AUDIOLOGY OF BONE CONDUCTION DEVICES

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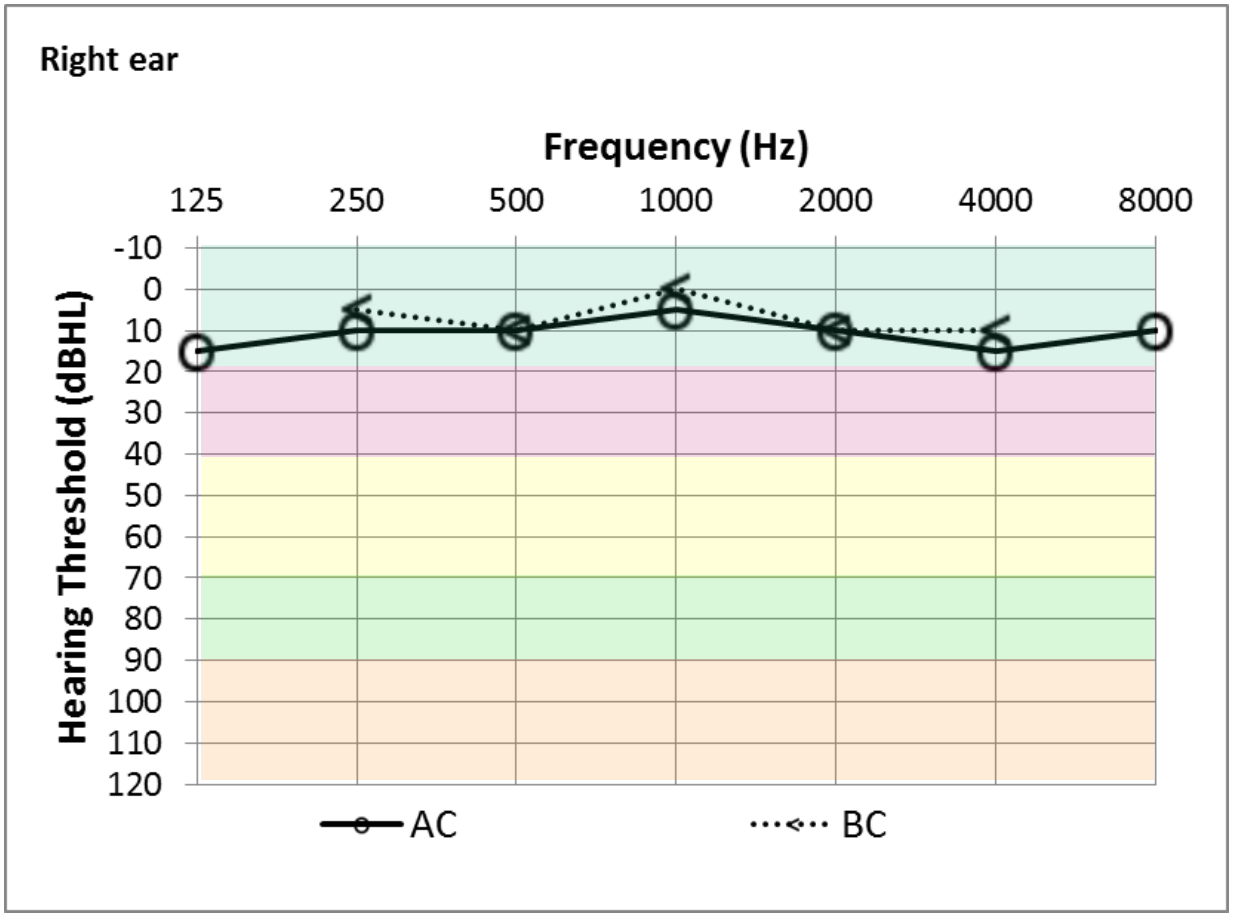
Antwerp University Hospital, Belgium

