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Chapter 5: Setting the Hearing Aid Response and Verifying Signal Processing and Features with Real-Ear Probe Microphone Measures

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ABSTRACT

The real-ear probe microphone system provides a powerful tool to individual hearing aid fittings accounting for your patient's hearing and ear canal characteristics. The primary treatment for hearing loss is audibility, returning an audible signal across frequencies and input levels given the constraints of the hearing loss. This chapter will provide detailed information on the measures needed to individualize the hearing aid fitting and will present various clinical scenarios that will allow you to work with this information and see how you apply this knowledge clinically. You will explore the verification of signal processing and features that allow you to support your patients.

KEYWORDS: real-ear probe microphone measures, real-ear to coupler difference, audibility, signal processing, hearing aid fitting formula

Many of the measures discussed in this chapter depend on data from the individual's dynamic range (i.e., the area where they can hear sound). The dynamic range of a person's hearing can be displayed by finding the threshold and uncomfortable listening levels (UCL) for an

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individual and converting the decibel (dB) hearing level (HL) data to dB sound pressure level (SPL) data so that the information can be used in the hearing aid fitting process. To enable the conversion of dB HL to dB SPL, we will be reviewing the use of RECD (real-ear to coupler difference) and REDD (real-ear to dial difference) using the Verifit 2 Audioscan System.

RECD is the difference in sound pressure in dB SPL between a 2-cc coupler (representing the average ear canal volume of a Caucasian adult male) and the patient's ear canal. RECD enables a clinician to convert hearing threshold data collected with insert phones from dB HL to dB SPL using the patient-specific RECD information. See Chapter 3 for a detailed description of the importance and use of RECD in hearing aid fittings. The fitting targets (e.g., DSLv.5,[1] NAL-NL2[2]) are based on the dB SPL thresholds; so, we want these to be accurate for each patient. Most importantly, the same transducer used for hearing testing must be used for RECD measurements. For some pediatric patients, an earmold may have been used when collecting hearing thresholds. If that is the case, the same earmold should be used when measuring RECD. However, if hearing thresholds were obtained with an insert earphone, do not use the earmold for the RECD measurement; use the insert earphone.

You will also see the term Wideband RECD (WRECD)[3] in this chapter. WRECD is a RECD measurement that is made with 0.4-cc coupler (as opposed to the standard 2-cc coupler), which allows for measurements to be made through a higher frequency range (the display ends at 16,000 Hz). This distinction is important here because WRECD data cannot be compared directly to RECD data, but we can view an equivalent RECD data using the Verifit 2 (described later in this chapter) if the information is needed.

REDD is the difference in dB between the SPL measured in the real-ear and the audiometer dial level that produced the signal. REDD is used to convert collected audiometric information (e.g., thresholds and UCLs) from dB HL to dB SPL when supra-aural earphones (as opposed to insert earphones) were used for hearing testing. Ideally, you will use insert earphones for testing and use the RECD procedure to convert HL data to SPL data. For the purposes of this workbook, we are going to focus on measuring RECD since that is the most common method for converting dB HL data to dB SPL data.

MEASURING THE REAL-EAR PORTION OF WRECD AND CALCULATING WRECD

Make sure you have completed the coupler measurement portion of WRECD prior to following these instructions (see Chapter 4).

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, probe tubes, insert earphones.

Activity 1

1. Set up your equipment as described in Chapter 4, including the WRECD coupler measurement.
2. Select **WRECD** on the home menu.
3. Select the WRECD coupling method that will be used on the ear. Audioscan software supports both foam ear tips and personal earmolds; however, this choice must be made prior to measurement. For our purposes, we will be using a foam tip (insert earphone) and will assume we test hearing with insert earphones.
4. Select **Measure real ear** to see the suggested test setup prompt.
5. Couple a standard foam insert earphone to the nozzle of the WRECD transducer.
6. Attach the probe tube to the on-ear probe microphone assembly and, using the adjustable red or blue loop, hang the probe module on the ear. Although the reference microphone port is not used in this measurement, it is good practice to have the reference microphone port facing out, away from the head. Ensure you have the correct assembly (right/left) on the correct ear.

Helpful hint: Use a clip to secure the probe deck to the shirt collar of the patient. This will help keep the weight off the tube and prevent it from slipping out of the ear canal.

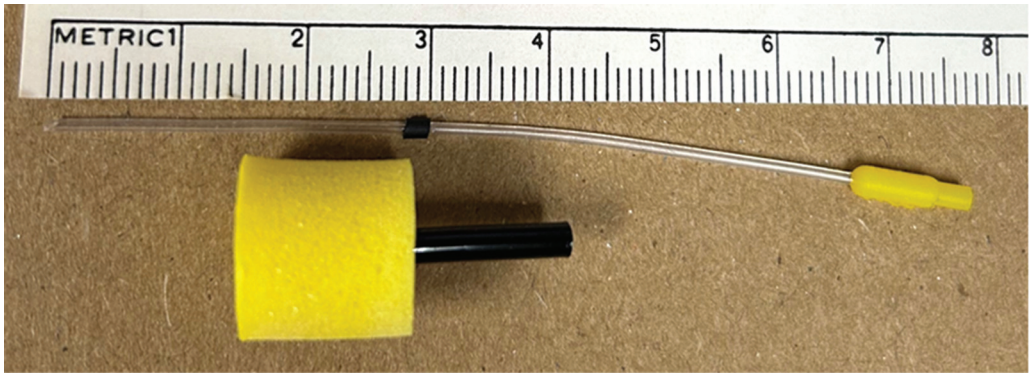

Figure 1 Identifying how far to place the probe microphone in the ear canal.

7. Insert the probe tube into the ear canal to a distance that is within 5 mm of the eardrum. Given that it is very hard to know where the probe tube is relative to the eardrum, you can use one of two options to make sure you have a correct placement:
   a. Place the probe tube alongside the insert earphone (Figure 1). You want to slide the black marker on the probe tube to align it with the outside edge of the insert earphone, ensuring that the end of the probe microphone tube extends beyond the end of the foam insert.

Helpful hint: While holding the probe tube next to a ruler, adjust the black marker on the probe tube by sliding it to a position that lines up approximately with one of the following measurements[4]:

- 28 mm from the end of the probe tube for adult females.
- 30 mm from the end of the probe tube for adult males.
- 20–25 mm from the end of the probe tube for children.

When inserting the probe microphone into the ear, you will insert the probe tube until the black marker is at the tragus. Then, when you insert the earphone, you know the end of the probe tube will extend past the end of the foam insert and be within an acceptable distance to the eardrum.

To insert the probe tube into the ear canal, pull up and back on the pinna to straighten the ear canal. Insert the tube until the black marker is resting on the tragal notch.

   b. Use the Probe guide feature (Figure 2), if your patient is an adult and has normal outer/middle ear function.

Once you select the Probe guide button, the setup prompt will guide you through the steps to complete this process (Figure 3).

8. After the probe microphone is inserted appropriately, slide the foam insert (connected to the WRECD transducer cable) into the ear directly beside the probe microphone (Figure 4). Be careful not to slide the probe tube further down the ear canal; it may help stabilize the probe microphone with your thumb as you slide the insert into the patient's ear. If you move the probe tube farther down the canal while placing the insert, you will not injure the patient, but it might make a "thud" sound when the tube hits the eardrum. It may feel like they are being pinched or they may feel a pressure sensation. If so, you will need to adjust the depth of the tube for the patient's comfort. Insertion depth for the insert earphone should be similar to when you are using insert earphones for hearing testing. Allow the foam tip to fully expand in the ear.

