- If you are viewing this course as a recorded course after the live webinar, you can use the scroll bar at the bottom of the player window to pause and navigate the course.
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Wireless connectivity in hearing aids

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Nikki Clark &
Carrie Rector
Audiology Assistants

Learning Objectives

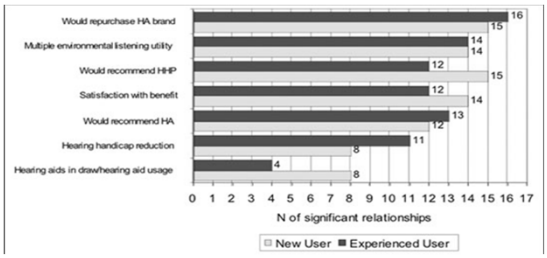
After this course learners will be able to:

- Provide an evidence-based rationale for external microphone recommendation.
- Compare the advantages and disadvantages of FM, Infrared, Loop and Bluetooth Systems.
- Prioritize amplification and wireless feature recommendations.
- Explain the reasons external microphones provide improved word recognition scores.
- Explain one of the more important variables associated with self-reported hearing aid satisfaction.

Today's inclusion criteria

External microphone and all media access required

Why this inclusion criteria



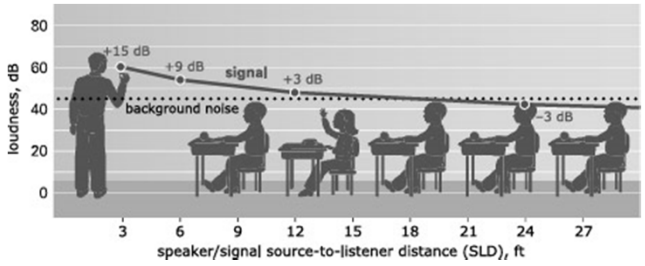
Overall summary of statistically significant relationships between outcome measures and protocol items

Kochkin S, Beck DL, Christensen LA, Compton-Conley C, Kricos PB, Fligor BJ, McSpaden JB, Mueller HG, Nilsson MJ, Northern JL, Powers TA, Sweetow RW, Taylor B, Turner RG. (2010). MarkeTrak VIII: The impact of the hearing healthcare professional on hearing aid user success. *Hear Rev*.;17(4):12-34.

1. Rationale for wireless connectivity

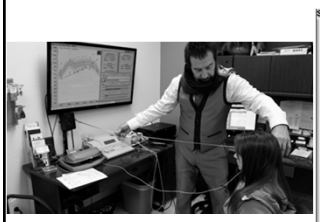
a. SNR improvement
b. Inverse square law considerations
c. Signal degradation considerations
d. SII improvement

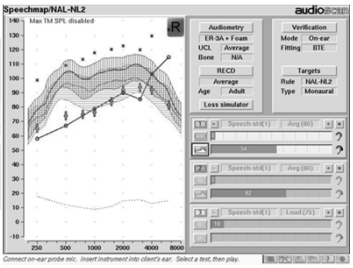
a/b. Inverse square law and SNR improvement



SOURCE: http://www.classroomhearing.org/acoustics.html

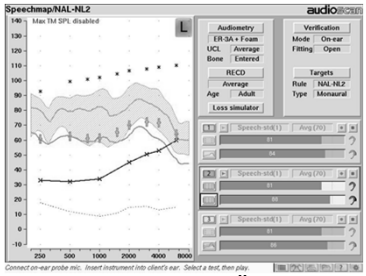
a/b. Inverse square law and SNR improvement





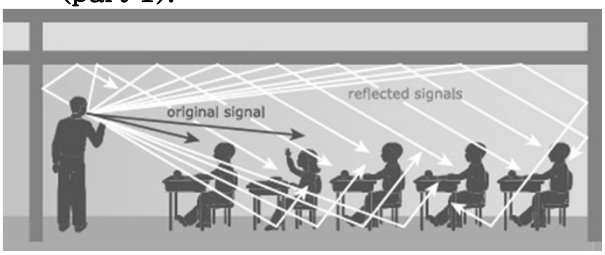
Severe Hearing Loss 5 ft vs 6" high-powered h. aid

a/b. Inverse square law and SNR improvement



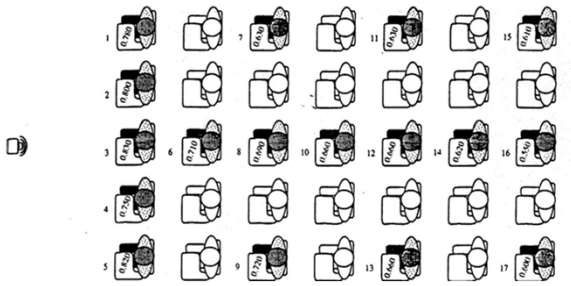
Mild Hearing Loss 5 ft vs 6" mild gain h. aid

c. Signal degradation considerations (part 1).



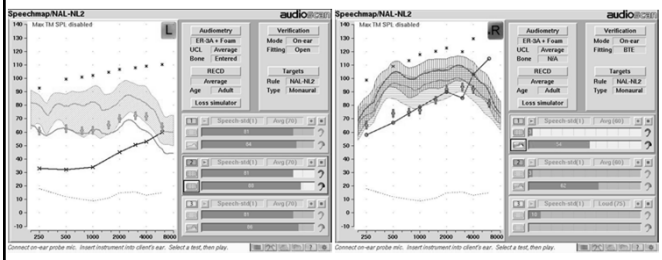
SOURCE: http://econtent.schools.ac.cy/mesi/fysiki/didaktiko_vliko/a_gymnasiou/a_gym_vivlio_mathiti_fysiki.pdf

c. Signal degradation considerations (part 2).

