perceived benefit might be assumed because four of the seven participants opted to keep the CROS device at the end of their study participation. Further evidence of the perceived usefulness of the CROS device was observed in the "Miscellaneous" section of the modified APS-SSD, which asks participants to indicate if they agree with certain statements based on their experience with the CROS device. Although the responses to these statements varied among the participants, six of seven CI recipients agreed with the statement, "Music sounds better." The positive report of improved music appreciation in CI recipients using a CROS device is an unexpected finding. This finding holds significant importance because music plays a vital role in many people's lives, and hearing loss can significantly affect the ability to enjoy music. Therefore, any assistive listening device that can enhance music appreciation is highly beneficial for individuals with hearing loss. The hypothesis that music appreciation could be better with CROS than unilateral CI alone listening is plausible, as the CROS system allows recipients to hear sounds from both sides rather than just one. Similarly, Ernst et al. (2019) reported a significant benefit of "music listening ease" in CROS users compared to unilateral CI; however, this hypothesis and additional investigation into the benefit of CROS on QoL should be further investigated through dedicated research during more precedented times.

A unique aspect of this study was investigating CROS benefits from the viewpoint of each participant's FCP. This was measured via the SOS-HEAR Questionnaire, which measures the impact of an individual's hearing loss on those they are close with. The results of the SOS-HEAR indicated a significant reduction in apprehensions related to their partner's hearing when CI recipients employed the CROS device, with a significant improvement in the "concern for partner" domain. The improvement in this domain highlights the positive impact of CROS device usage on the well-being of FCPs and their heightened confidence in their partner's ability to hear and communicate effectively. It underscores the importance of considering not only the individual CI recipient's needs but also the needs of their communication partners when evaluating the efficacy of devices such as the CROS, which may extend to any number of assistive technologies.

Limitations of the Study

Several limitations should be acknowledged when interpreting the results of this study. First, the sample size is small, consisting of only seven CI recipients and their FCPs. This limited sample size restricts the generalizability of the findings to larger and more diverse populations. Future research should aim to replicate the study with larger and more diverse cohorts. Second, the study design was influenced by the COVID-19 pandemic, resulting in adjustments to procedures and timelines. Specifically, the speech recognition testing initially scheduled for Visits 1 and 2 could not be conducted during Visit 2 due to pandemic restrictions. These modifications may have influenced device usage patterns and study outcomes. Despite these necessary modifications, the study prioritized data integrity and participant safety by adapting protocols to the challenging circumstances brought about by the COVID-19 pandemic.

Third, the study exclusively focused on participants with specific hearing configurations, implant, and processor types, potentially limiting the broader applicability of these findings to individuals with different device configurations and technology. Last, the absence of a control group hinders the ability to establish causal relationships between the CROS device and speech recognition and QoL outcomes. Although this study offers valuable insights into the use of the CROS device among unilateral CI recipients, it is essential to consider these limitations when interpreting the results.

Last, before the implementation of COVID-19 restrictions, the mean daily utilization of the CROS device was 12.7 hr per day, with individual usage ranging from 7 to 18 hr. However, even though device usage was consistently monitored through regular e-mail and text check-ins during the home trial, following the onset of COVID-19 restrictions, participants reported, among others, reduced CROS device usage due to remote work arrangements, decreased social interactions, and concerns related to health and mask wearing, which may have influenced the subjective results. We are currently exploring the feasibility of a

postpandemic follow-up study that could offer additional insights, particularly in assessing QoL in more typical social environments and changes in QoL over time with device use.

Conclusions

These emerging pilot data point to the value of CROS devices in improving the hearing experience and well-being of unilateral CI recipients and their FCPs. Although lifestyle changes related to COVID-19 made it challenging to compare pre- and poststudy data, these preliminary data provide evidence of the benefits that CROS devices offer to unilateral CI recipients, effectively addressing speech recognition challenges in noisy environments and an opportunity to enhance their overall QoL. The substantial improvement in speech recognition in noise highlights the significance of considering CROS devices as a valuable solution for unilaterally implanted individuals with minimal aidable hearing in the contralateral ear. Furthermore, the positive impact of CROS devices on FCPs, as evidenced by reduced concerns regarding their partner's hearing, underscores the potential for broader implications of CROS device use in enhancing communication and relationship dynamics. Audiologists and other health care professionals working with CI recipients should consider recommending the adoption of CROS devices and offering ongoing counseling and support to optimize their benefits. Given the preliminary nature of these data, further research is required to investigate the CROS device's benefits in more diverse social listening environments in the post–COVID-19 era and study its long-term effects on communication and the QoL for CI recipients and their FCPs.