Figure 2 Probe guide button. Note that "adult" must be selected under the Age dropdown menu to use this feature. The feature was developed using data from a variety of adult ears,[5] which cannot be generalized to pediatric ears.

Figure 3 Probe guide process. (**A**) Probe guide setup screen; (**B**) successful placement of probe microphone.

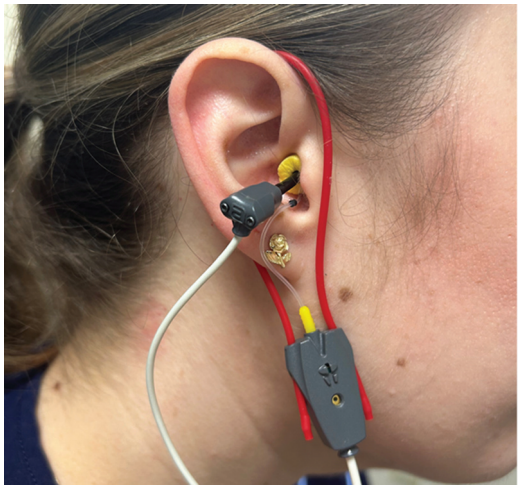

Figure 4 Set up for real-ear portion of the WRECD measurement.

9. Select the Measure real ear and then green check mark to generate the real-ear response curve. If the WRECD curve is negative and unstable in the low frequencies, check the seal of the foam tip. Increase the tip size, use a deeper insertion, and/or apply a lubricant to the foam tip to improve the seal.
10. When the curve is stable, select the green check mark to save it (Figure 5).

INTERPRETING WRECD AND RECD

The Verifit 2 uses a 0.4-cc wideband coupler for WRECD[3] measurements, allowing information to be displayed through 16,000 Hz (as compared to the standard 2-cc coupler used for non-wideband RECD measurements, which will display information through 8,000 Hz). If you want to make a comment about the size of an individual's ear in comparison to a 2-cc coupler ("average"), you need to first convert the WRECD data to RECD data. Fortunately, the Verifit 2 provides an easy and efficient way to make this conversion (Figure 6) and an easy way to compare the numbers in table format (Figure 7).

If the SPL measured in the real ear is louder than the SPL measured in the 2-cc coupler (i.e., more sound pressure build-up in the individual's ear than in the 2-cc coupler) as in the example illustrated in Figures 6 and 7, then we can assume that the individual's ear is smaller than the 2-cc coupler. RECD, however, is a measure of SPL, not size. When the system converts the dB HL audiometric data (thresholds and UCLs) to dB SPL, this difference (along with RETSPL, reference equivalent threshold in sound pressure to 2-cc coupler; see Chapter 3) will be used for this accurate conversion. This will now provide you with the individual's dynamic range in dB SPL and will allow for accurate fitting targets to be generated. If RECD is not obtained and applied to the audiometric data, the hearing aid may be over- or under-fit without the clinician knowing.

Note that you can measure WRECD in one ear and use the Verifit's ability to "copy" the measurement to the other ear for verification purposes (given that there are little differences between right and left ears on this measurement, assuming the individual has not had trauma or surgery in one ear[6]). This can be helpful when working with children if they

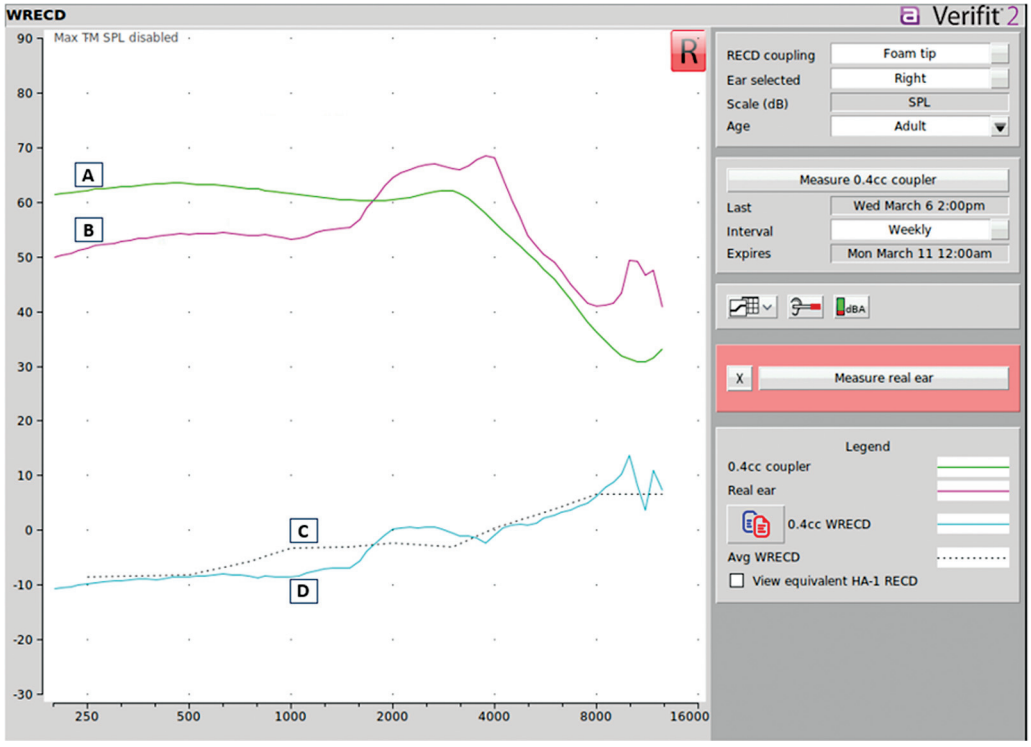

Figure 5 This graph illustrates a patient's WRECD. (**A**) The 0.4-cc coupler response (output); (**B**) the real-ear response (output); (**C**) the average expected WRECD from an average ear; (**D**) the individual's measured WRECD.

cannot sit still for the second measurement. To do this, you will click the button highlighted in Figure 8 below.

Helpful hint: The real-ear portion of WRECD takes a few seconds to collect once the probe tube and insert earphone are in place. For a young child, you may need their guardian to hug them to keep them still. You may want to call the probe tube a "tickle tube" since it may tickle. Even crying children take a breath. You can run the test on the inhale. This is an essential measure for accurate pediatric hearing aid fittings.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, probe tubes, insert earphones.

Activity 2

1. Follow steps 1 to 10 in Activity 1 to measure WRECD in your own ear or of someone else's ear. Your response will likely be reasonably similar to the graph in Figure 5. Make sure you take time to measure how far the probe microphone should be inserted into the ear.
2. Convert your WRECD results to equivalent HA-1 RECD (Figure 6). Given the RECD values that you measured, do you think that average RECD values would have produced different results regarding the hearing aid fitting?
3. Explain why or why not?
4. Why does a smaller ear canal produce a larger RECD in the positive direction (i.e., the real ear is building up more sound)?

WHAT ARE FITTING FORMULAE AND TARGETS?