BACKGROUND

✓ Degree of hearing loss



→ Normal hearing

→ Mild hearing loss

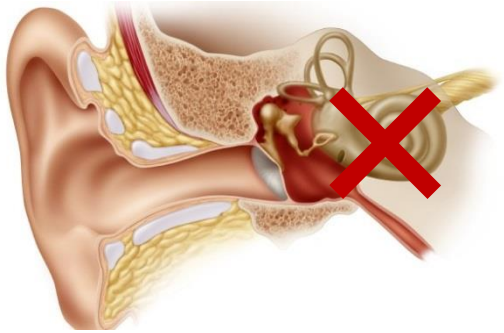
→ Moderate hearing loss

→ Severe hearing loss

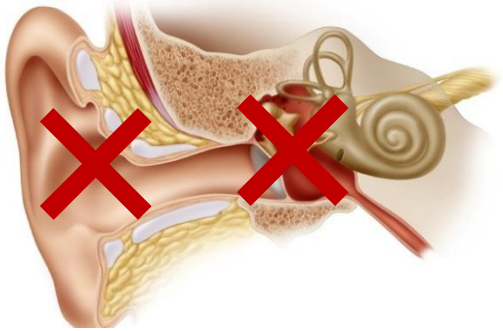
→ Profound hearing loss

BACKGROUND

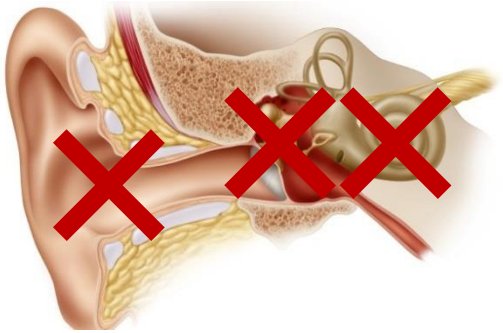
✓ Different types of hearing loss



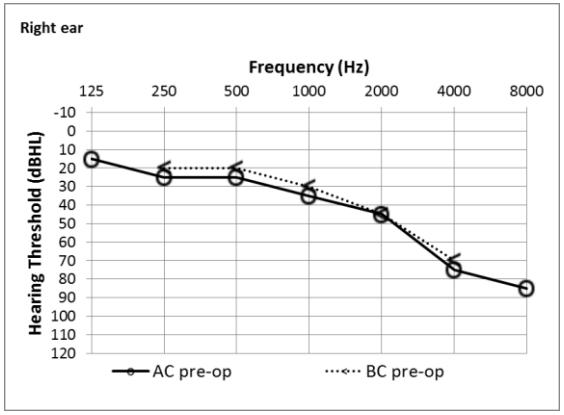
SENSORINEURAL
hearing loss

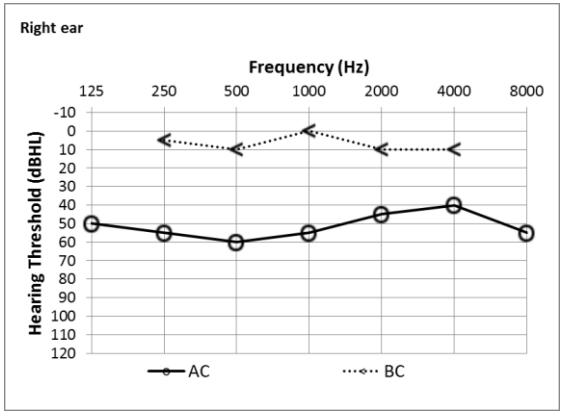


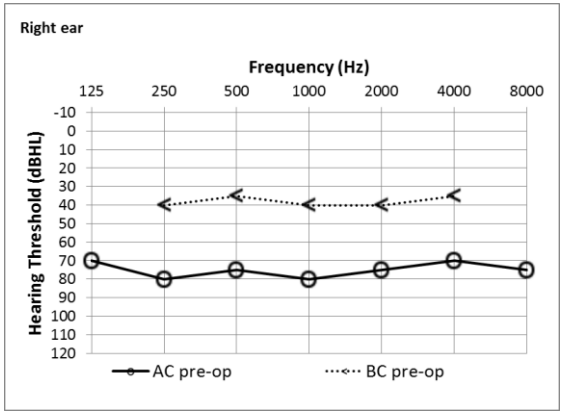
CONDUCTIVE
hearing loss



MIXED
hearing loss

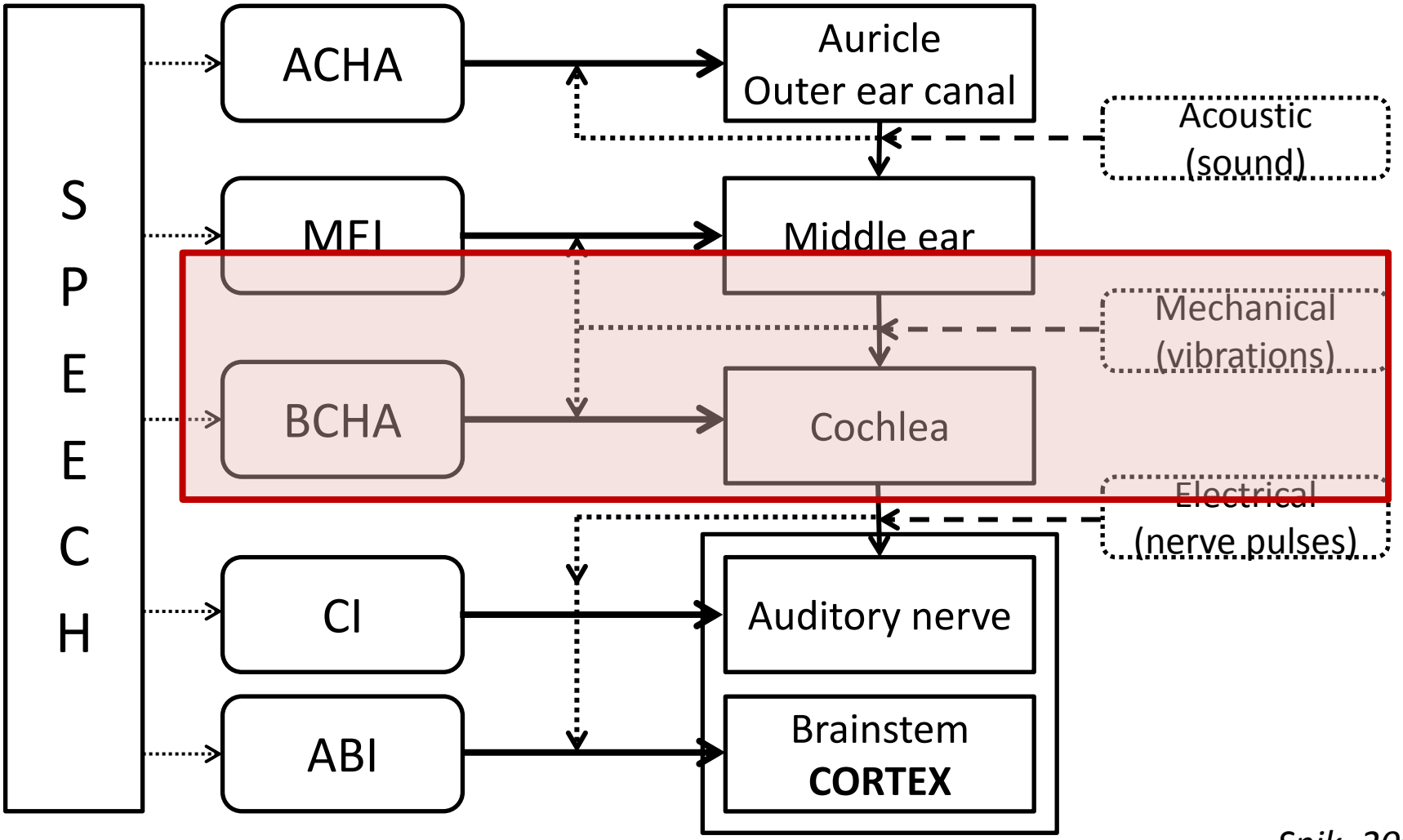






BACKGROUND

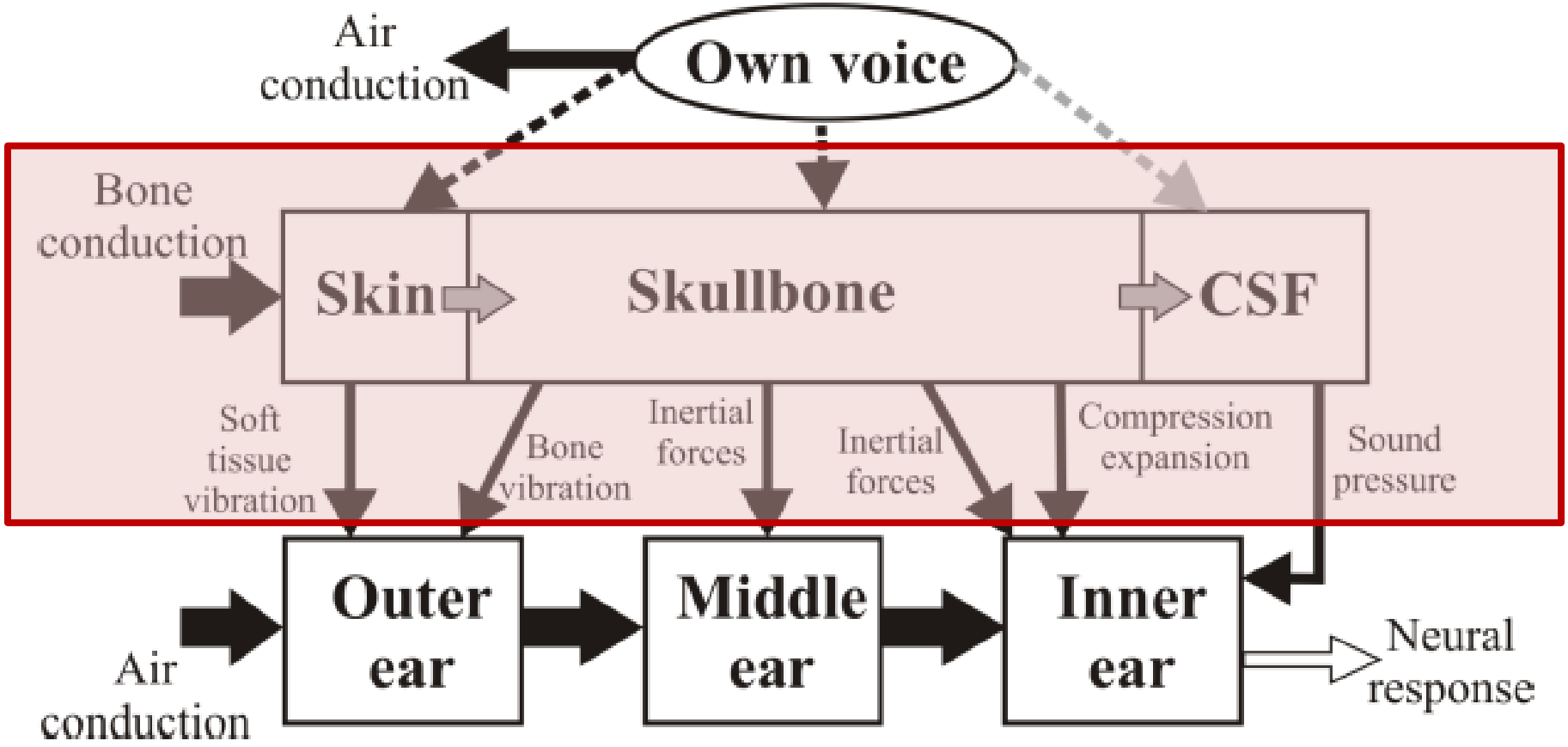
✓ Different types of hearing loss



Snik, 2007

BACKGROUND

- ✓ Bone conduction hearing



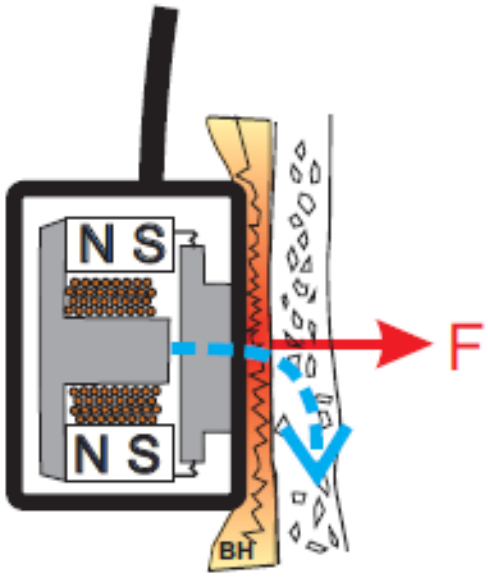
Stenfelt, 2011

OVERVIEW BC SOLUTIONS

- ✓ CONVENTIONAL BC SYSTEMS
  - Transcutaneous solutions
- ✓ PERCUTANEOUS BC SYSTEMS
  - Cochlear **Baha®** system
  - Oticon **Ponto** system
- ✓ TRANSCUTANEOUS PASSIVE BC SYSTEMS
  - Otomag **Sophono** Alpa system™
  - Cochlear **Baha® Attract** system
- ✓ TRANSCUTANEOUS ACTIVE BC SYSTEMS
  - Medel **Bonebridge™**
  - **BCI** (Hakansson et al.)
- ✓ OTHER BC SYSTEMS
  - Sonitus Medical **Soundbite™**

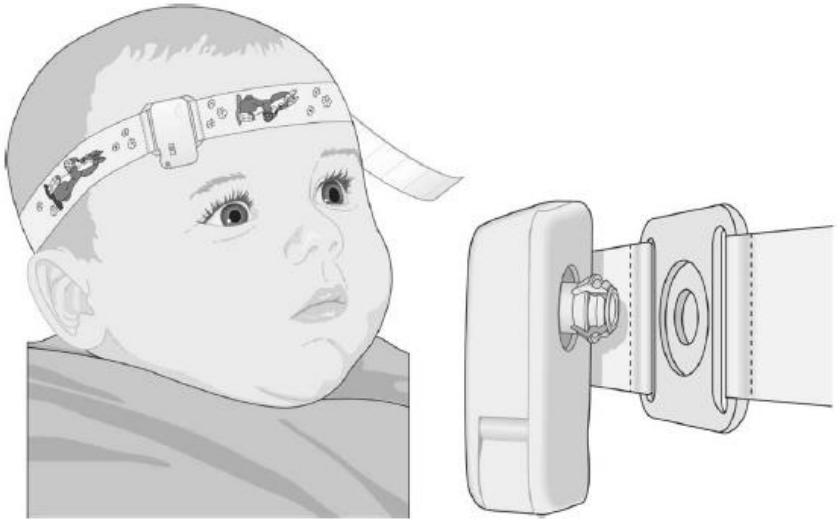
CONVENTIONAL BC SOLUTIONS

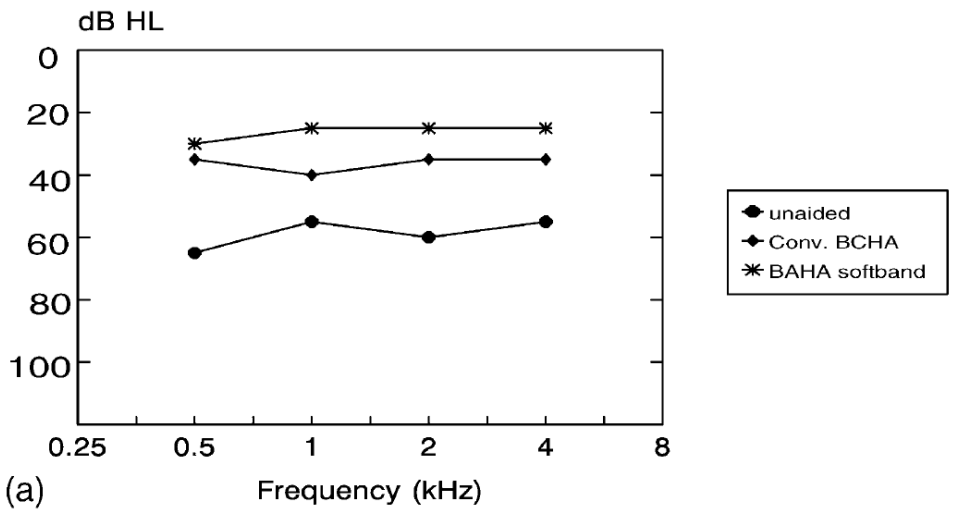
1. Functioning
2. Results
3. Advantages & Disadvantages