Statement of Ethics

This study protocol received approval from the local institutional review board under Approval No. 00110953. All participants provided written informed consent to participate in the study.

Author Contributions

Kate Johnson: Conceptualization, Methodology, Investigation, Writing – review & editing. **Eun Kyung Jeon:** Methodology, Data curation, Writing – original draft. **Robert Dwyer:** Data curation, Formal analysis, Writing – original draft, Visualization. **Smita Agrawal:** Conceptualization, Methodology, Writing – original draft, Visualization, Supervision. **Richard Gurgel:** Investigation, Writing – review & editing.

Data Availability Statement

The data sets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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References

Agrawal, S. S. (2008). *Spatial hearing abilities in adults with bilateral cochlear implants*. University of Wisconsin–Madison.

Amann, E., & Anderson, I. (2014). Development and validation of a questionnaire for hearing implant users to self-assess their auditory abilities in everyday communication situations: The Hearing Implant Sound Quality Index (HISQUI19). *Acta Oto-Laryngologica, 134*(9), 915–923. https://doi.org/10.3109/00016489.2014.909604

Bergeron, F., Agrawal, S., Lemolton, A., Fariney, T., Demers, D., Berland, A., & Bouchard, B. (2022). Hearing assessment and training in immersive virtual reality; clinical model and validation with cochlear implant users. *Journal of Otolaryngology, 8*(4). https://doi.org/10.32474/SJO.2022.08.000292

Buchman, C. A., Gifford, R. H., Haynes, D. S., Lenarz, T., O'Donoghue, G., Adunka, O., Biever, A., Briggs, R. J., Carlson, M. L., Dai, P., Driscoll, C. L., Francis, H. W., Gantz, B. J., Gurgel, R. K., Hansen, M. R., Holcomb, M., Karltorp, E., Kirtane, M., Larky, J., . . . Zwolan, T. (2020). Unilateral cochlear implants for severe, profound, or moderate sloping to profound bilateral sensorineural hearing loss: A systematic review and consensus statements. *JAMA Otolaryngology—Head & Neck Surgery, 146*(10), 942–953. https://doi.org/10.1001/jamaoto.2020.0998

Ching, T. Y. C., Incerti, P., Hill, M., & van Wanrooy, E. (2006). An overview of binaural advantages for children and adults who use binaural/bimodal hearing devices. *Audiology & Neuro-Otology, 11*(Suppl. 1), 6–11. https://doi.org/10.1159/000095607

Devocht, E. M. J., Janssen, A. M. L., Chalupper, J., Stokroos, R. J., Kingma, H., & George, E. L. J. (2020). Self-assessment of unilateral and bimodal cochlear implant experiences in daily life. *PLOS ONE, 15*(12), Article e0242871. https://doi.org/10.1371/journal.pone.0242871

Dorman, M. F., Cook Natale, S., & Agrawal, S. (2018). The value of unilateral CIs, CI-CROS and bilateral CIs, with and without beamformer microphones, for speech understanding in a simulation of a restaurant environment. *Audiology & Neuro-Otology, 23*(5), 270–276. https://doi.org/10.1159/000493844

Dorman, M. F., Cook, S., Spahr, A., Zhang, T., Loiselle, L., Schramm, D., Whittingham J., & Gifford R. (2015). Factors constraining the benefit to speech understanding of combining information from low-frequency hearing and a cochlear implant. *Hearing Research, 322,* 107–111. https://doi.org/10.1016/j.heares.2014.09.010

Dorman, M. F., & Gifford, R. H. (2010). Combining acoustic and electric stimulation in the service of speech recognition. *International Journal of Audiology, 49*(12), 912–919. https://doi.org/10.3109/14992027.2010.509113

Dunn, C. C., Tyler, R. S., & Witt, S. A. (2005). Benefit of wearing a hearing aid on the unimplanted ear in adult users of a cochlear implant. *Journal of Speech, Language, and Hearing Research, 48*(3), 668–680. https://doi.org/10.1044/1092-4388(2005/046)

Dunn, C. C., Tyler, R. S., Witt, S. A., Ji, H., & Gantz, B. J. (2012). Sequential bilateral cochlear implantation: Speech perception and localization pre– and post–second cochlear implantation. *American Journal of Audiology, 21*(2), 181–189. https://doi.org/10.1044/1059-0889(2012/12-0004)

Dwyer, R. T., Kessler, D., Butera, I. M., & Gifford, R. H. (2018). Contralateral routing of signal yields significant speech in noise benefit for unilateral cochlear implant recipients. *Journal of the American Academy of Audiology, 30*(3), 235–242.