Fitting formulae are evidence-based algorithms that generate output targets across frequency for the hearing aid fitting. Targets provide the goal for the output of the hearing aid as a function of input level (soft, moderate, loud) and frequency. There are two evidence-based targets that are typically used by clinicians: DSLv.5[1] and

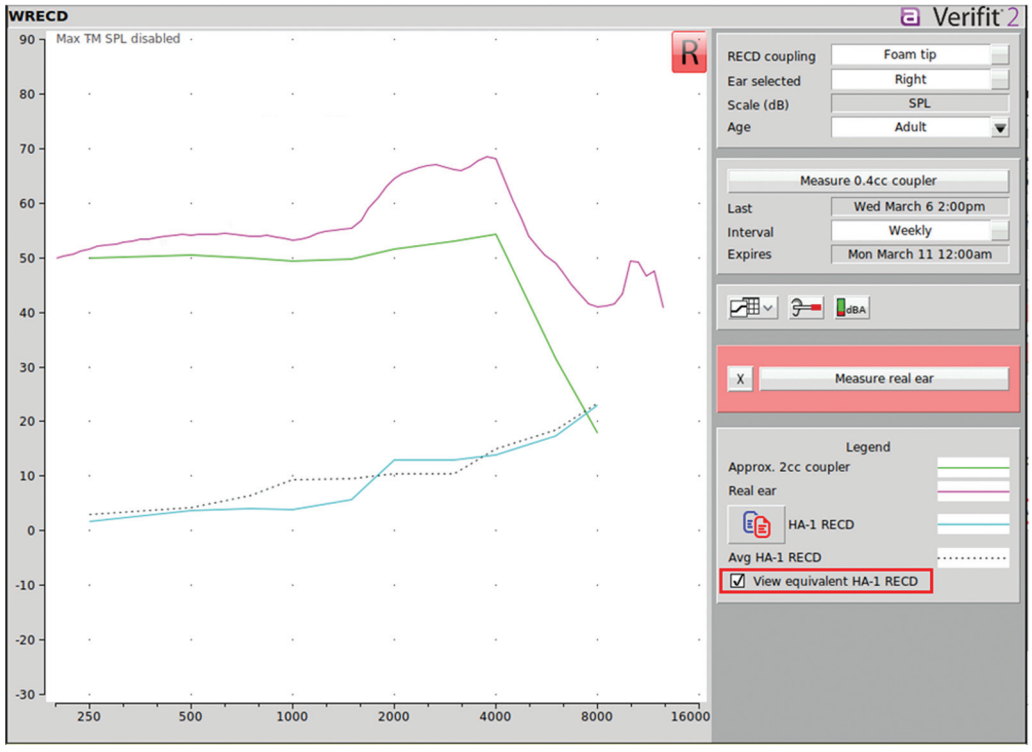

Figure 6 Equivalent HA-1 RECD (accessed by clicking the checkbox highlighted in the bottom right corner).

WRECD

										Max TM SPL	150	
R	250	500	750	1k	1k5	2k	3k	4k	6k	8k	10k	12k5
0.4cc coupler	62	63	63	62	60	61	62	56	46	36	31	33
Real ear	52	54	54	53	55	65	66	68	49	41	49	41
0.4cc WRECD	-10	-9	-8	-9	-7	0	-1	-1	3	6	14	7
HA-1 RECD	2	4	4	4	6	13	13	14	17	23		
Avg WRECD	-9	-8	-6	-3	-3	-2	-3	0	4	7	7	7
Avg HA-1 RECD	3	4	7	9	10	10	11	15	19	23		

Figure 7 WRECD (0.4-cc coupler) and RECD (2-cc coupler) data in table format.

NAL-NL2.[2] Fitting to targets provides the best possible audibility for the patient given the constraints of their hearing loss (i.e., they may have so much hearing loss in certain frequencies that audibility cannot be returned, especially for soft input levels).

When you are using a manufacturer's software to program hearing aids, you will find that you can select the fitting formula you want to use to set the hearing aids. These may include DSL and NAL as choices, along with the manufacturer's proprietary algorithm. In each case, unless you have measured or entered the patient's WRECD, these will not produce an individualized fitting for your patient because they do not account for the patient's ear canal characteristics. Because you are using real-ear probe microphone measures (WRECD and REAR) to verify the fitting, it does not matter what starting point you use in the software in terms of achieving an audible fitting because you will manually adjust the output to meet the

Figure 8 Button allowing you to copy data from one ear to the other.

targets you have selected. In your REAR measures, you will select the fitting formula (i.e., targets) you want to use and then set the hearing aid accordingly. You are in control of the acoustics of this fitting when you use real-ear probe microphone measures. Now that you are familiar with the need to verify the audibility of your hearing aid fitting, let us measure WRECD and REAR.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, probe tubes. For students, use a receiver-in-the-canal (RIC) hearing aid with a variety of dome sizes for this exercise or a behind-the-ear (BTE) hearing aid with a non-custom tip. You can use a hearing aid that is connected to programming software or a hearing aid that has been pre-programmed. In the case of a hearing aid that is connected to programming software, you will be able to make changes and re-run the output curves to verify that you have met the output targets. If you are using a pre-programmed hearing aid, you will be able to comment on what changes are needed to meet targets (but not make changes). For clinicians, you will use whatever hearing aids you are fitting.

Activity 3

1. Set up the equipment as described in Chapter 4. Make sure the coupler measurement of WRECD is complete.
2. Right-click the mouse and select **Speechmap** under the On-ear menu. "Speechmap" is the term that the Verifit systems use to indicate real-ear aided response (REAR) measures.

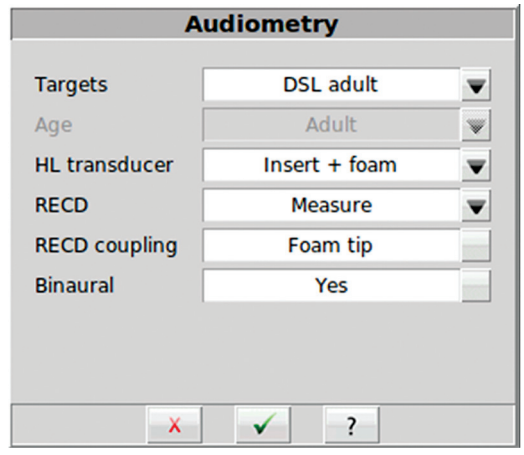

Figure 9 Audiometry menu options.

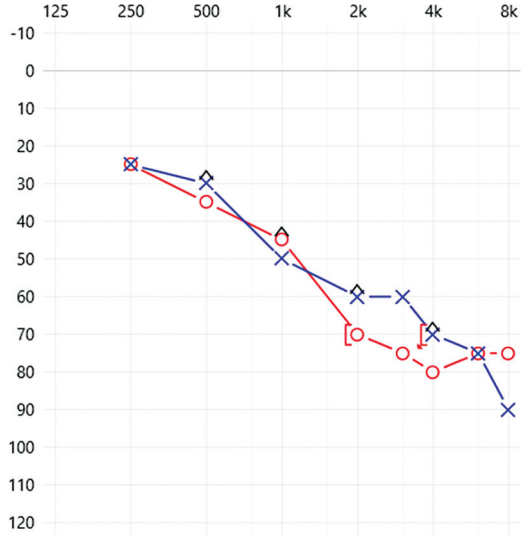

Figure 10 Audiogram for Activity 3.

3. Select the appropriate hearing instrument style (e.g., BTE, RITE) (see Figure 10).
4. Select "open" or "occluding," depending on how you are coupling the hearing aid to the ear.
5. Select **Audiometry**. Select the appropriate options as they apply to the patient (Figure 9).
   - Under **Targets**, select the type of target that you want to use to fit the hearing aid (e.g., DSL adult, DSL child, NAL-NL2). Note that the selection of certain targets may prompt additional setup options. For example, if you select "DSL adult," you

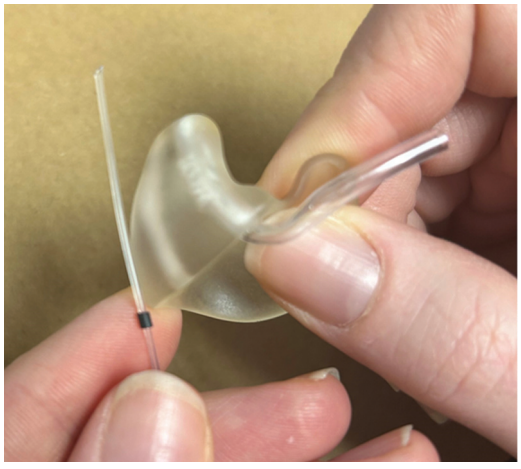

Figure 11 Probe tube preparation with an earmold.

will have to indicate whether the fitting is binaural or monaural. If "NAL-NL2" is selected, you will have to indicate whether the language is tonal or non-tonal.