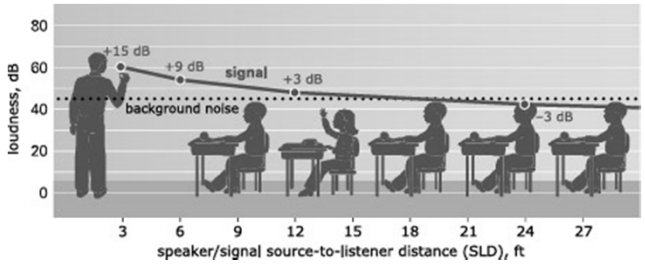


Source: Leavitt, R., & Flexer, C. (1991). Speech degradation as measured by the Rapid Speech Transmission Index (RASTI). *Ear Hear*, 12, 115–118.

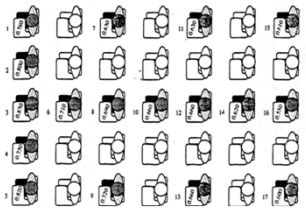
d. Aided SII improvement

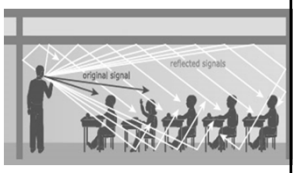


In summary, when the microphone is closer to the talker the SII is improved



..and speech degradation is minimized





SO it would appear that an external mic offers many advantages.

..and this is well documented in the literature for single microphone use

Anderson, KL and Goldstein H (2004). Speech perception benefits of FM and infrared devices to children with hearing aids in a typical classroom. *Lang Speech Hear Serv Sch.* 2004 Apr;35(2):169-84

Anderson KL, Goldstein H, Colodzin L, Iglehart F. (2005) :Benefit of S/N enhancing devices to speech perception of children listening in a typical classroom with hearing aids or a CI. *J Educ Audiol* 12:14-28.

Boothroyd, A (2004). Evaluation of Speech Recognition in Noise with Cochlear Implants and Dynamic FM. *J Amer Acad Audiol*, 20(7): 409-421

Davies M.G., Yellon L., Purdy S.C. (2001):Speech-in-noise perception of children using cochlear implants and FM systems. *Aust N Z J Audiol* 23:52-62.

Hawkins D.B. (1984). Comparisons of speech recognition in noise by mildly-to-moderately hearing-impaired children using hearing aids and FM systems. *J Speech Hear Disord* 49:409-418. (15 dB)

Maddell J. (2004). Optimizing the CI-FM interface. In: ACCESS: Achieving Clear Communication Employing Sound Solutions 2003—Proceedings of the First International FM Conference. Fabry D., DeConde Johnson C.Chicago: Phonak AG:

Pittman AL[1], Lewis DE, Hoover BM, Stelmachowicz PG (1999). Recognition performance for four combinations of FM system and hearing aid microphone signals in adverse listening conditions. *Ear Hear.* 20(4):279-89.

•Schafer E.C., Thibodeau L.M. (2004): Speech recognition abilities of adults using cochlear implants and FM systems. *J Amer Acad Audiol* 15:678-691.

•Schafer E.C., Thibodeau L.M. (2006):Speech recognition in noise in children with cochlear implants while using bilateral, bimodal, and FM-system arrangements. *Amer J Audiol* 15:114-126.

•Thibodeau, L (2014), Comparison of speech recognition with adaptive digital and FM wireless technology by listeners who use hearing aids, University of Texas, Dallas, USA, *Amer J Audiol*. Volume 23, 201-210, June 2014.

BUT there is a multiple mic mythology in our profession

Which is not shared in other professions

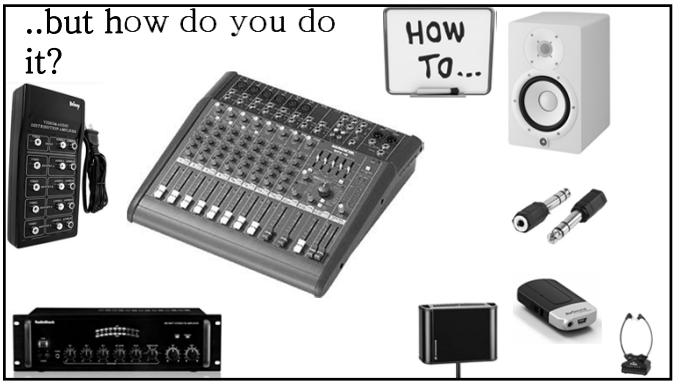
..and besides

I have a loud voice. I don't need the microphone

..which brings us to Dr. Hull's 10 person rule

Dr. Raymond Hull

..but how do you do it?

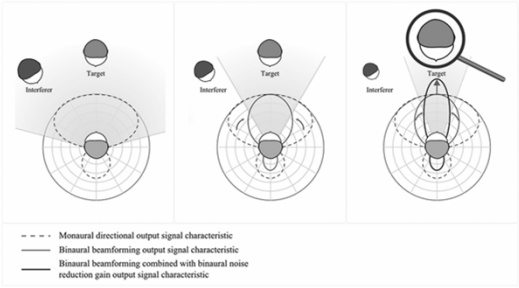


In summary: The benefit of remote microphones is well documented in the literature and..