Ernst, A., Baumgaertel, R. M., Diez, A., & Battmer, R.-D. (2019). Evaluation of a wireless contralateral routing of signal (CROS) device with the Advanced Bionics Naída CI Q90 sound processor. *Cochlear Implants International, 20*(4), 182–189. https://doi.org/10.1080/14670100.2019.1586151

Farinetti, A., Roman, S., Mancini, J., Baumstarck-Barrau, K., Meller, R., Lavieille, J. P., & Triglia J. M. (2015). Quality of life in bimodal hearing users (unilateral cochlear implants and contralateral hearing aids). *European Archives of Oto-Rhino-Laryngology, 272*(11), 3209–3215. https://doi.org/10.1007/s00405-014-3377-8

Firszt, J. B., Holden, L. K., Reeder, R. M., Cowdrey, L., & King, S. (2012). Cochlear implantation in adults with asymmetric hearing loss. *Ear and Hearing, 33*(4), 521–533. https://doi.org/10.1097/AUD.0b013e31824b9dfc

Härkönen, K., Kivekäs, I., Rautiainen, M., Kotti, V., Sivonen, V., & Vasama, J.-P. (2015). Sequential bilateral cochlear implantation improves working performance, quality of life, and quality of hearing. *Acta Oto-Laryngologica, 135*(5), 440–446. https://doi.org/10.3109/00016489.2014.990056

Hinderink, J. B., Krabbe, P. F. M., & Van Den Broek, P. (2000). Development and application of a health-related quality-of-life instrument for adults with cochlear implants: The Nijmegen Cochlear Implant Questionnaire. *Otolaryngology—Head and Neck Surgery, 123*(6), 756–765. https://doi.org/10.1067/mhn.2000.108203

Holder, J. T., & Gifford, R. H. (2021). Effect of increased daily cochlear implant use on auditory perception in adults. *Journal of Speech, Language, and Hearing Research, 64*(10), 4044–4055. https://doi.org/10.1044/2021_JSLHR-21-00066

Hoshino, A. C. H., Goffi-Gomez, M. V. S., Sierra, P. A. S., Agrawal, S., Rodriguez, C., Carvalho, A. C. M., de Carvalho A. C. M., & Tsuji R. K. (2022). Can the use of the CROS system provide head shadow effect contribution to unilateral cochlear implant users? *CoDas, 34*(5), Article e20210071. https://doi.org/10.1590/2317-1782/20212021071

Illg, A., Bojanowicz, M., Lesinski-Schiedat, A., Lenarz, T., & Büchner, A. (2014). Evaluation of the bimodal benefit in a large cohort of cochlear implant subjects using a contralateral hearing aid. *Otolology & Neurotology, 35*(9), e240–e244. https://doi.org/10.1097/MAO.0000000000000529

Kurien, G., Hwang, E., Smilsky, K., Smith, L., Lin, V. Y. W., Nedzelski, J., & Chen J. M. (2019). The benefit of a wireless contralateral routing of signals (CROS) microphone in unilateral cochlear implant recipients. *Otology & Neurotology, 40*(2), e82–e88. https://doi.org/10.1097/MAO.0000000000002078

Lindquist, N. R., Dietrich, M. S., Patro, A., Henry, M. R., DeFreese, A. J., Freeman, M. H., Perkins E. L., Gifford R. H., Haynes D. S., & Holder J. T. (2023). Early datalogging predicts cochlear implant performance: Building a recommendation for daily device usage. *Otolology & Neurotology, 44*(7), e479–e485. https://doi.org/10.1097/MAO.0000000000003917