- Under **Age**, select the appropriate age for the patient.
- Under **HL Transducer**, select "Insert + Foam" or "Insert + Mold" as appropriate (insert + foam for our purposes).
- Under **RECD**, select "Measure." Select "Foam tip" under **RECD Coupling** and then select the **green check mark**. (If you are going to enter RECD that was measured previously, select "Enter" and you will be prompted to do so.)

6. Enter the patient's audiogram (HL thresholds) in the Audiometric entry screen (use the data in Figure 10).
7. If you have not already measured RECD, you will be prompted to do this next (follow the steps described in Activity 1).
8. Connect the hearing aid to the appropriate software via the programming interface (Noahlink Wireless or other manufacturer-specific programming interface) or use a pre-programmed hearing aid.
9. Place the patient 12 to 18 inches (30.5–45 cm) away from the activated loudspeaker (internal vs. external). This should be near where you placed your probe microphone tube during the leveling procedure (see Chapter 4).
10. Visualize the patient's ear canal using otoscopy to have a better sense of the person's ear canal length and curvature. Additionally, make sure the canal is free from occluding ear wax.
11. If an earmold is being used with the hearing aid, you can adjust the black marker on the probe tube so that the length from the black marker to the opening of the tube is a little more than the ear mold canal length (see Figure 11). With adults, you also can use your judgment to determine how deep you insert the tube to become close to the eardrum (see the tips provided in Figures 1,2,3).
12. Gently insert the probe tubes into the person's ear canals. Use the black markers so that they rest in the tragal notch as illustrated in Figure 4.
13. Insert the hearing aids (custom devices), earmolds (BTEs/RICs), or domes (BTEs/RICs) into the person's ear with the probe tube in the ear canal (Figure 12). Make sure you do not further push the probe tube into the ear, which could be uncomfortable. The Verifit 2 allows for binaural on-ear and test box measurements, so you can complete Speechmapping binaurally to save time.

Figure 12 Probe tube and RITE in an ear.

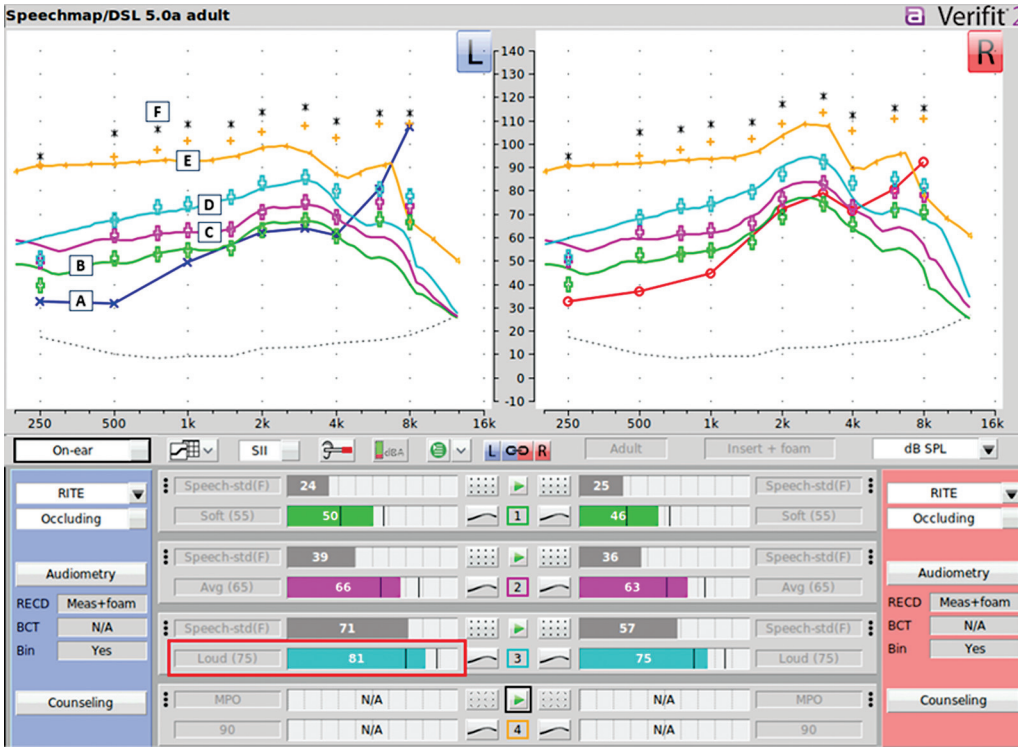

Figure 13 Speechmapping or REAR. (**A**) Thresholds; (**B**) soft input (55 dB SPL); (**C**) moderate input (65 dB SPL); (**D**) loud input (75 dB SPL); (**E**) MPO; (**F**) estimated UCLs.

14. The output of the hearing aid should be measured for inputs of soft, moderate, and loud speech, and maximum power output (MPO).
15. Click the green arrow above Test 1 to select the input stimulus (Speech-std[F] or Speech-ISTS) and input level (55, 65, and 75 dB and MPO are recommended). Measure all these levels. Select a new test (1–4) each time so your data are saved.
16. Targets from the fitting formula you selected will appear on the screen once you start the test. Click the red circle to capture the graph.
    c. When looking at the graph, compare the output from the hearing aid (solid line representing output) to the targets that are displayed (see Figure 13) and the single line to the targets for MPO. Figure 13 shows all four measures together.
    d. When looking at the graph, compare REAR 1 to 4 to targets 1 to 4, respectively.
17. If the responses do not match the targets, you would make appropriate programming changes to the hearing aid(s).
18. Repeat steps 2 to 4 until the hearing aid(s) are set appropriately for the patient's hearing loss so that all soft, moderate, and loud sounds fit nicely within the person's dynamic range (between the threshold line in the bottom and the UCL target stars at the top with the constraints of the hearing loss) and match targets within ± 3 to 5 dB.7

Looking at Figure 13, you can see that the REAR (solid line) is matching the targets (the big plus signs) well across input levels and frequencies.

Helpful hint: Speech intelligibility index (SII)[8] is a calculation of the amount of the input signal that is audible based on the individual's hearing. This can be an efficient way to talk about audibility and to determine if you have provided appropriate audibility given the constraints of the level of this individual's hearing loss. In Figure 13, we have achieved an SII of 81% (0–100%) with 100% indicating that the entire signal is audible (see the highlighted box in Figure 13). The two vertical lines provide the SII

goal[9] for individuals in this age range with this level of hearing loss. 81% falls within these guidelines, so we should be satisfied with these results.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, probe tubes. For students, use a RIC hearing aid with a variety of dome sizes for this exercise or a BTE hearing aid with a non-custom tip. You can use a hearing aid that is connected to programming software or a hearing aid that has been pre-programmed. In the case of a hearing aid that is connected to programming software, you will be able to make changes and re-run the output curves to verify that you have met the output targets. If you are using a pre-programmed hearing aid, you will be able to comment on what changes are needed to meet targets (but not make changes). For clinicians, you will use whatever hearing aids you are fitting.