N S
N S
F
BH

BILATERAL CONDUCTIVE HEARING LOSS

BEHAVIOURAL EVALUATION





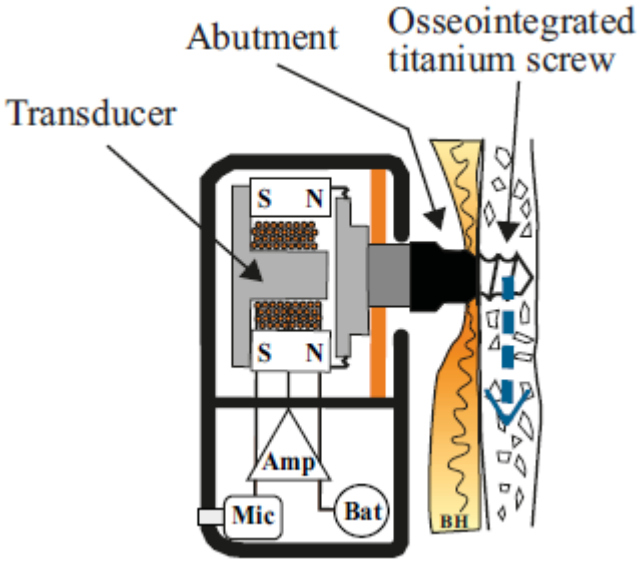
Hol et al., 2005, n = 2

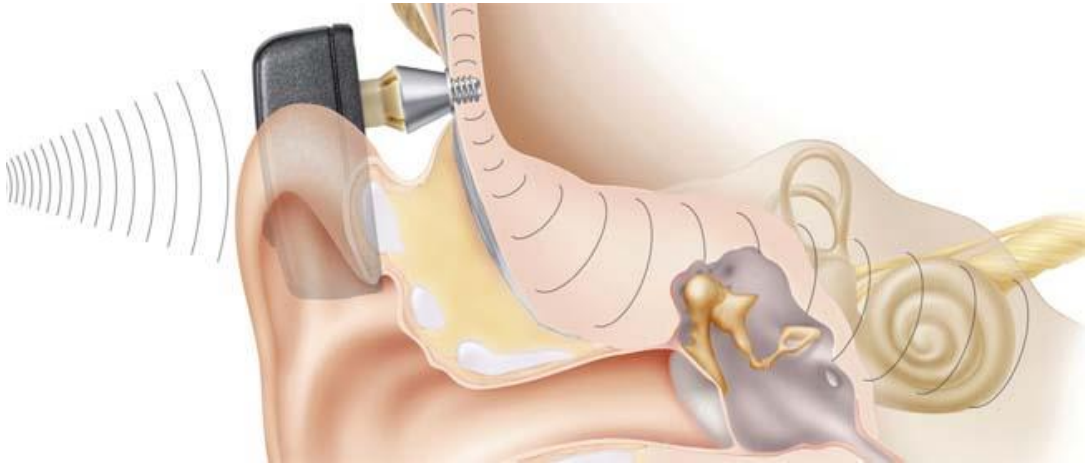
- ✓ Advantages:
  - Children
  - Temporary solution
  - Completely non-invasive

- ✓ Disadvantages:
  - Pressure / discomfort (Hakansson, 1994; Snik, 2004)
  - Aesthetics
  - Loss of gain (Verstraeten, 2008)

PERCUTANEOUS BC SOLUTIONS

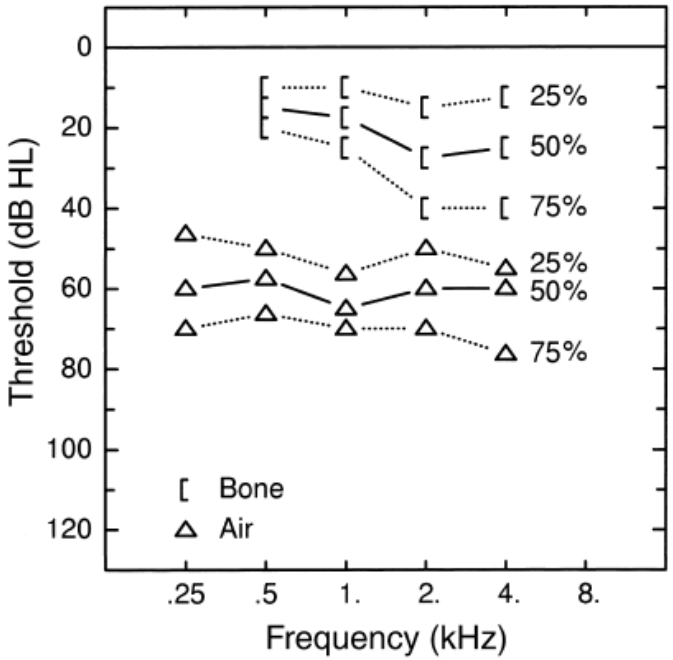
1. Functioning
2. Results
3. Advantages & Disadvantages