Litovsky, R. Y., Goupell, M. J., Godar, S., Grieco-Calub, T., Jones, G. L., Garadat, S. N., Agrawal, S., Kan, A., Todd, A., Hess, C., & Misurelli, S. (2012). Studies on bilateral cochlear implants at the University of Wisconsin's Binaural Hearing and Speech Laboratory. *Journal of the American Academy of Audiology, 23*(6), 476–494. https://doi.org/10.3766/jaaa.23.6.9

Mosnier, I., Lahlou, G., Flament, J., Mathias, N., Ferrary, E., Sterkers, O., Bernardeschi D., & Nguyen Y. (2019). Benefits of a contralateral routing of signal device for unilateral Naída CI cochlear implant recipients. *European Archives of Oto-Rhino-Laryngology, 276*(8), 2205–2213. https://doi.org/10.1007/s00405-019-05467-9

Neubert, A., Fernandes, O. B., Lucevic, A., Pavlova, M., Gulacsi, L., Baji, P., Klazinga, N., & Kringos, D. (2020). Understanding the use of patient-reported data by health care insurers: A scoping review. *PLOS ONE, 15*(12). https://doi.org/10.1371/journal.pone.0244546

Núñez-Batalla, F., Fernández-Junquera, A. B., Suárez-Villanueva, L., Díaz-Fresno, E., Sandoval-Menéndez, I., Gómez Martínez, J., & Llorente-Pendás J. L. (2020). Application of wireless contralateral routing of signal (CROS) technology in unilateral cochlear implant users. *Acta Otorrinolaringologica Española, 71*(6), 333–342. https://doi.org/10.1016/j.otorri.2019.10.004

Reeder, R. M., Firszt, J. B., Holden, L. K., & Strube, M. J. (2014). A longitudinal study in adults with sequential bilateral cochlear implants: Time course for individual ear and bilateral performance. *Journal of Speech, Language, and Hearing Research, 57*(3), 1108–1126. https://doi.org/10.1044/2014_JSLHR-H-13-0087

Scarinci, N., Worrall, L., & Hickson, L. (2009). The effect of hearing impairment in older people on the spouse: Development and psychometric testing of the Significant Other Scale for Hearing Disability (SOS-HEAR). *International Journal of Audiology, 48*(10), 671–683. https://doi.org/10.1080/14992020902998409

Schafer, E. C., Baldus, N., D'Souza, M., Algier, K., Whiteley, P., & Hill, M. (2013). Behavioral and subjective performance with digital CROS/BiCROS hearing instruments. *Journal of the Academy of Rehabilitative Audiology, 46,* 62–93.

Snapp, H. A., Hoffer, M. E., Spahr, A., & Rajguru, S. (2019). Application of wireless contralateral routing of signal technology in unilateral cochlear implant users with bilateral profound hearing loss. *Journal of the American Academy of Audiology, 30*(07), 579–589. https://doi.org/10.3766/jaaa.17121

Spahr, A. J., Dorman, M. F., Litvak, L. M., Van Wie, S., Gifford, R. H., Loizou, P. C., Loiselle, L. M., Oakes, T., & Cook, S. (2012). Development and validation of the AzBio sentence lists. *Ear and Hearing, 33*(1), 112–117. https://doi.org/10.1097/AUD.0b013e31822c2549

Stronks, H. C., Briaire, J. J., & Frijns, J. H. M. (2022). Residual hearing affects contralateral routing of signals in cochlear implant users. *Audiology & Neuro-Otology, 27*(1), 75–82.

Taal, C. H., van Barneveld, D. C. P. B. M., Soede, W., Briaire, J. J., & Frijns, J. H. M. (2016). Benefit of contralateral routing of signals for unilateral cochlear implant users. *The Journal of the Acoustical Society of America, 140*(1), 393–401. https://doi.org/10.1121/1.4955307

Tavora-Vieira, D., Marino, R., Acharya, A., & Rajan, G. P. (2015). The impact of cochlear implantation on speech understanding, subjective hearing performance, and tinnitus perception in patients with unilateral severe to profound hearing loss. *Otology & Neurotology, 36*(3), 430–436. https://doi.org/10.1097/MAO.0000000000000707