Activity 4

1. Set up the equipment as described in Chapter 4. Make sure the coupler measurement of WRECD is complete.
2. Complete steps 2 to 15 in Activity 3 with a real person and use the audiogram data in Figure 14.
3. Using the data you have collected, complete Table 1. You will indicate whether you need to increase or decrease gain in each frequency region for soft and moderate inputs in order to match the output to the targets.

HOW DO I FIT CROS OR BICROS HEARING AIDS WITH REAL-EAR MEASURES WHEN NO SOUND IS GOING TO ONE OF THE EARS?

Introduction

CROS (*c*ontralateral *r*outing *o*f *s*ignal) hearing aids are designed for patients with unaidable hearing loss in one ear and normal hearing in the other ear. A transmitter (microphone) is placed on the side of the unaidable ear, and the input is then transferred to the hearing instrument (receiver) fitted on the good ear via a wireless signal. All sound is delivered to the "good" ear.

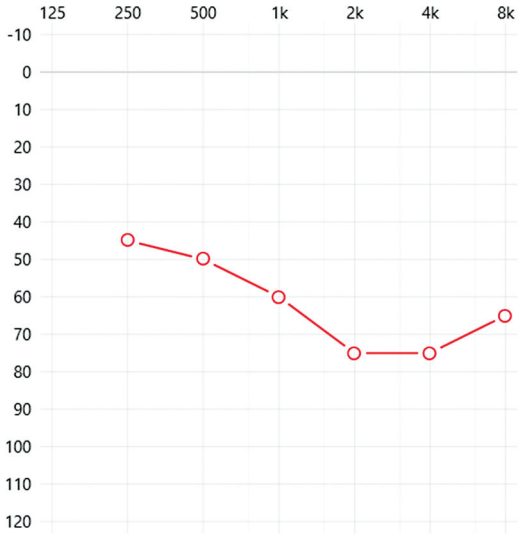

Figure 14 Audiogram to be used for Activity 4.

Table 1 What changes do you need to make so that the output for soft and moderate inputs will match targets?

Input	Low frequencies	Mid frequencies	High frequencies
Soft			
Moderate			

Key: + need more gain; – need less gain.

BiCROS (*Bi*lateral *CROS*) hearing aids are designed for patients with unaidable hearing loss in one ear and aidable hearing loss in the other ear (the better ear). A transmitter (microphone) is placed on the side of the unaidable ear, and the input is then transferred to the hearing instrument (receiver) fitted on the better hearing ear via a wireless radio frequency signal. All sound goes to the "aidable" ear. Unlike patients fitted with CROS devices, the patients fitted with BiCROS devices require amplification for the better ear, given the hearing loss on that side.

A CROS or BiCROS fitting does not improve speech understanding in noise or localization. Our brains require input to both ears for these types of processing. These technologies help the individual hear if sound is on the side of their non-functioning ear. This can be particularly helpful for people in meetings,

during social activities, and when riding in a car. In these situations, they no longer miss sounds that are directed to their "bad" ear or must make sure everyone is on their "good" side.

During fitting and verification procedures with CROS/BiCROS hearing aids, the probe-tube microphone must always be in the ear canal of the better ear. This is where the sound is delivered. The other (unaidable) ear does not need a probe-tube microphone to be inserted into the ear because there will not be any sound delivered to that ear.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, CROS hearing aid system, probe tubes, insert earphones.

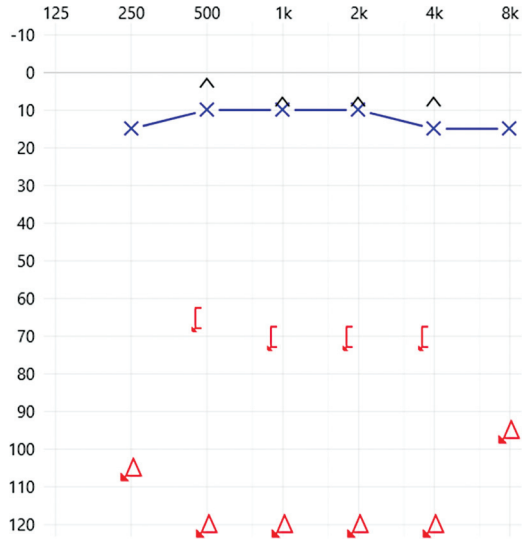

Figure 15 Audiogram for CROS fitting example.

Activity 5

1. Set the equipment up following the instructions in Chapter 4.
2. Ensure that both pieces of the CROS system (microphone and receiver) are in the patient's ears, turned on, and connected to each other. For these measurements, the CROS microphone needs to be actively transmitting sound.

Helpful hint: Depending on the devices you are fitting, you may need to save the fitting and exit the software to activate the CROS microphone piece for your measurements. This is manufacturer-dependent.

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3. Right-click the mouse and select Speechmap under the On-ear menu. View the screen in single graph mode, with the ear selected being the ear with the better hearing (i.e., select the ear that corresponds with the probe-tube microphone being used).
4. At the top right of the screen, select the appropriate hearing instrument style worn in the better hearing ear.
   e. If this is a CROS fitting, it is likely that you will choose RITE or BTE with an open vent selection.
   f. If this is a BiCROS fitting, you will select whatever style and coupling are appropriate.

   For this example, let us say we are fitting a person with a CROS system because they have no aidable hearing in their right ear and the left ear has normal hearing sensitivity (audiogram below, Figure 15). In this case, there is no reason to enter the audiogram into the measurement system because you are not trying to match targets; rather, we are trying to match the frequency response.
5. Place the left probe-tube microphone into the left ear and hang the right probe module on the right ear (remember, there is no probe-tube needed on the right side because no sound will be coming out of this device). See Activity 1 for probe tube placement tips.
6. The first measurement you take will be essentially a measurement of the open ear on the left side with a broadband stimulus (e.g., pink noise). In this case, you want the speaker to be positioned approximately at 45 degrees facing the left (good) ear (see Figure 16). If you indicated that the ear is open, you will be prompted to equalize the fitting (see Chapter 4).
7. Select the **green arrow** above Test 1 and select Pink Noise (55 dB). Click the **red circle** to capture the recording (Figure 17).
8. While staying on the left ear single graph view, change your instrument selection to CROS (this activates the reference

Figure 16 Setup for open-ear measurement of the normal hearing ear (probe microphone in left ear only, speaker at 45 degrees).

microphone on the right side while still measuring from the probe-tube microphone on the left side). Do not clear the data from Test 1. At this time, switch the position of the speaker so that it is approximately at 45 degrees facing the right (unaidable) ear (Figure 18).

9. Select the **green arrow** above Test 2 and select Pink Noise (55 dB). Click the **red circle** to capture the recording (Figure 19).
10. If the manufacturer's software allows for programming adjustments to the CROS balance, adjust the programming and repeat step 9 until the curve from Test 2 matches the Test 1 curve.