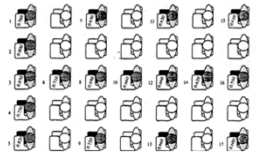
..the use of multiple remote microphones by audiologists lags sadly behind that of musicians…

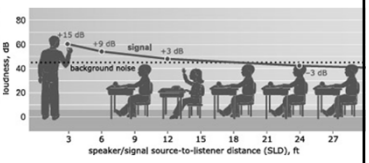
..and video and audio production hobbyists…

..but what about binaural directional microphones and their narrow beam forming capabilities?



Don't they make multiple remote microphones unnecessary?





Leavitt, R., & Flexer, C. (1991). Speech degradation as measured by the Rapid Speech Transmission Index (RASTI). *Ear Hear,* 12, 115-118

Don't they make multiple remote microphones unnecessary?

International Journal of Audiology 2013; Early Online: 1–6

informa
healthcare

Technical Report

Hearing-aid users' voices: A factor that could affect directional benefit

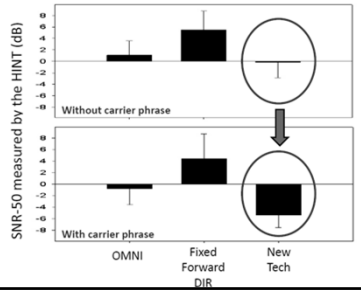
Yu-Hsiang Wu, Elizabeth Stangl & Ruth A. Bentler

Department of Communication Sciences and Disorders, The University of Iowa, Iowa City, USA

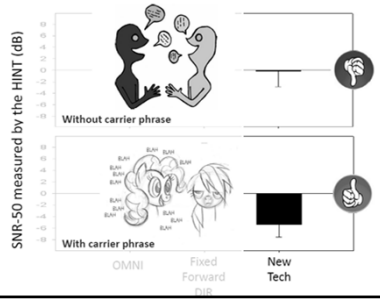
Abstract

Objective: Backward-facing directional processing (Back-DIR) is an algorithm that employs an anti-cardioid directivity pattern to enhance speech arriving from behind the listener. An experiment that was originally designed to evaluate Back-DIR, together with its follow-up experiment, are reported to illustrate how hearing-aid users' voices could affect directional benefit. *Design:* Speech recognition performance was measured in a speech-180°/noise-0° configuration, with aids programmed to Back-DIR enabled or omnidirectional processing. In the original experiment, the conventional hearing-in-noise test (HINT) was used, wherein listeners repeated heard sentences. In the follow-up experiment, a modified HINT was used, wherein a carrier phrase was presented before each sentence. *Study sample:* Fifteen adults with sensorineural hearing loss participated in both experiments. *Results:* Significant Back-DIR benefit (relative to omnidirectional processing) was observed in the follow-up experiment, while not in the original experiment. *Conclusions:* In the original experiment, hearing aids were affected by listeners' voices such that Back-DIR was not always activated when the target speech was presented. In the follow-up experiment, listeners' voice effects were eliminated by the carrier phrase activating Back-DIR before the sentences were presented. The results suggest that the effect of hearing-aid technologies is highly dependent on the characteristics of listening conditions.

Don't they make multiple remote microphones unnecessary?



Don't they make multiple remote microphones unnecessary?



So remote microphones are still needed even with improvements in mic directionality in hearing aids..

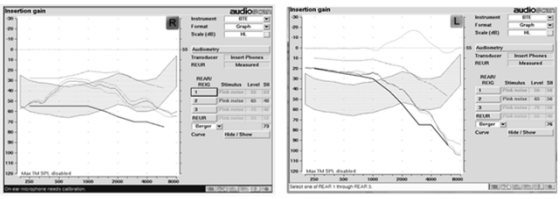
So does that mean that every hearing aid user needs a wireless mic?

At least three considerations come into play:

1. Aided SII
2. SNR Loss at 60 dB SPL in best binaural aided condition
3. Consideration of expected listening environments

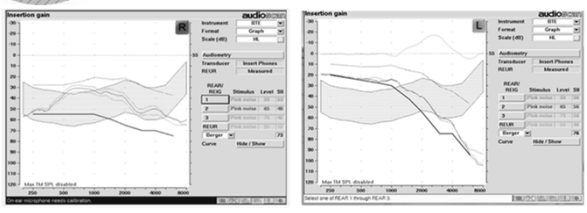
Let's look at each

1. Aided SII: Both of these patients would need a wireless mic if we didn't look at their poor hearing aid fitting first.



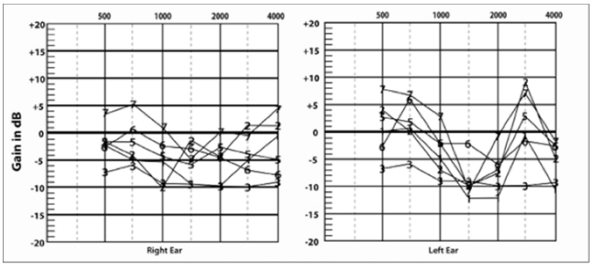
BECAUSE

when there is poor aided audibility everyone will look like they need a wireless mic



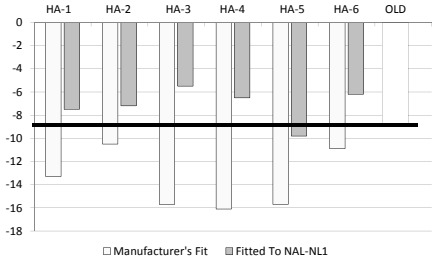
Are you saying improved aided audibility can change a person's SNR loss?