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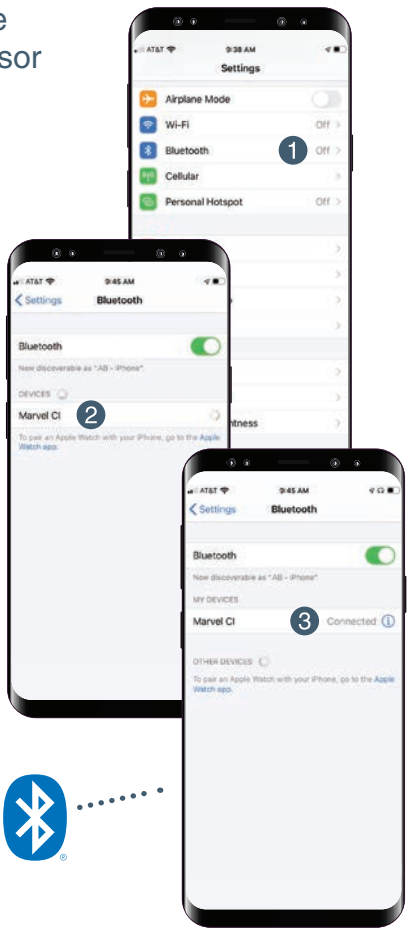
SOUND PROCESSORS

Stream directly from your phone to your Marvel CI sound processor



1. BLUETOOTH MENU

Open the Bluetooth® menu on your phone (often found in *"Settings"* or *"Tools"*). Enable Bluetooth.

2. PAIRING

Turn on your Marvel CI sound processor by connecting a battery to start the 3 minute pairing window. Once your sound processor appears in the list of Bluetooth devices, select your sound processor. A beep will confirm successful pairing.

3. PHONE CALLS AND STREAMING

Try making a call or streaming some music directly to your processor. Phone calls are hands-free, so there is no need to hold the phone up to your mouth.

4. ADJUST

A short press of the button on your sound processor will answer an incoming phone call. Once you are on a call or listening to audio, you can use the multi-function button to adjust the volume of the audio.

ADVANCED BIONICS
POWERFUL CONNECTIONS

Marvel CI
SOUND PROCESSORS

Discreet control and device check at your fingertips

5. DOWNLOAD THE AB REMOTE APP

After completing the Bluetooth pairing, visit the App Store (Apple devices) or Google Play (Android devices). Search for *"AB Remote"* and download the mobile app.

Download on the App Store

GET IT ON Google Play

6. OPEN THE APP

Follow the easy instructions to pair your hearing devices to the app.

7. ADJUST, PROGRAM, & MORE

Enjoy easy control of your device volume, programs, check microphone, status, lock, and other device components.

For more information, visit
AdvancedBionics.com/MarvelCIProductSupport

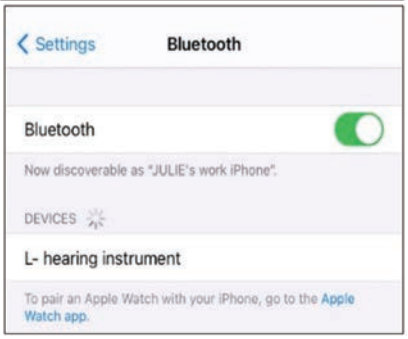
- Instructional videos
- Frequently asked questions
- Compatibility information

Bluetooth Connection Guide

ADVANCED BIONICS
POWERFUL CONNECTIONS

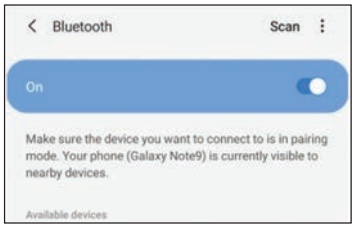
Connect your Marvel CI sound processors to your Bluetooth® devices to stream audio and make hands-free phone calls

TO PAIR AN APPLE IOS DEVICE



1. Go to your device home screen and tap on the *Settings* icon.
2. In the *Settings* menu, tap on the Bluetooth icon.
3. Tap on the slider next to *Bluetooth* to turn it On.
4. Connect the M Battery to Marvel CI to start the three-minute pairing window (your devices will attempt to connect).
5. After several seconds, the customized name of your Marvel CI will appear on the iOS® device screen under "Other Devices." Tap on it to select.
6. You may see a message: *Bluetooth Pairing Request.* Click *Pair*.
7. A connection beep will be heard in the paired Marvel CI.
8. Your iOS device is now connected to Marvel CI.