The BiCROS hearing aid fitting principles vary somewhat from those used in the CROS hearing aid. In a BiCROS hearing aid fitting, there are two goals:

1. Eliminate the head-shadow effect for signals presented from the bad side (unaidable ear). This is the same goal we have for a CROS fitting. We achieve this by delivering the signal that reaches the unaidable ear wireless to the "good" or "better" ear.
2. Provide gain to the "better" ear (aidable ear) for inputs presented from all locations. The difference is that we first fit the better ear as if

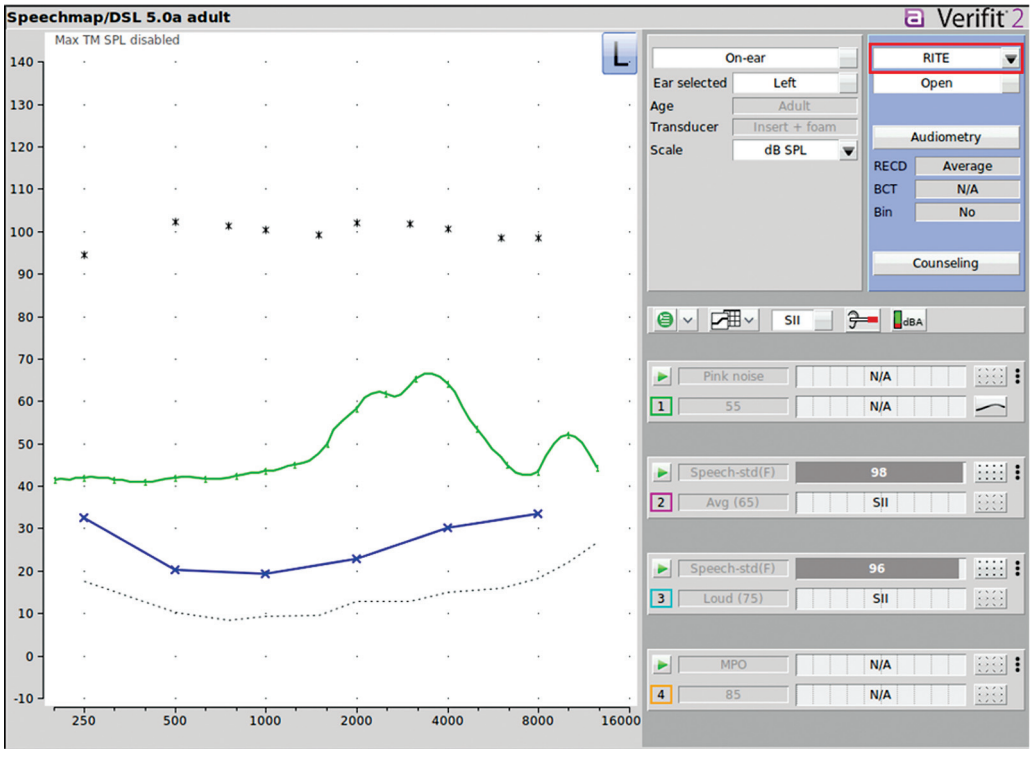

Figure 17 Open-ear measurement of the normal hearing ear when pink noise is presented.

Figure 18 Setup for CROS verification (probe microphone still in left ear only, reference microphone on right side, speaker at 45 degrees).

we were fitting a traditional hearing aid. The resulting REAR becomes the target for the signal that is crossed from the bad ear over to the better ear. Once you have established the desired REAR for the better (aidable ear), complete steps 2 to 9 in Activity 5 to fit the CROS side of this fitting and match the response as closely as possible to the better ear REAR.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, CROS hearing aid system, probe tubes, insert earphones.

Activity 6

1. Using a CROS hearing aid system, complete steps 1 to 8 in Activity 5 to verify the fitting.
2. Is the CROS system working as desired?
3. If not, what would you change?

WHY CAN'T I USE PROBE-MICROPHONE MEASUREMENTS FOR VERIFYING COCHLEAR IMPLANT FITTINGS?

The probe-microphone system can be used for a lot of things; unfortunately, it is not a useful system with regard to cochlear implants (CIs).

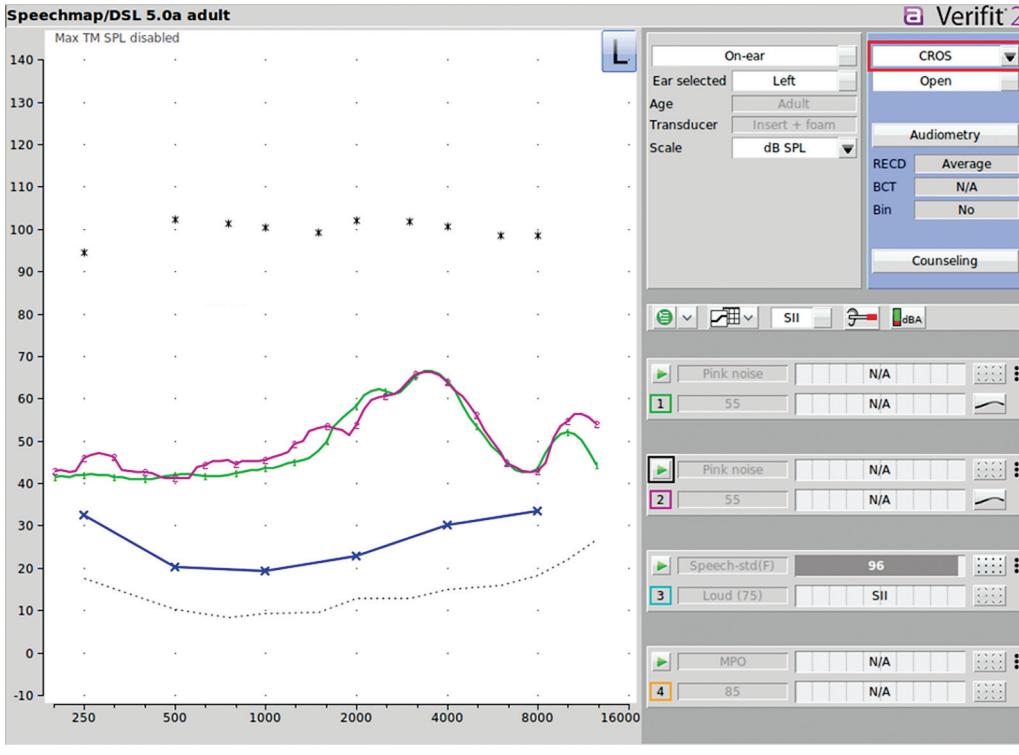

Figure 19 CROS verification.

A CI is an electronic device that is surgically implanted in patients who have so much hearing loss that they receive minimal benefit from hearing aids, even when they are fit appropriately using evidence-based procedures. CIs are very different from hearing aids because they do not produce sound in the ear canal. Instead, CIs bypass the outer and middle ear and directly stimulate the nerve of hearing with an electric stimulus.

Use of a probe microphone in the ear canal implies that there is sound in the ear canal to measure. CIs stimulate the auditory system using electrical signals, which *do not* produce acoustic sound in the ear canal. Importantly, any device that *does* make produce acoustic sound (e.g., MP3 players, over-the-counter hearing aids, prescription hearing aids) can be measured and the sound can be compared to the individual's dynamic range for safety and audibility.

CAN I VERIFY OSSEOINTEGRATED DEVICE OR BONE-ANCHORED HEARING DEVICE FITTINGS USING PROBE-MICROPHONE MEASUREMENTS?

An osseointegrated device (OID) (or bone-anchored hearing device—two names for the same thing) is a type of hearing aid that can be surgically implanted into the skull or held tightly against the skull with either a magnet or a band of some sort that applies the appropriate amount of force. It operates by vibrating the skull, which transmits vibration to the cochlea. In implantable OIDs, the implanted piece is made of titanium and there is either a small abutment that is exposed on the outside of the skin or a magnet under the skin to create a coupling to the outside portion of the device. A sound processor is connected to the abutment or magnet and is used to transmit sound vibrations to the inner ear, where the hair cells are activated and stimulate the hearing nerves. Again, no sound is produced in the ear canal.