Are you saying improved aided audibility can change a person's SNR loss?



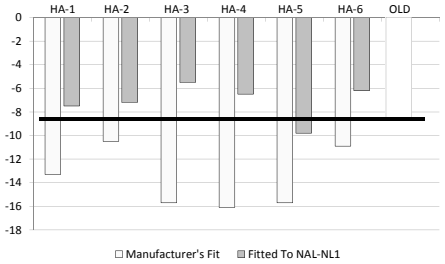
Leavitt RJ, Flexer C. The importance of audibility in successful amplification of hearing loss. Hearing Review. 2012;19(13):20-23.

Performance for the aided QuickSIN presented in sound field at 57 dB SPL. Bars indicate "SNR-Loss": The average SNR *disadvantage* compared to individuals with normal hearing



Leavitt RJ, Flexer C. The importance of audibility in successful amplification of hearing loss. Hearing Review. 2012;19(13):20-23.

On average we saw an 8.5 dB improvement in SNR loss across the six largest manufacturers by simply providing more audibility.



Leavitt RJ, Flexer C. The importance of audibility in successful amplification of hearing loss. Hearing Review. 2012;19(13):20-23.

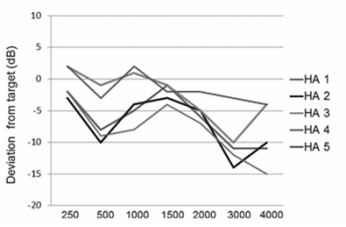
We aren't the only ones who have noted poor aided audibility with manufacturer's best fit..

Of 51 fittings 71 percent failed to come within 10 dB of the NAL-NL1 real ear insertion gain (REIG) target at one or more frequencies between 250 and 4000 Hz using the "first-fit" prescription.

71.8 %

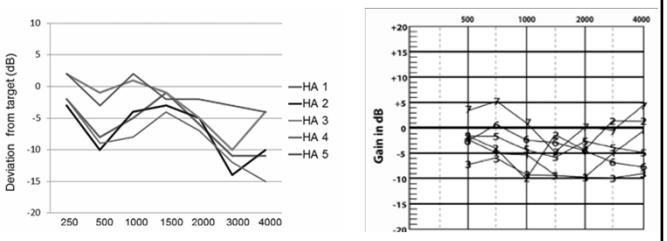
Source: Aazh, H., Moore, B., & Prasher, D. (2012). The accuracy of matching target insertion gains with open-fit hearing aids. *American Journal of Audiology, 21*, 175-180.

We aren't the only ones who have noted poor aided audibility with the manufacturer's best fit..



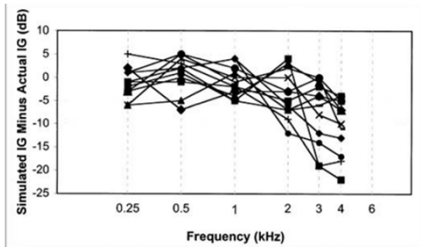
Source: Sanders J, Stoody T, Weber J, Mueller HG. Manufacturers' NAL-NL2 Fittings Fail Real-ear Verification. *Hearing Review.* 2015;21(3):24.

This looks familiar..



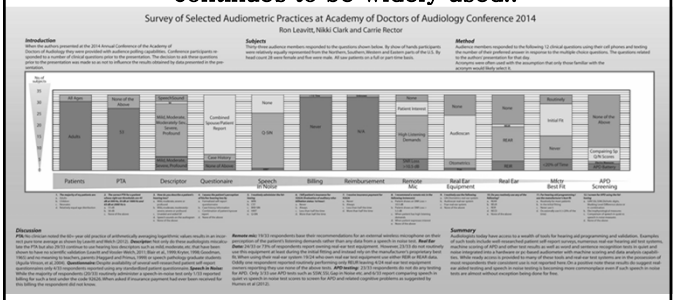
Sources: Sanders J, Stoody T, Weber J, Mueller HG. Manufacturers' NAL-NL2 Fittings Fail Real-ear Verification. *Hearing Review*. 2015;21(3):24. and Leavitt RJ, Flexer C. The importance of audibility in successful amplification of hearing loss. *Hearing Review*. 2012;19(13):20-23.

..and this has been known for a long time.



Source: Hawkins, D. & Cook, J. (2003). Hearing aid software predictive gain values: How accurate are they? *Hearing Journal* 56,(7) 26-34.

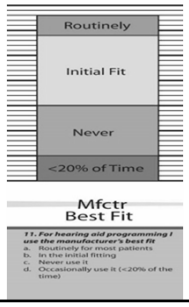
..and it appears the manufacturers' best fit continues to be widely used..



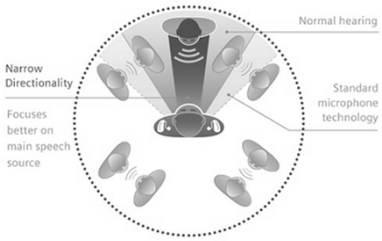
Leavitt, RJ, Clark, AN & Rector, CE (2015) Survey of Select Audiometric Practices at Academy of Doctors of Audiology Conference 2014, Proceedings of Audiology Now 2015, San Antonio Tx

..and it appears the manufacturers' best fit continues to be widely used..