TO PAIR AN ANDROID DEVICE:



1. Go to the device *Settings* and tap on *Connections*.
2. In the *Connections* menu, tap on the slider to turn Bluetooth on.
3. Connect the M Battery to Marvel CI to start the 3-minute pairing window (your devices will attempt to connect).
4. Once the Android™ device Bluetooth is turned on, it will automatically scan for available devices nearby.
5. On the Android phone, you will now see a message: *Available Devices*. If no devices appear, slide the battery on your Marvel CI off then on and tap *Scan* again.
6. The name of your Marvel CI will appear. Tap on it to select.
7. A message may pop up on your Android device for you to confirm the pairing request.
8. A connection beep will be heard in the paired Marvel CI.
9. Your Android device is now connected to Marvel CI.

TO PAIR WITH OTHER BLUETOOTH DEVICES (E.G., COMPUTER, TV, TABLET)

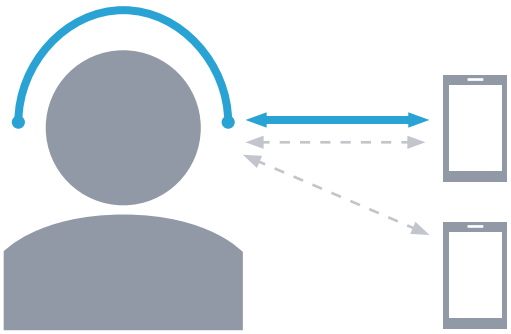
1. Go into the Bluetooth settings menu of your device
2. Slide your M Battery on and off your Marvel CI to start the three-minute pairing window.
3. Add Bluetooth device and select Marvel CI to pair and connect.
4. If requested, the pairing code is 0000.

If you are using two devices (two Marvel CIs or one Marvel CI and one Phonak Link M hearing aid), only the side set by your audiologist as your "Bluetooth side" will show in your device's Bluetooth menu.

Marvel CI Bluetooth Quick Tips

WHAT IS BLUETOOTH?

Bluetooth is a wireless technology that allows two different devices to connect to one another. It is a universal protocol, making phone calls and streaming available for all devices with Bluetooth from any brand.



Paired to up to two devices at a time
Pairing is the process of establishing a link between two devices, allowing them to communicate with on another

Connected to one device at a time
Connecting happens when the two devices are actively exchanging information like streaming music

If you wear two marvel CIs or a CI with Phonak Link M hearing aid, streaming media and phone calls will always be heard on both side.

MAKING A PHONE CALL

1. If not already paired, follow instructions on page 1 to pair your phone to Marvel CI.
2. Connect your phone to Marvel CI.
   - A paired device will be already connected.
   - If already paired to the phone but connected to another device (e.g., tablet), slide off the M Battery and slide it back on or turn Bluetooth off on the device you do not want to use for the call.
3. You are ready to make the call.

What is Own Voice Pickup?

Own Voice Pickup allows for truly hands-free phone calls by using the Marvel CI microphones, rather than the microphones in your phone, to pick up your voice.

RECEIVING A PHONE CALL

1. If a phone is paired and connected, phone ringtone and audio will sound in your Marvel CI. If you wear two Marvel CIs or a CI with Phonak Link M hearing aid, the ring tone and phone call will be heard in both ears.
2. A short press of the button on your sound processor will answer the incoming phone call. You can use the multi-function button to adjust the volume of the audio.
3. If your phone is paired but not connected, you will not hear the ring tone in your Marvel CI.

OWN VOICE PICKUP

Own Voice Pickup is the default setting when your phone is connected to your Marvel CI. If you do not want sound to stream directly to your processor, disconnect your phone in its Bluetooth menu.

ADJUSTING VOLUME IN A BLUETOOTH PHONE CALL

Change the phone volume with the volume buttons on the side of the phone or using the button on your Marvel CI. The AB Remote app does not control volume during a phone call.

LISTENING TO MUSIC OR VIDEO MEDIA

1. If not already paired, follow instructions on page 1 to pair your phone to Marvel CI.
2. Connect your phone to Marvel CI.
- A newly paired device will be already connected.
- If already paired to the phone but connected to another device (e.g., tablet), slide off the M Battery and slide it back on.
3. You can increase the volume on the Marvel CI or on the audio device.
4. You can use the app to control your audio. See the section “USING THE APP”

Listening with Two Ears

Your hearing care professional will choose one of your Marvel CIs to connect to Bluetooth. Both ears will be able to hear the sound.