OID fittings can be verified to DSL-BCD[10] fitting formulae (adult or child) using the Verifit 2, if an accessory called the "skull simulator" has been purchased and the device is percutaneous (i.e., the device must have a connection that goes through the skin; it can't be held against the skull with a band or magnet). The skull simulator measures the force applied through the device and displays the information on the screen in a graph that is very similar to Speechmapping for air conduction devices. Please see the Verifit 2 manual for instructions.

HOW DO I VERIFY THAT MY PATIENT'S DIRECTIONAL MICROPHONES ARE WORKING?

Patient Report: "I Know You Said I Have Directional Microphones, but I Don't Think They're Helping Me in Noisy Settings"

INTRODUCTION

See the background information related to directional testing in Chapter 3. Chapter 3 provided information about how directional capabilities can be verified in the test box. Below, you will see how On-ear Speechmapping can be a helpful tool to verify that the directional microphone setting on your patient's hearing aid is working.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, hearing aid with directional microphones activated that can be manually switched into directional mode via a program change, probe tubes, insert earphones. Students, use a RITE hearing aid with a dome for this activity.

Activity 7

1. Set up the equipment using instructions in Chapters 1 and 4.
2. Measure RECD using instructions from Activity 3 in Chapter 4 and Activity 1 in Chapter 5.
3. Right-click and select **Speechmapping** under On-ear measures. Select that the RITE instrument is being fit as an open instrument. When you go through the **Audiometry** options, select "None" for **Targets**. You will need to enter at least one threshold to move past the threshold entry screen. This is a relative measure; we are comparing two tracings to each other. Therefore, you do not need to carry out all the typical real-ear

measures set up (RECD, etc.) because you are not comparing to threshold or verifying audibility; you are simply comparing directional microphone settings.

4. Insert the probe microphone tubes bilaterally. See Activity 1 for probe microphone placement.
5. Center the speaker directly in front of the patient (Figure 20).
6. For the first test, select the **green arrow** above Test 1 and equalize with the hearing aid(s) off.
7. Turn the hearing aid(s) on, run the REAR measurement at **65 dB**, and press the **red circle** to record the response.
8. Turn the patient or move the speaker so that it is centered directly behind them, ensuring the speaker is the same distance from their hearing aid(s) as it was from the front (Figure 21).
9. Take a second measurement (leaving the first one on the screen) again using **Average** at **65 dB** (Figure 22). If the directional setting is effective, the measurement taken with the speaker behind the patient should have an output that is lower by $\geq$ 3 dB than the measurement taken when the speaker was in front. In a directional setting, the sensitivity of the microphone should be decreased for signals coming from the back (thereby providing an advantage to signals coming from the front). We expect adults to look where they are listening. Your measurement will be different from Figure 22 because you are using a different hearing aid.

Figure 20 Patient facing the speaker during REAR.

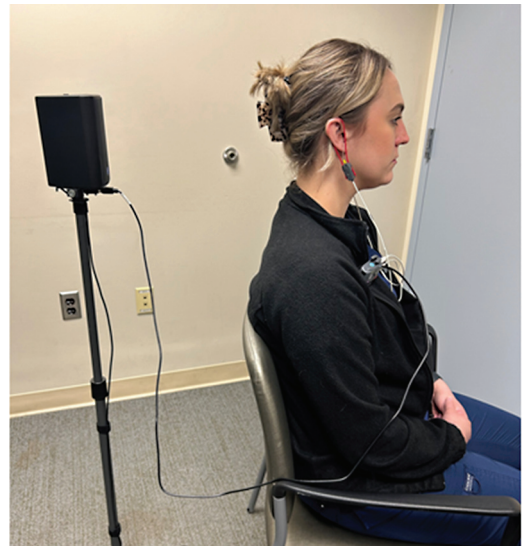

Figure 21 Patient facing away from the speaker.

Helpful hint: This measurement can be used when patients are questioning whether this setting is working effectively in noisy situations. It may also be helpful to show them that the output changes only when the noise is *behind* them.

Materials needed for this activity: Measurement from Activity 7.

Activity 8

Your measurement above was with an open-fit hearing aid.

1. Would you expect the directional feature to work well in the lower frequencies?
2. Why or why not?

Helpful hint: With an open ear, the same amount of sound is getting into the ear whether it is coming from in front or behind, this sound is being provided naturally and not through the hearing aid microphone which is where the directional setting would be an advantage. Patients who need an excellent directional signal will need to have a more closed fitting.

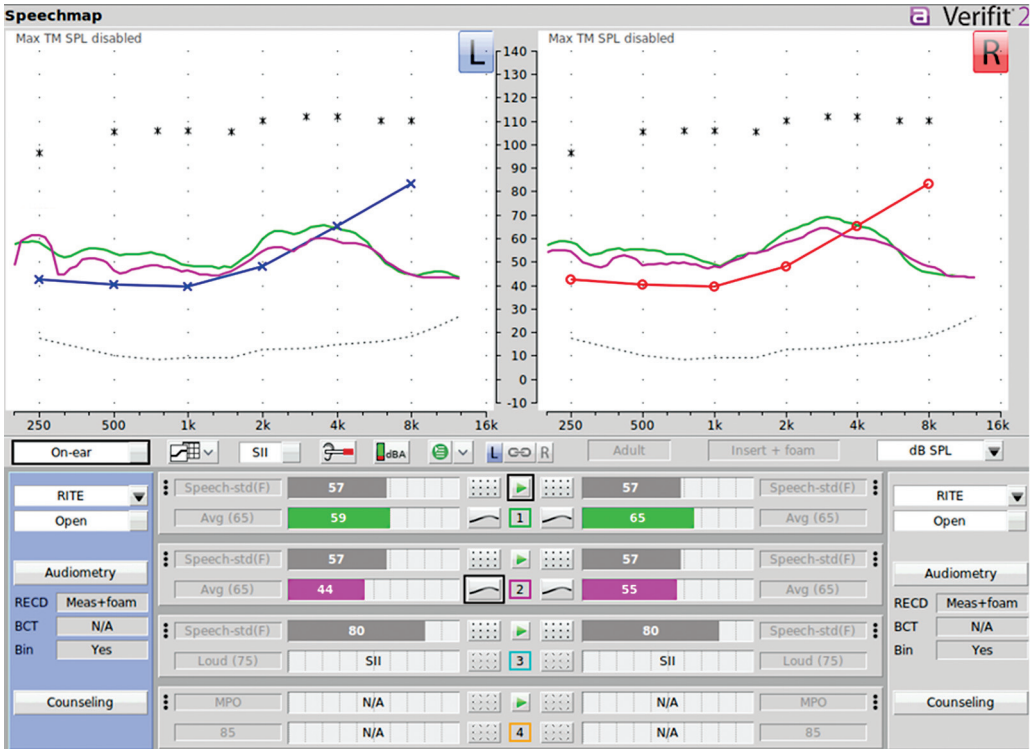

Figure 22 Directional results.

Materials needed for this activity: Your knowledge about common patient complaints.

Activity 9

Think of three complaints your patient may have that would cause you to verify that their directional microphones are working.

1. _____
2. _____
3. _____

HOW DO I VERIFY THAT MY PATIENT'S NOISE REDUCTION CAPABILITIES ARE WORKING?

Patient Complaint: "When I Enter a Noisy Room, the Hearing Aids Turn Off. All of the Sound Disappears and Then Slowly Returns"

INTRODUCTION

See the background information related to directional testing in Chapter 3. Chapter 3 provided information about how noise reduction can be verified in the test box. Below, you will see how Speechmapping can be a helpful tool to verify on-ear that the noise reduction setting on your patient's hearing aid is working. This is a relative measure: noise reduction *on* (with varying levels of strength) or noise reduction *off*. Therefore, you do not need to carry out all the typical real-ear measures setup (RECD, etc.) because you are not comparing to threshold or verifying audibility, you are simply comparing noise reduction settings.