70% of respondents use it some, most or all of the time



..and the hearing aids' directional microphones can't help if there is insufficient audibility



Source: Magnusson, L., Claesson, A., Persson, M., & Tengstrand, T. (2013). Speech recognition in noise using bilateral open-fit hearing aids: The limited benefit of directional microphones and noise reduction. *International Journal of Audiology, 52*(1), 29-36.

..and poor aided audibility also affects the academic success of children with hearing loss

Aided SII incorporates hearing aid amplification characteristics and speech frequency weightings and may provide a more valid estimate of the child's access to and ability to learn from auditory input in real-world environments.

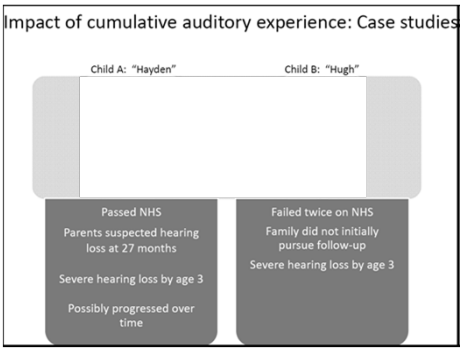
Source: Stiles, D.J., Bentler, R.A., & McGregor, K.K. (2012). The speech intelligibility index and the pure-tone average as predictors of lexical ability in children fit with hearing aids. *Journal of Speech Language and Hearing Research, 55*, 764-778.

..and there is too much poor aided audibility out there in both children..

Fifty-five fittings (28%) had at least one ear that deviated from prescriptive targets by more than 5 dB RMS on average.

Source: McCreery, R., Bentler, R., & Roush, P. (2013). Characteristics of hearing aid fittings in infants and young children. *Ear and Hearing, 34*(6), 701–710.

Impact of cumulative auditory experience: Case studies



Source: Walker E, McCreery R (2015). Effects of Amplification on Auditory Development Outcomes for Children Who Are Heard of Hearing. American Academy of Audiology, San Antonio, TX

Differences in auditory experience

Child	Age at confirmation of hearing loss	Age at hearing aid fitting	Amount of daily hearing aid use	Measured SII	Target SII (based on DSL)
Hayden	3 years, 3 months	3 years, 4 months	12 hours/day at every visit	.73	.70
Hugh	3 years, 2 months	3 years, 5 months	0 to 6 hours/day at age 7 and 8	.39	.68

Source: Walker E, McCreery R (2015). Effects of Amplification on Auditory Development Outcomes for Children Who Are Heard of Hearing. American Academy of Audiology, San Antonio, TX

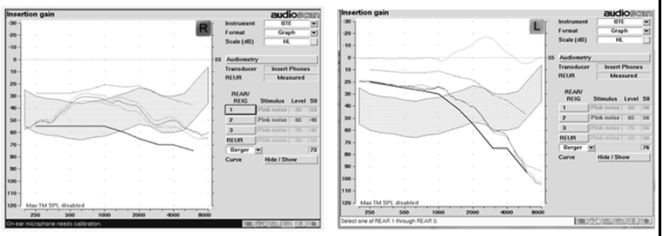
Differences in outcomes at 7 years of age

Child	Hearing	Vocabulary	Grammar	Articulation	Spelling
Hayden	66.25 dB HL	84	95	Raw score: 4 Standard score: 100 28th percentile	114
Hugh	66.25 dB HL	48	55	Raw score: 47 Standard Score <40 <1st percentile	70

Average standard scores for children with normal hearing: 100

Source: Walker E, McCreery R (2015). Effects of Amplification on Auditory Development Outcomes for Children Who Are Heard of Hearing. American Academy of Audiology, San Antonio, TX

..and adults..



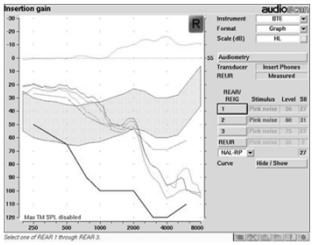
..and adults..

In about two-thirds of all of the (hearing aid) fittings, patients ended up with incorrect amplification.

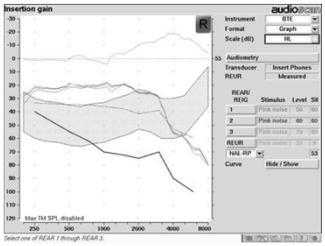
67 %

Hear well in a noisy world. Consumer Reports. July 2009:32-37. http://www.consumerreports.org/cro/hearing-aids/buying-guide.htm

2. SNR Loss at 60 dB SPL in binaural aided sound field

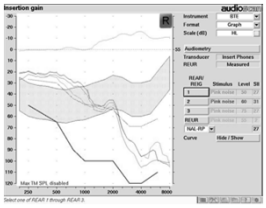


+ 20.5 SNR Loss

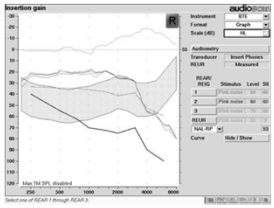


+ 5.5 SNR Loss

BUT ..how much SNR loss warrants a remote microphone?