Your two Marvel CIs are configured as one system. The second processor cannot stream from a different device at the same time.

USING SKYPE, FACETIME, AND WHATSAPP WITH MARVEL CI

Marvel CI supports Skype, FaceTime, and WhatsApp for audio and video calling. The call will be heard in Marvel CI just like typical phone calls. If using popular video calling apps such as Skype and Facetime on a tablet or computer, Marvel CI must be paired and connected to that device.

1. If not already paired, follow instructions on page 1 to pair your phone to Marvel CI.
2. Connect your phone to Marvel CI.
- A paired device will be already connected.
- If already paired to the phone but connected to another device (e.g., tablet), slide off the M Battery and slide it back on.

When your phone is connected to your Marvel CI, Own Voice Pickup will be used. If you do not want sound to stream directly to your processor and use the Marvel microphone, disconnect your phone in its Bluetooth menu.

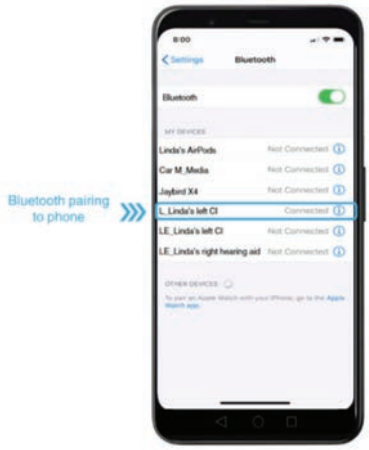
BLUETOOTH VS. BLUETOOTH LE (AB REMOTE APP)

The AB Remote app and your Marvel CI are separate in your device’s Bluetooth menu.

The app connection will appear as “LE_”. This is because the app uses Bluetooth LE (Low Energy).

If you are listening with two Marvel CIs or one CI and one Link M hearing aid, only one CI will connect with Bluetooth, but both ears will connect to the app (LE_). This is because the app controls both devices at the same time.

It is recommended to pair to your phone for phone calls first before pairing to the app.



Bluetooth Device (Bluetooth Classic)

- Stream music and media.
- Stream phone calls.
- Stream Skype, WhatsApp, or FaceTime conversations.

AB Remote App (Bluetooth LE)

- Adjust volume and balance.
- Change programs.
- Change progressive levels.
- Perform device check.
- Review battery level and usage.

Troubleshooting Bluetooth Connectivity

CHECK THIS FIRST

- Make sure your devices are charged. Some Bluetooth devices may automatically change streaming settings when in low power mode.
- Make sure your phone is within range. If you were out of range (10m / 30ft) for a longer period of time, it may take up to two minutes for Marvel CI to connect again. You may need to unpair and re-pair (follow instructions to pair on page 1).

BLUETOOTH AUDIO DOES NOT SEEM TO BE PLAYING

1. Check that Bluetooth is enabled on your device by going to **Settings > Bluetooth**.
2. Make sure the right device is connected to your Marvel CI.
3. Check that the volume of the streaming audio is not turned all the way down.
4. Unpair and re-pair your Marvel CI.

POOR SOUND QUALITY DURING PHONE CALLS

1. Unpair and re-pair your Marvel CI and Bluetooth device.
2. Restart your Marvel CI and your phone.
3. Adaptive Bluetooth is a default setting that might affect sound quality for some phone models or operating systems. To disable Adaptive Bluetooth using the app, tap on the settings icon (upper right corner), select **My Devices > Adaptive Bluetooth > switch OFF**.

BLUETOOTH KEEPS DISCONNECTING

1. If you are using the AB Remote app, unpair and re-pair. It is recommended to pair your Bluetooth device first before pairing to the AB Remote app.
2. Unpair and re-pair your Marvel CI and Bluetooth device.

DISABLING TOUCH SOUNDS AND NOTIFICATIONS

- On an iOS device, go to **Settings > Select Sounds >** Change the **Keyboard Clicks** and **Lock Sound** to **OFF**.
- On an Android device, go to **Settings > Sounds and Vibration > System Sound/Vibration Control >** turn on/off the settings you wish to change.

Find more troubleshooting tips on MyABOnline.com

https://www.advancedbionics.com/us/en/home/support/com-portal-update.html