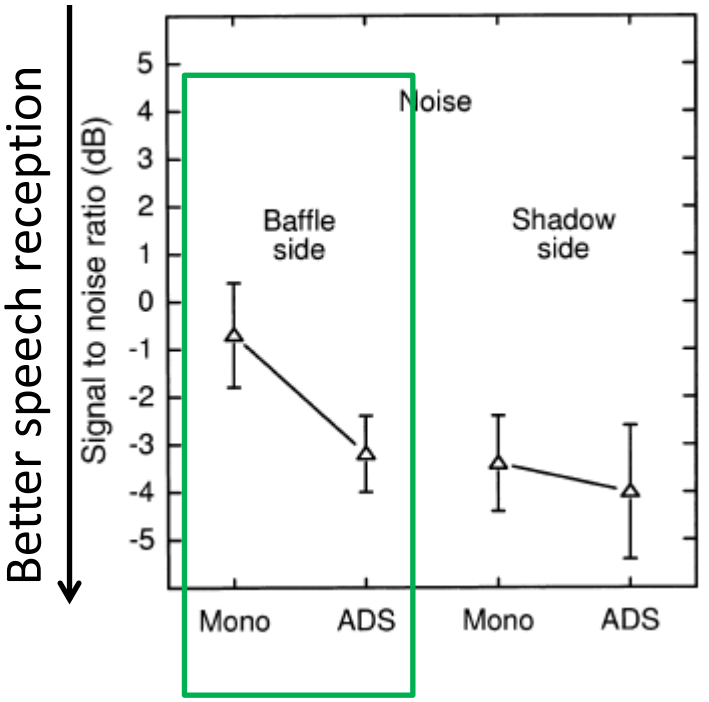

Abutment
Osseointegrated titanium screw
Transducer
S N
S N
Amp
Mic
Bat
BH



BILATERAL CONDUCTIVE HEARING LOSS + BILATERAL BCD

SPEECH IN NOISE



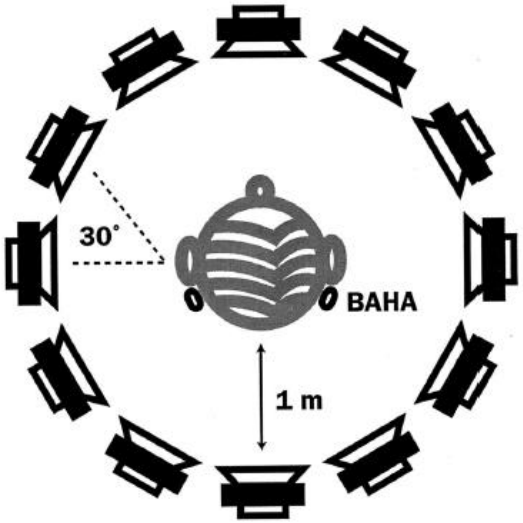


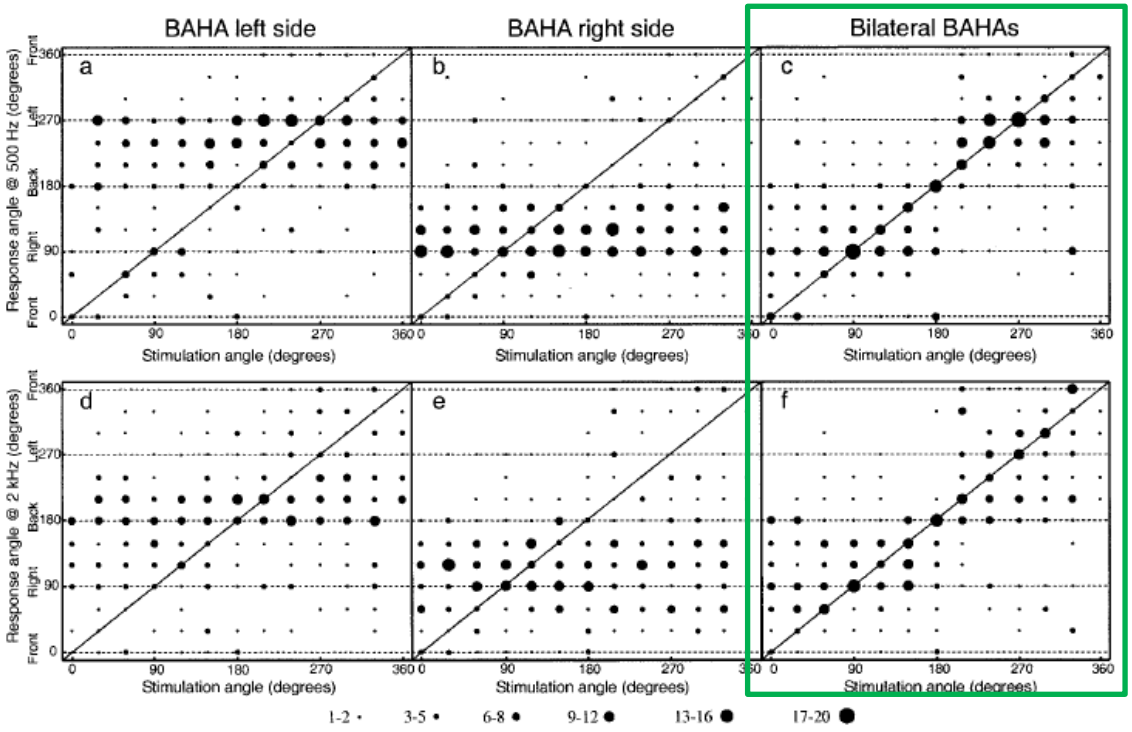
-3,3 dB SNR; p < 0,01

Bosman et al. , 2001; n = 25

BILATERAL CONDUCTIVE HEARING LOSS + BILATERAL BCD

LOCALIZATION





Priwin et al. , 2004, n = 12

BILATERAL CONDUCTIVE HEARING LOSS + BILATERAL BCD

SUBJECTIVE BENEFIT

92% reported QOL improvement

Benefit scores	Bilateral BAHA	Unilateral BAHA		
		Arunachalam et al. (17)	McLarnon et al. (19)	Gillett et al. (20)
Overall	+38 (33–44)	+31 (22–41)	+33 (25–42)	+32 (10–55)
Number in study	93	60	94	59
Total response	71	51	69	41
Response rate	76%	85%	73%	69%

Glasgow Benefit Inventory, Eu Chin Ho et al. , 2009 n = 71

UNILATERAL CONDUCTIVE HEARING LOSS

SPEECH IN NOISE

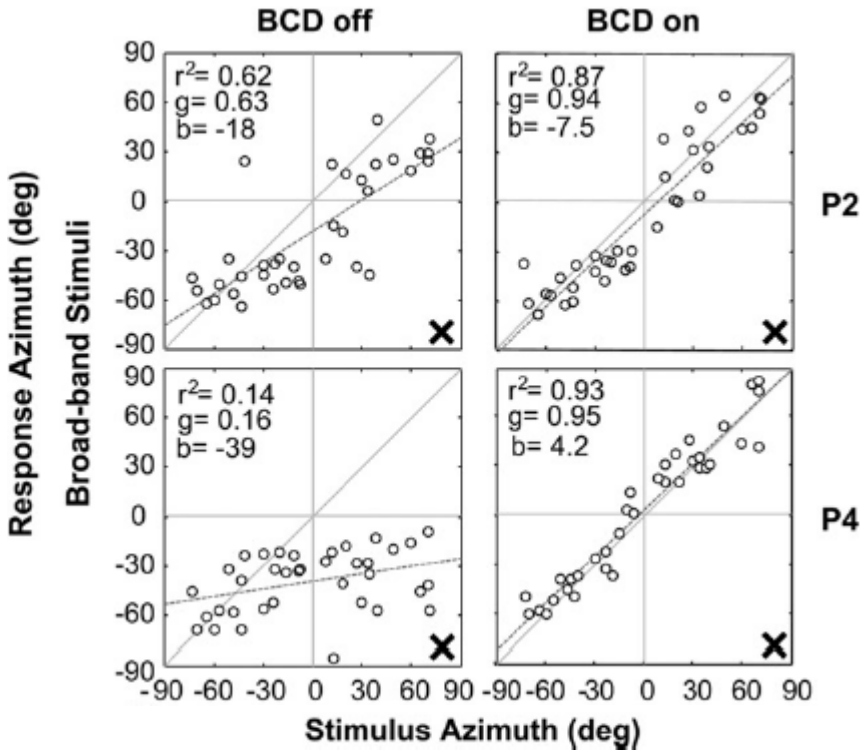
Patient	S/N results, position noise source (dB)					
	Near impaired ear			Near normal ear		
	Mon	Bin	Change	Mon	Bin	Change
P1	–5.6	–7.3	1.7*	–1.6	–6.7	5.1*
P2	–6.4	–6.4	0	1.6	–1.6	3.2*
P3	–3.0	–2.6	–0.4	–1.1	–1.1	0
P4	–9.0	–9.2	0.2	0.6	–5.1	5.7*
P5	–1.7	–1.2	–0.5	1.2	–2.8	4.0*
P6	–10.8	–11.2	–0.3	–3.0	–7.4	4.4*
P7	–6.3	–6.5	0.2	–3.4	–8.1	4.7*
P8	–9.0	–9.1	0.1	–7.6	–9.4	1.8*
Control subjects Mean	–9.3	–9.5	0.2	–4.9	–9.5	4.6*
SD	1.2	1.1	1.2	1.1	1.1	1.6

4.6 dBSNR

Snik et al. , 2002 n = 8

UNILATERAL CONDUCTIVE HEARING LOSS

LOCALIZATION



Agterberg et al. , 2012, n = 13

UNILATERAL CONDUCTIVE HEARING LOSS

SUBJECTIVE BENEFIT

Table 3. Results of questions 6–12 in the questionnaire

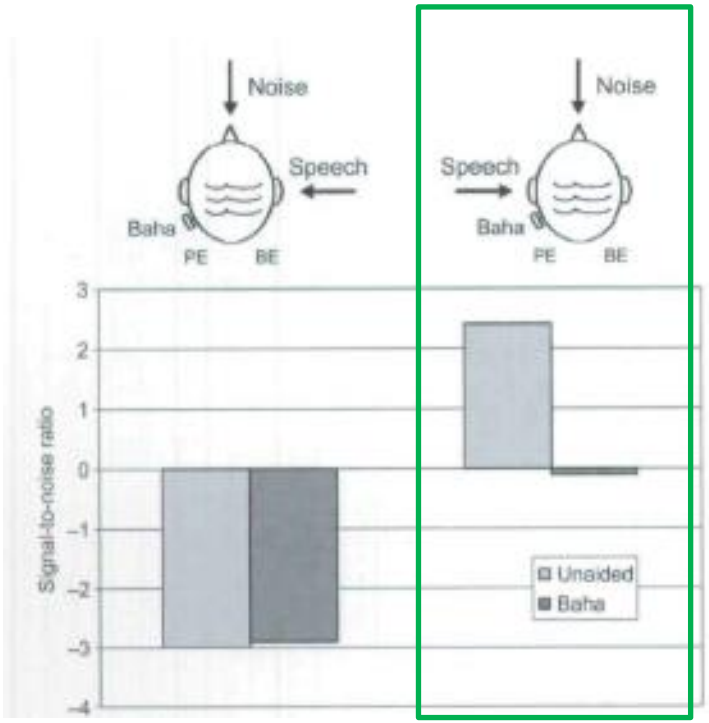
	BAHA	No BAHA	No preference
When you are listening to speech in quiet situations involving 1 or 2 persons, do you find listening easier using:	18	0	0
When you are listening to TV, radio, or compact discs, do you find listening easier using:	18	0	0
When you are listening to a conversation from a distance (over 6 m), do you find listening easier using:	16	0	2[a]
When you are listening to speech in noisy situations, do you find listening easier using:	15	3[b]	0
When you are at a meeting, church or theatre, do you find listening easier using:	17	1[c]	0
When you have to locate sounds, e.g. car horn, do you find listening easier using:	17	0	1[d]
When you are listening, do you find it more comfortable (more relaxed and easier) using:	17	1[c]	0

Disability-specific questionnaire (Chung & Stephens; 1986), Hol et al. , 2005

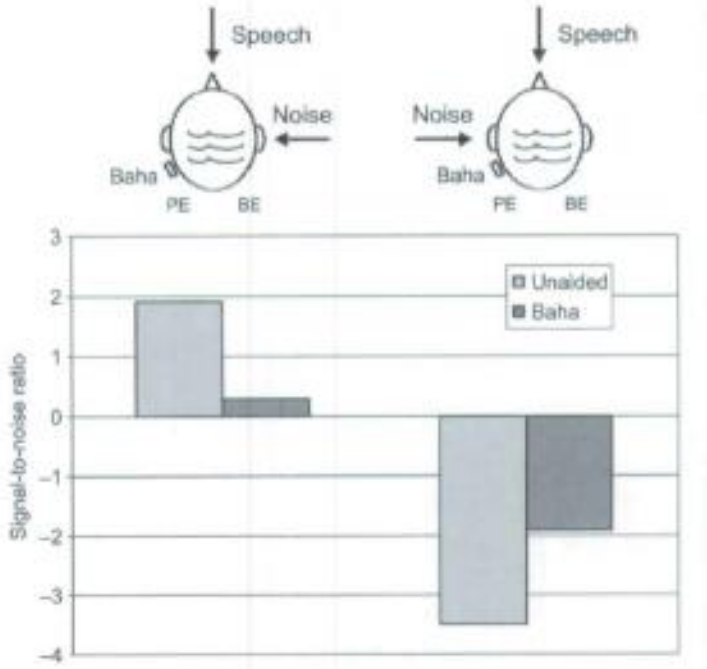
SEVERE UNILATERAL SENSORINEURAL HEARING LOSS