+ 20.5 SNR Loss



+ 5.5 SNR Loss

..there are data that helps answer this question

3. Consideration of expected listening environments

TABLE 2. Mean speech and background levels in dBA, indoors and outdoors, for urban and suburban homes. Standard deviations in ( ).

	Background Noise		Speech 1 m		Conversation Distance	
	Urban	Suburban	Urban	Suburban	Urban	Suburban
Outside	61 (5	48 (4)	65 (4)	+4 55 (5)	66 (4)	5 (5)
Inside	48 (2)	41 (3)	57 (6)	+9 55 (5)	57 (6)	55 (5)

Note. All values are rounded to the nearest dB. From Table II in Pearsons et al. (1977).

3. Consideration of expected listening environments

TABLE 3. Mean speech and background levels in dBA in hospitals and department stores. Standard deviations in ( ).

	Background Noise	Speech 1 m	Conversation Distance
Hosp. Patient's Room	45 (2)	56 (2)	+8 55 (1)
Hosp. Nurses' Station	52 (5)	56 (3)	+4 57 (4)
Department Store	54 (3)	58 (3)	+4 61 (3)

Note. All values are rounded to the nearest dB. From Table II in Pearsons et al. (1977).

3. Consideration of expected listening environments

TABLE 4. Mean speech and background levels in dBA in trains and airplanes. Standard deviations in ( ).

	Background Noise	Speech 1 m	Conversation Distance
Train	74 (3)	66 (2)	-8 73 (3)
Airplanes	79 (3)	68 (4)	-11 77 (4)

Note. All values are rounded to the nearest dB. From Table II in Pearsons et al. (1977).

October 1998

Public school classrooms are also noisy..

Sanders (1965) +1 to +5
Paul (1967) +3
Blair (1977) -7 to 0
Markides (1986) +3
Finitzo-Hieber (1988) +1 to +4

Sanders, D. (1965). Noise conditions in normal school classrooms. *Exceptional Children, 31*, 344–353.
Paul, R. (1967). *An investigation of the effectiveness of hearing aid amplification in regular and special classrooms under instructional conditions.* Unpublished doctoral dissertation, Wayne State University, Detroit, MI.
Markides, A. (1986). Speech levels and speech-to-noise ratios. *British Journal of Audiology, 20*, 115–120.
Finitzo-Hieber, T. (1988). Classroom acoustics. In R. Roeser (Ed.), *Auditory disorders in school children* (2nd ed., pp. 221–233). New York: Thieme-Stratton.
Blair, J. (1977). Effects of amplification, speechreading, and classroom environment on reception of speech. *Volta Review, 79*, 443–449.

these are old studies, things must be better now right?

..since ANSI and ASHA now support a + 15 dB SNR requirement in school classrooms

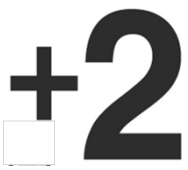
ANSI/ASA S12.60-2010/Part 1, *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 1: Permanent Schools*
ANSI/ASA S12.60-2009/Part 2, *American National Standard Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools, Part 2: Relocatable Classroom Factors*

Unfortunately it does not appear that things are getting better..

Measurements of noise and reverberation were collected for 5 different classrooms in 3 different schools while class was in session. Activities taking place during the measurements were recorded to compare with sound level measures.

Larsen JB[1], Blair JC (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. Lang Speech Hear Serv Sch. 39(4):451-60

When classroom amplification was used, students heard the teacher's voice at a level that was an average of 13 dB above the noise floor as compared to an average of + 2 dB above the noise floor without amplification.

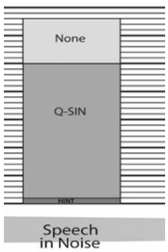


Larsen JB[1], Blair JC (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. Lang Speech Hear Serv Sch. 39(4):451-60

So we might conclude all but those whose SNR loss is < 2.5 dB SNR might benefit from a remote mic assuming their listening demands and physiological variables warrant this accessory.

Larsen JB[1], Blair JC (2008). The effect of classroom amplification on the signal-to-noise ratio in classrooms while class is in session. Lang Speech Hear Serv Sch. 39(4):451-60

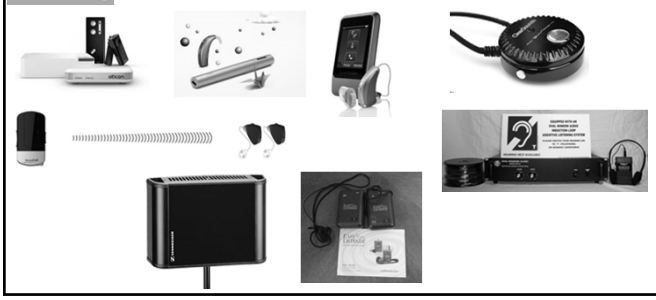
This also assumes we are measuring SNR loss on every hearing aid wearer.



Leavitt, RJ, Clark, AN and Rector CE (2015).

3. ..and some people unfortunately have lower listening demands…

..now we've talked about why wireless is a good idea and who might need it let's discuss which wireless devices



Which type of wireless connectivity is better?

System type	Infrared	Fm/aka RF	Loop	Bluetooth
Multiple uses	D–	B+	B	D
Ease of use	B	B	A–	D–/F
Fidelity	A	A–	C–	B–
Expense to user	A	C+	C–	C+
Audiologist time	C	B–	D–	D
Large auditorium use	D–	B+	C–	F
Small class use	B	B	B–	F
Portability	F	A	D–	A
Overall score	**2.18**	**3.17**	**1.99**	**1.46**

Source: Expert opinion

So it depends on where and how it will be used.