Materials needed for this activity: For these activities, you will need a real-ear probe microphone system, hearing aid test box, probe microphones, hearing aid with noise reduction *activated* in one program and noise reduction *off* in a second program or two hearing aids (one with each setting). Students, use a RITE hearing aid with a dome for this activity.

Activity 10

1. Set up the equipment using instructions in Chapter 4. You do not need to measure

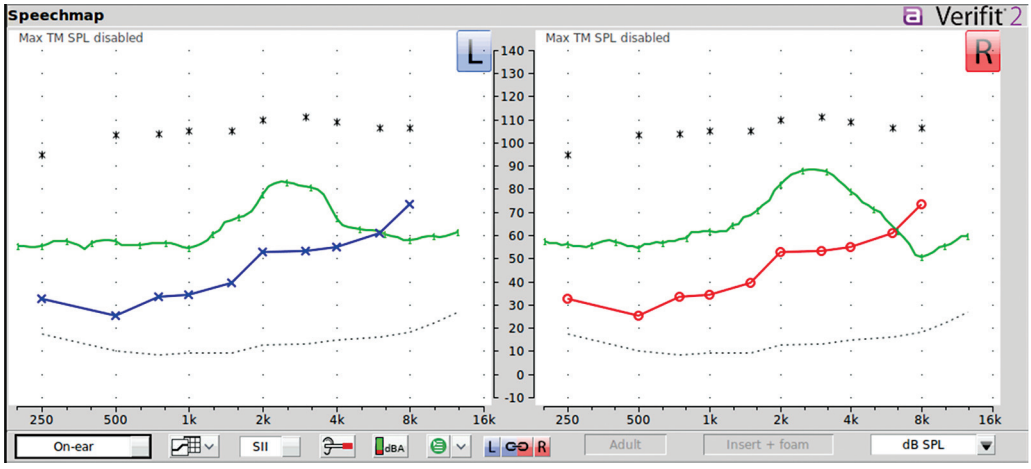

Figure 23 Pink noise presented at 70 dB with no noise reduction engaged.

RECD or enter audiometric results because these are relative measures, and you are just comparing the measures to each other.

2. Place the probe microphone in the patient's ear and have them face the speaker. See Activity 1 for probe microphone placement.
3. Place the hearing aid in the ear. The hearing aid should be turned on, but it should be in a setting with noise reduction turned *off*.
4. Right click the mouse and select the **Speechmap** option under the On-ear menu. Click the **green arrow** above Test 1 and select a continuous broadband noise signal such as **Pink noise** at 70 dB SPL. Remember, you need the signal to be loud enough to engage the noise reduction signal processing once you have it turned on. Leave the signal on for a little while and you will see that the curve does not change because no noise reduction processing is occurring. You can stop the signal. Observe the measured curve (Figure 23). You used noise in this measurement because the noise reduction algorithm reacts to a noise input.
5. In the programming software, turn on the noise reduction for all channels. Alternatively, if you have a second hearing aid that has noise reduction engaged, you can put this in the ear and use this hearing aid (otherwise the two hearing aids need to be programmed identically to make this comparison).
6. Now run another curve using the same input. As time goes by, you will observe a drop in real-ear output gain (Figures 24 and 25).

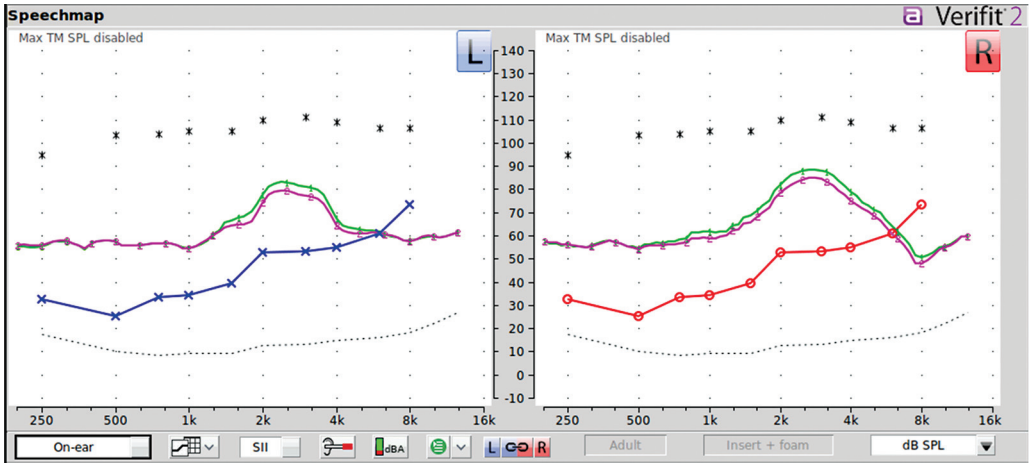

Figure 24 Reduction in gain with noise reduction activated (weak).

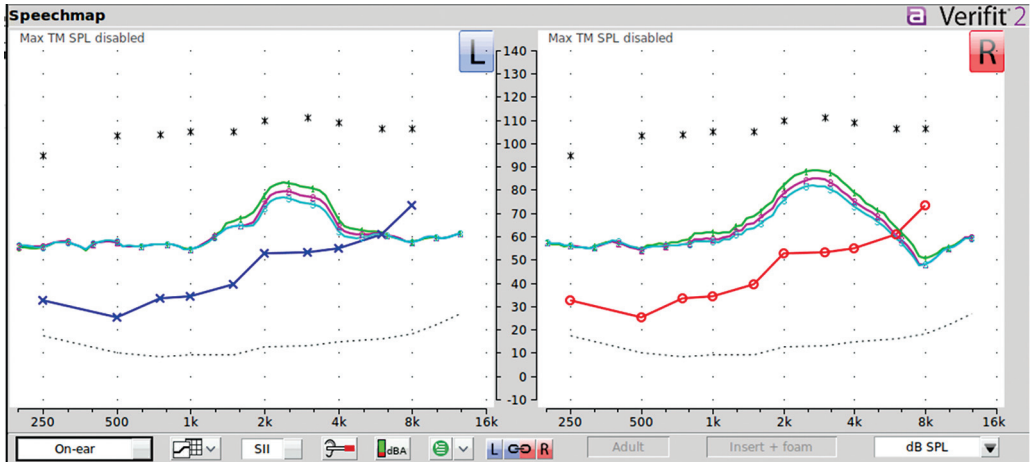

Figure 25 Reduction in gain with noise reduction activated (moderate).

It may be helpful for your patient to watch the screen as this happens so that they understand how the noise reduction feature works. Note the time that it takes for maximum reduction to occur.

7. Based on your findings, you may want to change the strength of the noise reduction feature. You also may want to try different speech or noise signals to see how this feature works in different listening situations.

Materials needed for this activity: Your knowledge of managing hearing in noise.

Activity 11

List three strategies that can help an individual hear better in noise.

1. _____
2. _____
3. _____

Helpful hint: We hear in noise with our brain. The most important thing your patient can do to hear well in noise is to use binaural amplification (if possible, given their hearing loss) and wear their hearing aids full time (all waking hours). The most important thing the audiologist can do is create an audible hearing aid fitting.

CONCLUSION

Understanding how to use the real-ear probe microphone measurement system allows you to individualize your hearing aid fittings as well as verify any specific signal processing or features that you have selected for your patient. Being able to understand what measurements provide the information you need to manage your patients' complaints and questions is empowering. When in doubt, measure!

CONFLICT OF INTEREST
None declared.

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