SPEECH IN NOISE

Better speech reception



-2,5 dB SNR

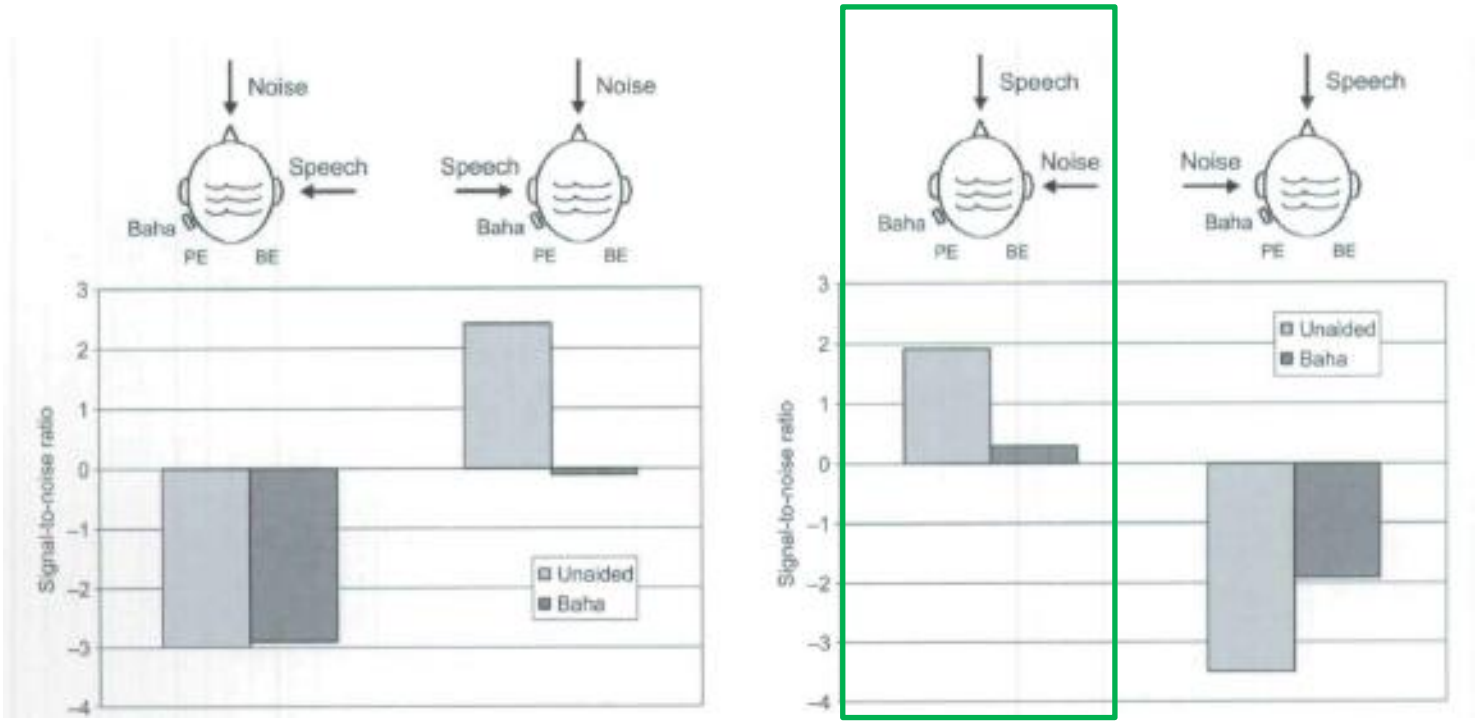


Hol et al. , 2010 n = 56

SEVERE UNILATERAL SENSORINEURAL HEARING LOSS

SPEECH IN NOISE

Better speech reception



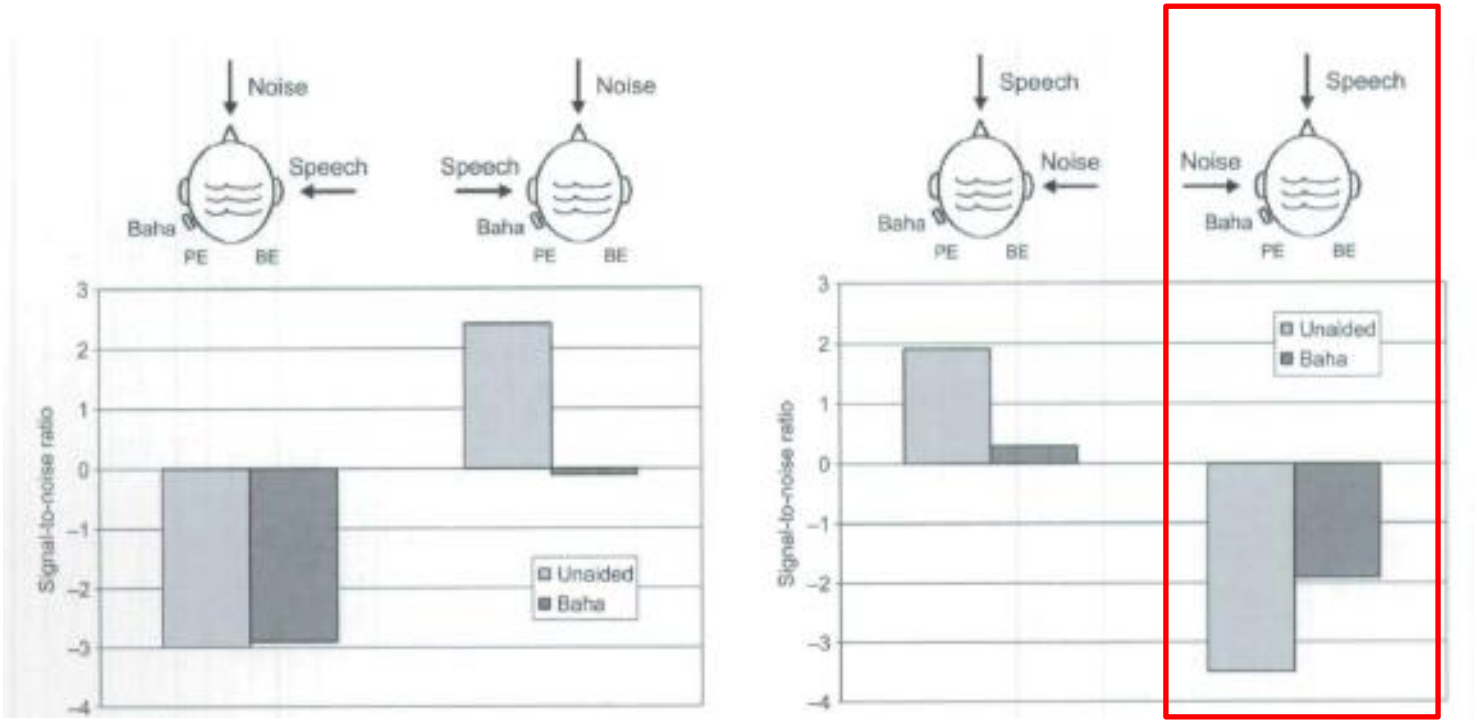
-1,1 dB SNR

Hol et al. , 2010 n = 56

SEVERE UNILATERAL SENSORINEURAL HEARING LOSS

SPEECH IN NOISE

Better speech reception

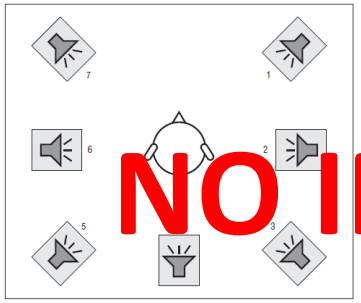


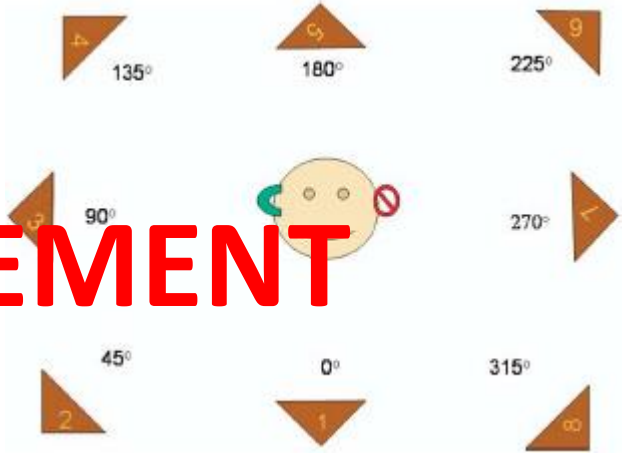
+ 1.6 dB SNR

Hol et al. , 2010 n = 56

SEVERE UNILATERAL SENSORINEURAL HEARING LOSS

LOCALIZATION





NO IMPROVEMENT

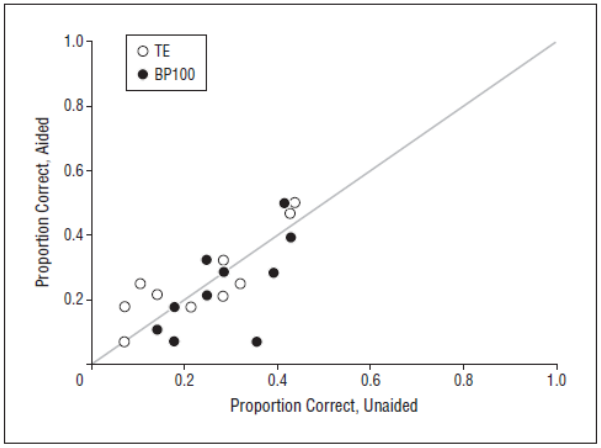


Table 3. Percent accuracy* of unaided localization judgments by subjects with unilateral sensorineural hearing loss (N = 8)

Frequency (Hz)	% Correct		
	Mean	Minimum	Maximum
500	13	8	20
3000	19	10	35

*Number correct/40 presentations × 100.