System type	Infrared	Fm/aka RF	Loop	Bluetooth
Multiple uses	D–	B+	B	D
Ease of use	B	B	A–	D–/F
Fidelity	A	A–	C–	B–
Expense to user	A	C+	C–	C+
Audiologist time	C	B–	D–	D
Large auditorium use	D–	B+	C–	F
Small class use	B	B	B–	F
Portability	F	A	D–	A
Overall score	**2.18**	**3.17**	**1.99**	**1.46**

Source: Expert opinion

There are also some user criteria.

Source: Expert opinion

User criteria

1.No external receivers
2.No flashing lights
3.No large microphones
4.User control of h. aid & external mics
5.No loss of aided SII
6.No head position signal degradation
7.Usable with all media

Source: Expert opinion

This is the closest we have come…



Source: Expert opinion

Does it work well?

At noise levels of 65dB and higher, people with hearing loss performed better in the speech recognition test than those with normal hearing. At a noise level of 75 dB, those with hearing loss achieved 69% accurate word recognition compared with only 7% by people with normal hearing.

Thibodeau, L (2014), Comparison of speech recognition with adaptive digital and FM wireless technology by listeners who use hearing aids, University of Texas, Dallas, USA, *Amer J Audiol*. Volume 23, 201-210, June 2014.

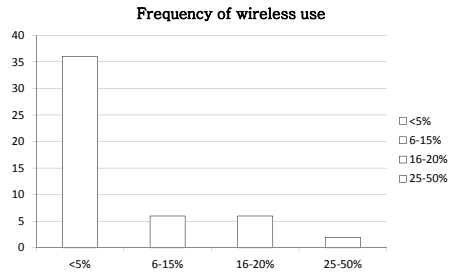
Because of its complexity this will take a considerable amount of clinic teaching time.

Source: Expert opinion

So if we are willing to spend that clinic teaching time will everyone start using it?

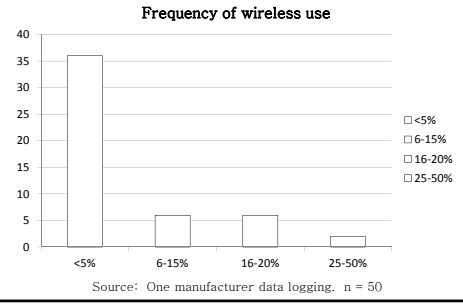
Source: Expert opinion

Here's our data on 50 randomly selected patients with remote microphones for their wirelesss hearing aids based on the hearing aids' data logging.



Source: One manufacturer data logging. n = 50

This doesn't mean these patients don't like the wireless feature, it's just that most don't use it very often.



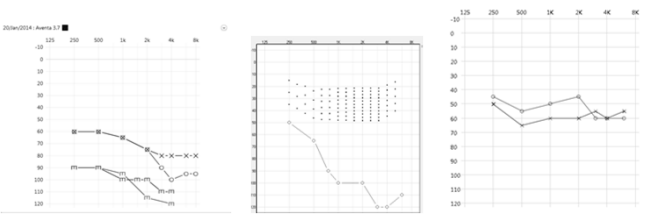
Source: One manufacturer data logging. n = 50

8. Observations of user wireless data

a. Wireless connectivity is not used extensively by 72% of these patients.

8. Observations of user wireless data

b. There was no significant correlation between degree of loss (unaided SII) and wireless use data.



8. Observations of user wireless data

c. There was no significant correlation between age and wireless use

8. Observations of user wireless data

d. The two most frequent users had no educational similarities (one had a Ph.D.; the other a high school graduate

8. Observations of user wireless data

e. Three of these infrequent use patients hold a master's degree in rehabilitation counseling of the deaf & hard of hearing

8. Observations of user wireless data

f. All of these patients received a minimum of three 30 minute appointments in use of hearing aids and wireless devices in a 30-day period with a 90-day follow up per Kochkin (2010). Specifically,….

90 MINUTE RULE

Kochkin S, Beck DL, Christensen LA, Compton-Conley C, Kricos PB, Fligor BJ, McSpaden JB, Mueller HG, Nilsson MJ, Northern JL, Powers TA, Sweetow RW, Taylor B, Turner RG. MarkeTrak VIII: The impact of the hearing healthcare professional on hearing aid user success. *Hear Rev.* 2010:17(4):12–34.

8. Observations of user wireless data

"Interestingly, almost half of the below-average patients had 4 or more visits."

4

8. Observations of user wireless data

g. Although there are 11 loop systems in this university town of 64,000 not one patient reported using a loop system in the last 90 days.

OSU Oregon State University

CONTINUED™

8. Observations of user wireless data

h. Our community education program has met for 30 years every month yet fewer than 10 of these patients use the loop system at any meeting.

8. Observations of user wireless data

i. Some of these patients have attended dozens of these meetings in the past 20 years.

8. Observations of user wireless data

j. One of the 50 subjects uses his external mic at the community education workshops while many hearing aid users in the audience own external mics but do not use them.

8. Observations of user wireless data

k. When infrared, loop system and FM systems are provided at these same meetings the infrared system has never been used even though many in the audience own TV ears.

8. Observations of user wireless data

Thus our data do not suggest that our training and educational programs greatly influence use of wireless connectivity among people with hearing loss

..and finally let's switch gears and discuss wireless connectivity to telephones.