Table 4. Percent accuracy* of BAHA-aided localization judgments by subjects with unilateral sensorineural hearing loss (N = 8)

Frequency (Hz)	% Correct		
	Mean	Minimum	Maximum
500	16	8	23
3000	15	8	23

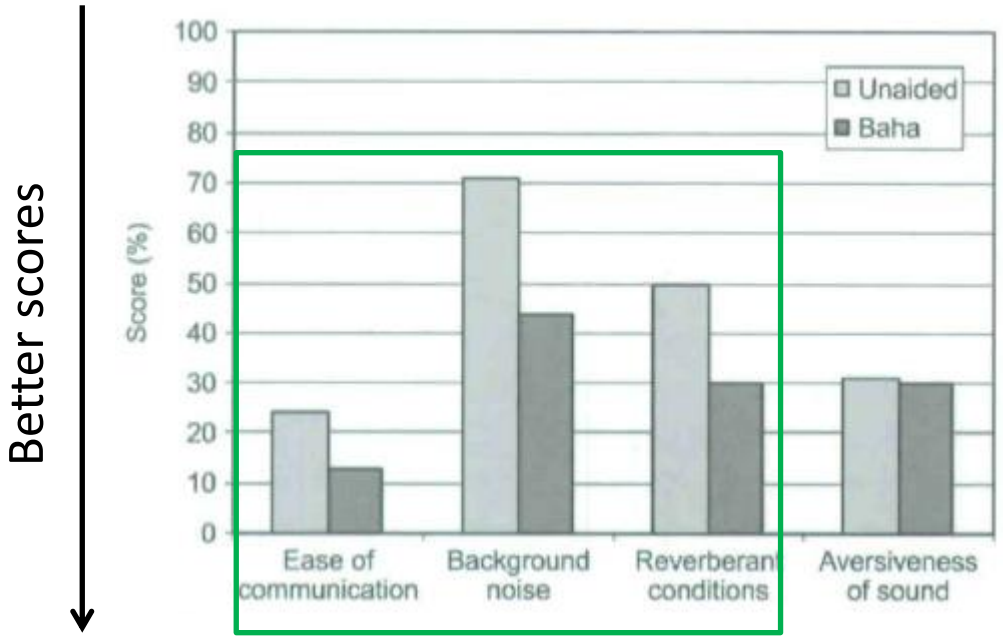
*Number correct/40 presentations × 100.

Battista et al., 2013 n = 10

Wazen et al. , 2005 n = 8

SEVERE UNILATERAL SENSORINEURAL HEARING LOSS

SUBJECTIVE BENEFIT



p < 0,025

Hol et al. , 2010 n = 56

- ✓ Advantages
  - More gain than transcutaneous systems
  - Possible to close the air-bone gap (BC ≤ 55 dB HL)
  - MRI/NMR
- ✓ Disadvantages
  - Adverse skin reactions (4,6%) and life-long care
  - Loss of the implant (8,3%)
  - Children
  - Aesthetics

Dun et al. , 2012

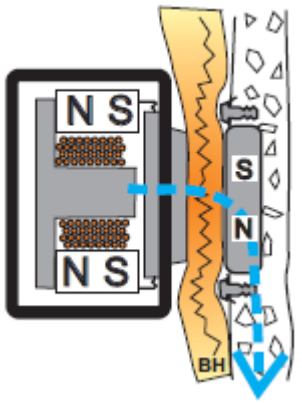
TRANCUTANEOUS PASSIVE BC SOLUTIONS

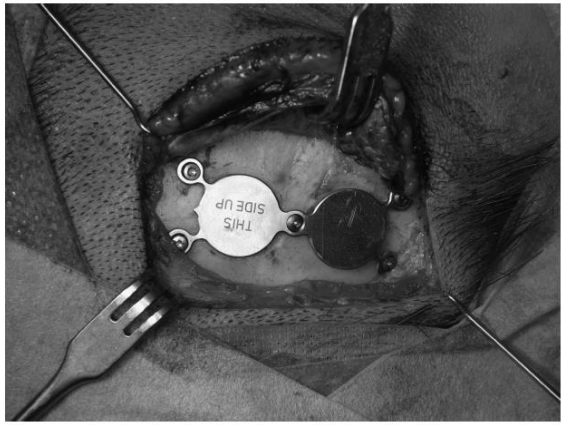
SOPHONO

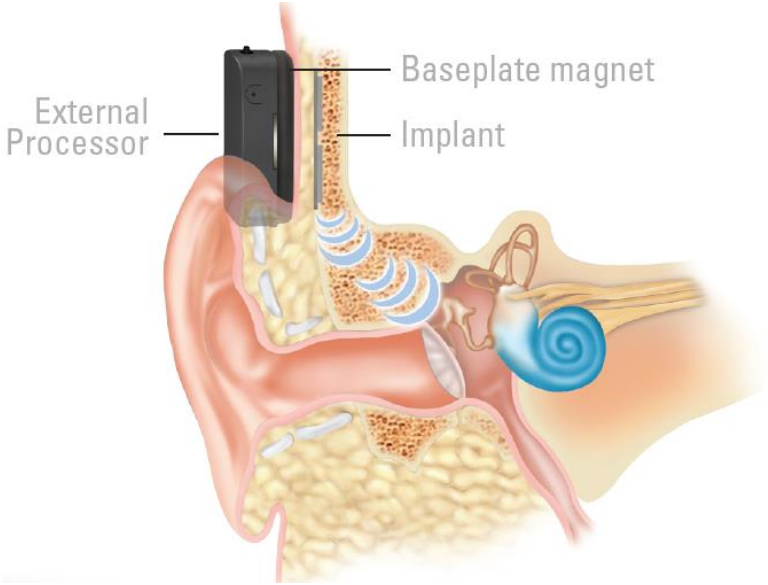
1. Functioning
2. Results
3. Advantages & Disadvantages

BAHA® ATTRACT

1. Functioning
2. Results
3. Advantages & Disadvantages

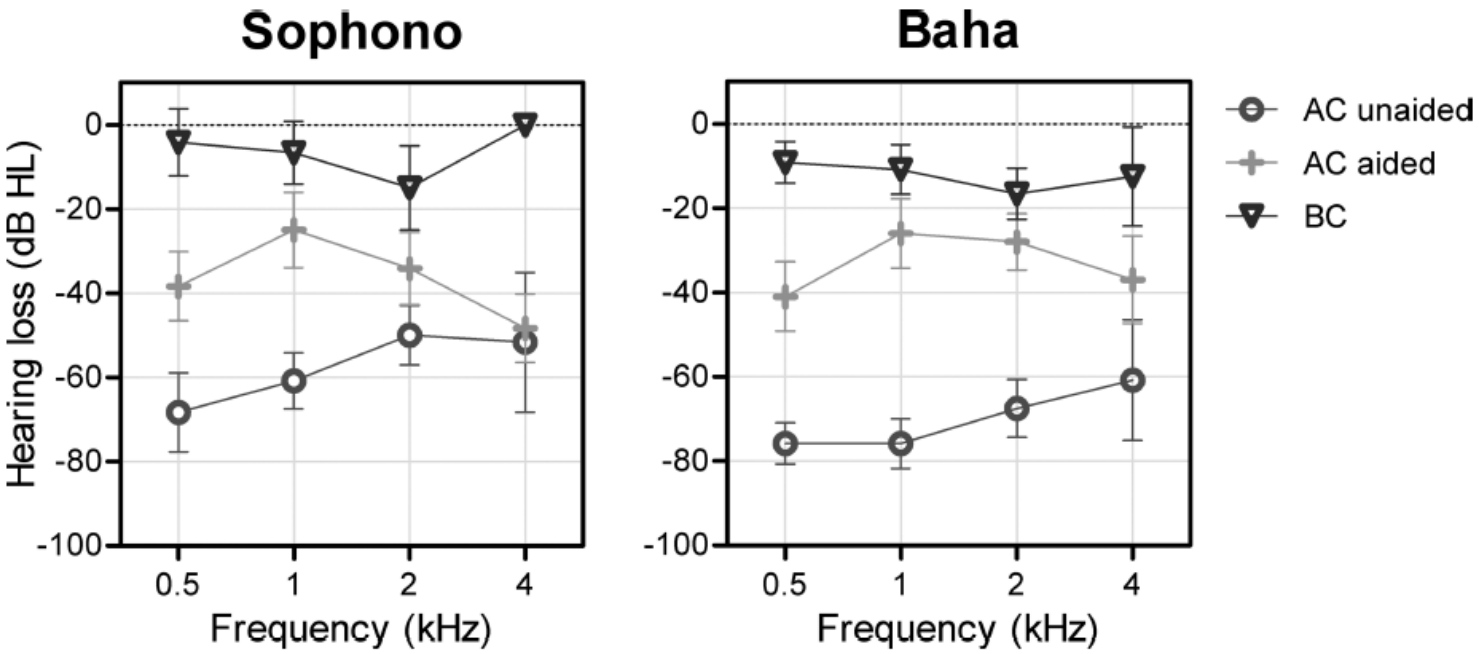






Two magnetic parts – multiscrew system

SOUND FIELD AUDIOMETRY



Hol et al. , 2013 n = 6 children

SPEECH IN NOISE

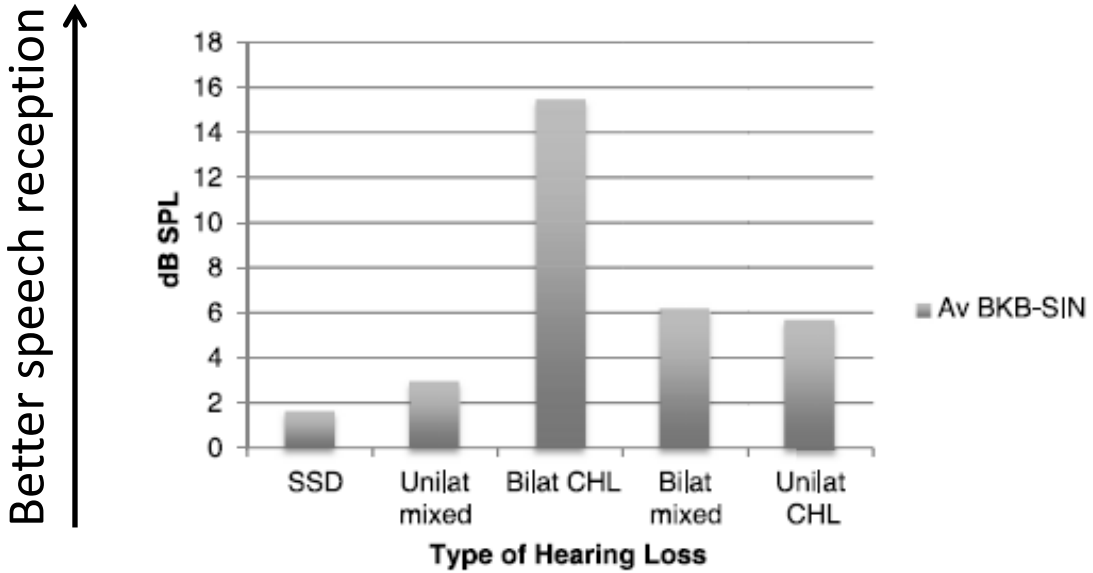


FIG. 9. Average improvement in BKB-SIN at 70 dB SPL.

Sylvester et al. , 2013 n = 18

SUBJECTIVE BENEFIT

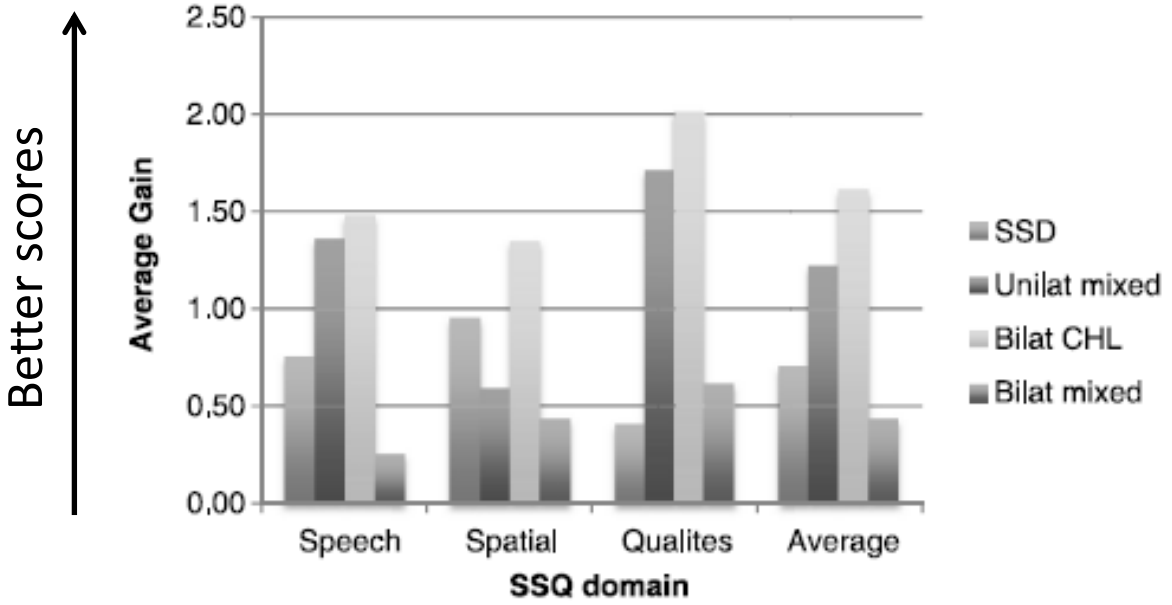


FIG. 10. Outcomes of quality-of-life improvement using SSQ-B score.

Sylvester et al. , 2013 n = 18

BI300 Implant

Magnetic implant

Baha® sound prcessor

External Magnet
&
SoftWear™ Pad

Two magnetic parts – single screw system

SUBJECTIVE BENEFIT

World-first hearing aid is music to Alex's ears

The West Australian CATHY O'LEARY MEDICAL EDITOR The West Australian
October 30, 2013, 8:58 am

Share

The West Australian

Perth schoolboy Alex Brewer can hear a whole new world, including the sound of wind blowing, traffic and air-conditioning.

The 17-year-old Christ Church Grammar student, who has just finished Year 12, has become the first teenager in the world to get a new type of hearing device that can be used in people with conductive hearing loss, where sound cannot get through to the inner ear.

Although he has hearing in his left ear, he has been unable to hear out of his partially-formed right ear since birth, which has meant missing out on many everyday sounds.

Two months ago, Ear Science Institute Australia director Marcus Atlas implanted the internal part of a new magnetically attached hearing device known as Cochlear Baha Attract.

The titanium implant does not penetrate through the skin but instead uses magnetic force to attach an external speech processor, and harnesses the body's natural ability to send sound via bone directly to the inner ear.

When it was switched on last month, Alex was stunned to hear some sounds for the first time.

Next on his wish list is watching all his favourite movies without relying on subtitles.

"I've been looking forward most to renting The Blues Brothers movie, as well as listening to music and feeling more confident to socialise," he said.

Plotseling doof geworden Gabry kan na operatie alles weer verstaan

Perfect gehoor door magneetje in het hoofd

De aan één kant dove Gabry Rijkhoek is de eerste Nederlandse met een magneetje in haar hoofd. Hierop kan ze straks haar gehoorapparaat vastklikken en alles weer perfect horen. Het AD keek mee hoe het stukje staal werd geplaatst tijdens een unieke operatie.

HANNEKE VAN HOUWELINGEN

ZWIJNDRECHT | Gabry ligt, net onder narcose gebracht, overlevo op de operatietafel in het Albert Schweitzerziekenhuis in Zwijndrecht. Ze vindt het een eng idee dat er straks iets in haar hoofd zit, vertelde ze eerder. Maar haar verlangen om weer goed te horen, is groter dan haar angst. Dat ze de eerste Nederlandse is met een magnetisch implantaat gaat volledig aan de 39-jarige voorbij.

De schooljuffrouw werd in maart, van de ene op de andere dag, doof aan haar rechteroor. Ze was op het verjaardagsfeestje van haar vader; een griezelige boel tót de stemmen om haar heen plots vervormden. „Ik kon het niet aanhoren. Ik moest de kamer uit, zo erg was het." Daarna werd het stil aan haar rechterkant. De oorzaak is waarschijnlijk een virusinfectie geweest, al weten de artsen dat niet zeker. Circa 1500 mensen worden jaarlijks doof.

Gabry kwam na vele onderzoeken terecht bij kno-arts Dick Zaadnoordijk. Nu zit hij aan haar hoofdeind, klaar om voor het eerst een nieuwe werkwijze toe te passen om doven te helpen. Hij plaatst een kleine ronde magneet in haar schedel. Het magneetje is zo sterk dat straks aan de buitenkant van het hoofd een gehoorapparaatje blijft kleven.

Binnenoor

Het werkt als volgt: geluid wordt via het hoortoestel door het schedelbot heen naar binnen geleid, zodat het alsnog kan worden opgevangen door het binnenoor. Het trommelvlies is zo niet meer nodig.

Gabry ziet uit naar het moment dat ze het hoortoestel op haar hoofd mag plakken, maar de wond moet nog 4 weken helen. Ze is juffrouw in groep 5/6 in Alblasserdam en hoort de kinderen nu amper. „Als het rumoerig in de klas is, weet ik niet welk kind tegen mij praat. Aan het eind van elke schooldag ben ik uitgeput van de inspanning." De juf heeft de mazzel dat ze dezelfde leerlingen heeft als vorig schooljaar. „Zij weten dat ik doof ben geworden en proberen me zo veel mogelijk te helpen. Als ik met mijn rechteroor naar de deur sta en er komt iemand binnen, geven ze een seintje. Anders schrik ik me rot."

Vrienden weten inmiddels dat ze aan haar linkerkant moeten lopen om een normaal gesprek te voeren en in de auto komt het aan op heel hard schreeuwen. „Of ze moeten wachten tot we op de bestemming zijn," grinnikt Gabry. „Ja ik kan er inmiddels wel om lachen. Humor sleept me er doorheen."

Toen de juffrouw in maart plots doof werd, dacht ze in eerste instantie aan een onschuldige verkoudheid. „Ik liet mijn oor uitspuiten bij de dokter, maar dat hielp niet. Toen bij achter me ging staan en in zijn handen klapte, wist hij dat het mis was. Ik had niks gehoord."

Een uur later zat ze in het ziekenhuis. „Ik wist niet wat me overkwam. Ik had er nog nooit van gehoord dat je plots doof kon worden, maar na een paar weken dacht ik: 'ik moet hiernaar leren leven'. Het is gelukkig geen tumor, waaraan ook nog is gedacht."

Een normaal gehoorapparaatje werkte averechts bij Gabry. „Als er een blaadje van het prikbord viel, vloog ik van mijn stoel. Dat geluid kwam zo hard binnen. Maar als iemand naast mij stond te praten, hoorde ik dat amper."

Het nieuwe hoortoestel - met het magneetje - moet de oplossing zijn. „Ik heb al iets getest dat daarop leek, en het geluid was veel beter. Straks kan ik de kinderen in de klas weer goed horen," verwacht ze.

Het magnetische model is een uitvinding van Cochlear, een Zweedse fabrikant die al tientallen jaren gehoortoestellen met botgeleiding ontwikkelt, zogenoemde baha's. Voorheen stak bij dit type gehoorapparaat een pinnetje uit het hoofd, dat veel patiënten een eng idee vonden. Vandaar het alternatief. „Bovendien is het gevaar op infecties groter als er iets uit je hoofd steekt. Dat risico loop je bij een magneetje niet," legt kno-arts Zaadnoordijk het verschil uit.