We believe effective wireless connectivity to telephones remains an unsolved problem..

would you say that? My patients love their wireless telephone device!

It is certainly true for the person wearing the hearing aids

"Speech recognition performance was poorest with acoustic coupling to the telephone and best with bilateral wireless routing. Telecoil coupling resulted in better speech recognition performance than acoustic coupling, but was significantly poorer than bilateral wireless routing. "

n = 18 adults, aged 49–88 yr., with moderate-to-severe sensorineural hearing loss

Source: Picou EM, Ricketts TA (2013). Efficacy of hearing-aid based telephone strategies for listeners with moderate-to-severe hearing loss. J Am Acad Audiol. 24(1):59-70..

It is not always true for the listener on the other end of the line

Five blinded recording engineers were asked to give a letter grade to each of four wireless hearing aid-phone devices in terms of sound quality and intelligibility in noisy listening environments when listening with their usual phone.

The noise was amplitude compressed crowd noise from Widex played at 60 dB SPL as measured at the microphone of the wireless telephone device. The primary talker was the first author using a VU meter on the sound level meter to monitor vocal output at 65 dB SPL reading Az Bio Lists.

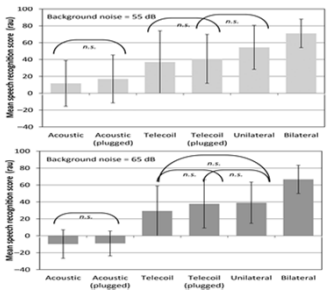
These judges were instructed to compare the sound quality to their usual phone not to a high fidelity listening system.

Here are their grades

Wireless System	1	2	3	4	5
Reviewer1	**C:** Many dropouts, but clearly intelligible, too much high frequencies.	**C–/D+ :** Poor quality, somewhat comprehendible.	**D:** Speech unintelligible, with several dropouts.	**F:** Many dropouts, worst of all, cannot understand anything.	**D+ :** Best sound quality but notable dropouts.
2	**C**: Amplitude flutter, unpleasant sounding.	**C**: Improper damping of main speech signal causing acoustic trail.	**B/B+ :** Much cleaner, overemphasis in high frequency.	**F:** Raucous distortion, almost unintelligible c/o concentration.	**A:** Excellent noise suppression and fidelity, could understand every word.
3	**B+ :** Second best, very useful.	**A–:** Much better sound quality.	**B:** Speech is too abrupt, conversation was garbled.	**D–:** Almost unintelligible.	**C:** Is somewhat understandable, but I really had to concentrate.
4	**B+ :** Reasonably clear with perhaps too much upper mid.	**C:** Upper mids were slightly exaggerated and overtones inaccurate.	**C:** too much high frequency.	**F:** Worst audio, too much buffering and frequency range is more restricted.	**B+ :** Good sound quality, apparent peak around 700Hz.
5	**D:** A lot of digital artifacts, very significant, unusual latency products.	**C:** Still heard pumping sound and poor noise reduction.	**C–:** Sounds like a bad cellphone, voice had a ringing artifact.	**F:** Sounds like an overseas phone call in 1922, couldn't understand a word.	**A:** Way better fidelity, much better than the rest.
	C+	**C+**	**C**	**F**	**B**

In conclusion binaural wireless telephone streaming does not meet industry standards for the normal hearing listener on the other end.

..but it's great for the hearing aid user



Source: Picou EM, Ricketts TA (2013). Efficacy of hearing-aid based telephone strategies for listeners with moderate-to-severe hearing loss.J Am Acad Audiol. 24(1):59-70..

Look at the differences in Carrie's scores on the Az Bio at 65 dB SPL at + 5 dB SNR using these five different wireless cell phone interface devices..

Wireless system	1	2	3	4	5
Sound engineer cumulative grade	C+	C+	C	F	B
Carrie's Az Bio Score +5 SNR	57%	18%	83%	66%	81%

1. Wireless connectivity in hearing aids offers much improved word recognition in quiet and in noise due to improved SNR, decreased degradation in the speech signal, improved unaided/aided SII, bilateral listening and minimization of reverberation.

2. Wireless connectivity in hearing aids has been around for a long time and the best type of wireless connectivity for a given situation depends on numerous factors as previously described.

System type	Infrared	Fm/aka RF	Loop	Bluetooth
Multiple uses	D-	B+	B	D
Ease of use	B	B	A-	D-/F
Fidelity	A	A-	C-	B-
Expense to user	A	C+	C-	C+
Audiologist time	C	B-	D-	D
Large auditorium use	D-	B+	C-	F
Small class use	B	B	B-	F
Portability	F	A	D-	A
Overall score	**2.18**	**3.17**	**1.99**	**1.46**

3. Although our patients' use of remote microphones is typically less than 10 % of the time spent wearing the hearing aids that does not necessarily mean they do not benefit from this technology when they use it.

4. Based on available SNR data in a variety of listening environments it is likely that a remote microphone would be useful to socially active patients whose SNR loss is poorer than 2.5 dB. This is especially true for children with hearing loss in public school classrooms.

SUMMARY

5. While wireless connectivity on the telephone is usually beneficial to the hearing aid user, it is less well accepted by the person on the other end with some current systems.

SUMMARY

6. As with hearing aids, cosmetic concerns remain regarding the design of some contemporary wireless remote microphone systems for hearing aids.

what are Real Ear measures?