De medicus uit Zwijndrecht was één van de eerste artsen die zich meldde voor de studie van het nieuwe model. Straks volgt het Radboud UMC in Nijmegen. Ook in andere landen, zoals Zweden en Chili, is dit model al met succes getest.

Paperclips

Patiënten met een magneetje in hun hoofd, hoeven overigens niet bang te zijn dat paperclips direct naar hun oor vliegen of dat ze met hun oor aan de koelkast blijven kleven. Zo sterk is de magneet nu ook weer niet, stelt de arts gerust. Mochten ze in de toekomst een MRI-scan nodig hebben, dan kan dat. En bellen? Geen probleem.

Normale gehoorapparaatjes in het oor blijven de voorkeur verdienen, zegt Zaadnoordijk. Dan hoeft de patiënt niet onder het mes. Maar als zij geen geluid meer opvangen via hun gehoorgang óf chronische oorontstekingen hebben, kan het baha-model de oplossing zijn. „Het is wonderbaarlijk hoe goed botgeleiding werkt. Ik heb gevegeld patiënten in tranen gehad die weer konden horen," vertelt de kno-arts.

Artsen plaatsen het magneetje in Gabry's hoofd. FOTO MARCO DE SWART

▶ Gabry Rijbroek vindt het een eng idee dat er iets in haar hoofd zit. Maar haar verlangen om weer goed te horen, was groter dan haar angst. FOTO PRIVÉBEZIT

✓ Advantages

- Aesthetics: no skin penetration
- Not as much skin problems
- Wearing comfort (↔ conventional transcutaneous system)

✓ Disadvantages

- Not as much high frequency gain (Sophono)
- MRI compatible BUT large amount of distortion (around 10cm)
- Minor skin reactions

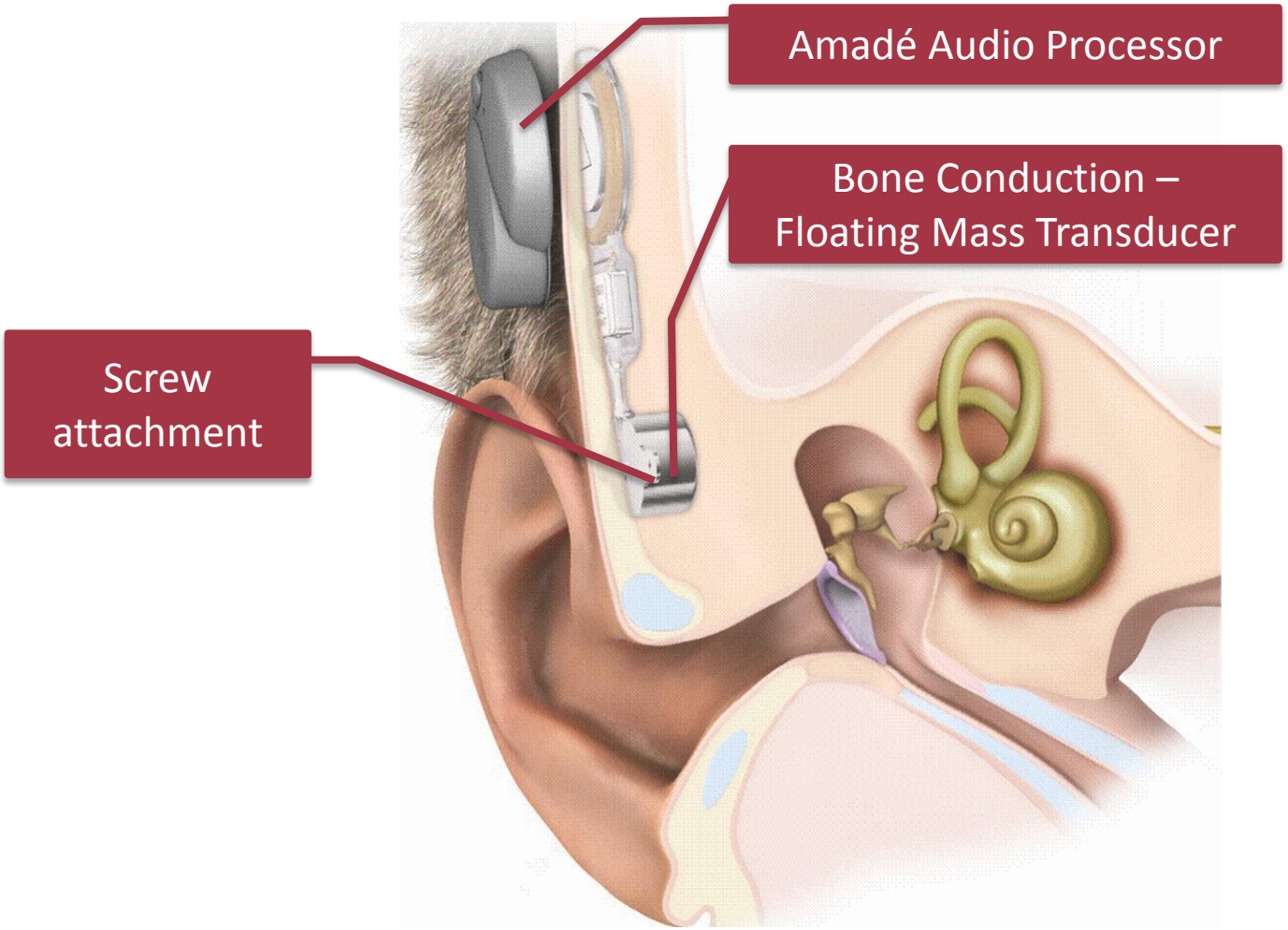
TRANCUTANEOUS ACTIVE BC SOLUTIONS

Medel BONEBRIDGE™

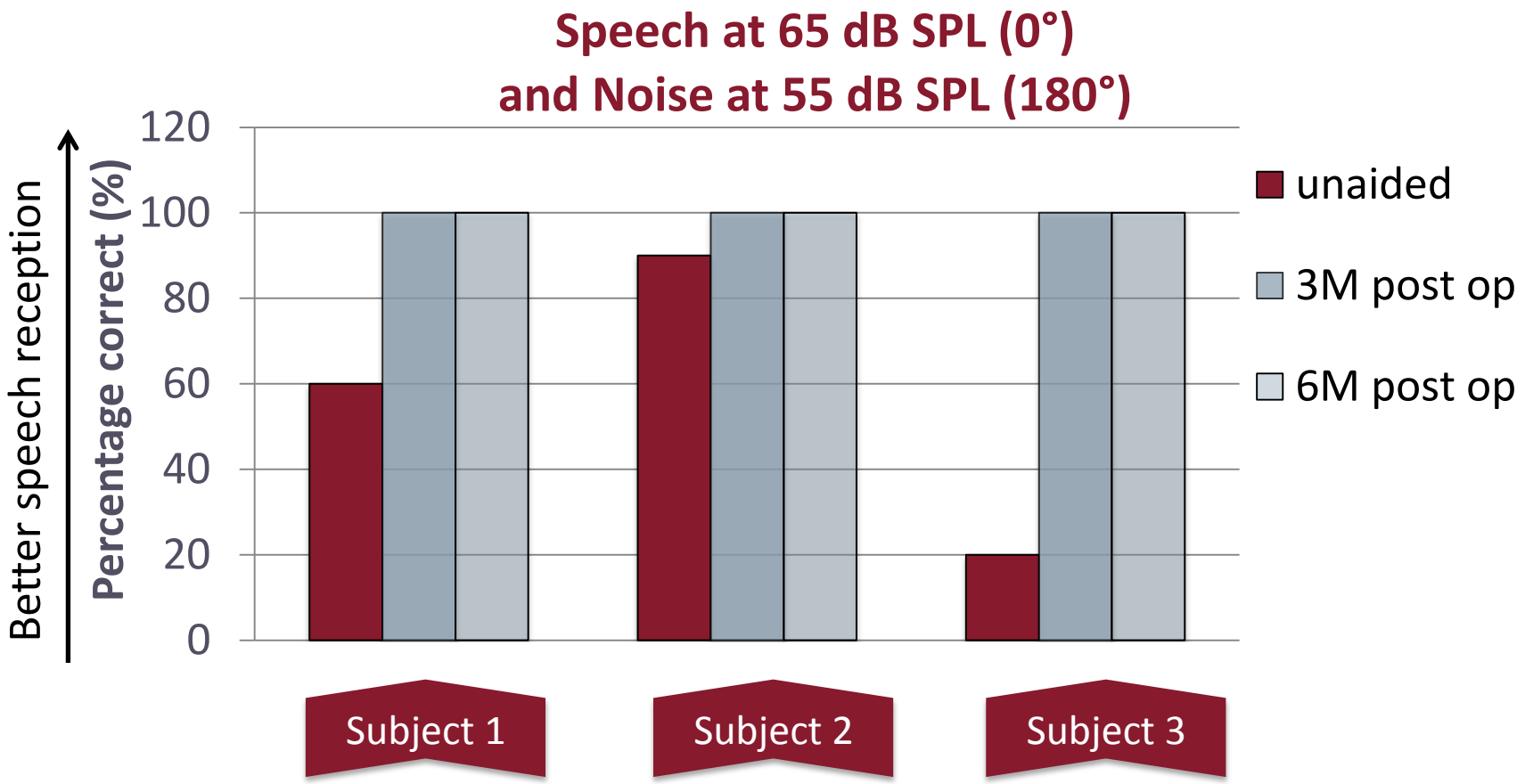
1. Functioning
2. Results
3. Advantages & Disadvantages

BCI

1. Functioning
2. Results
3. Advantages & Disadvantages

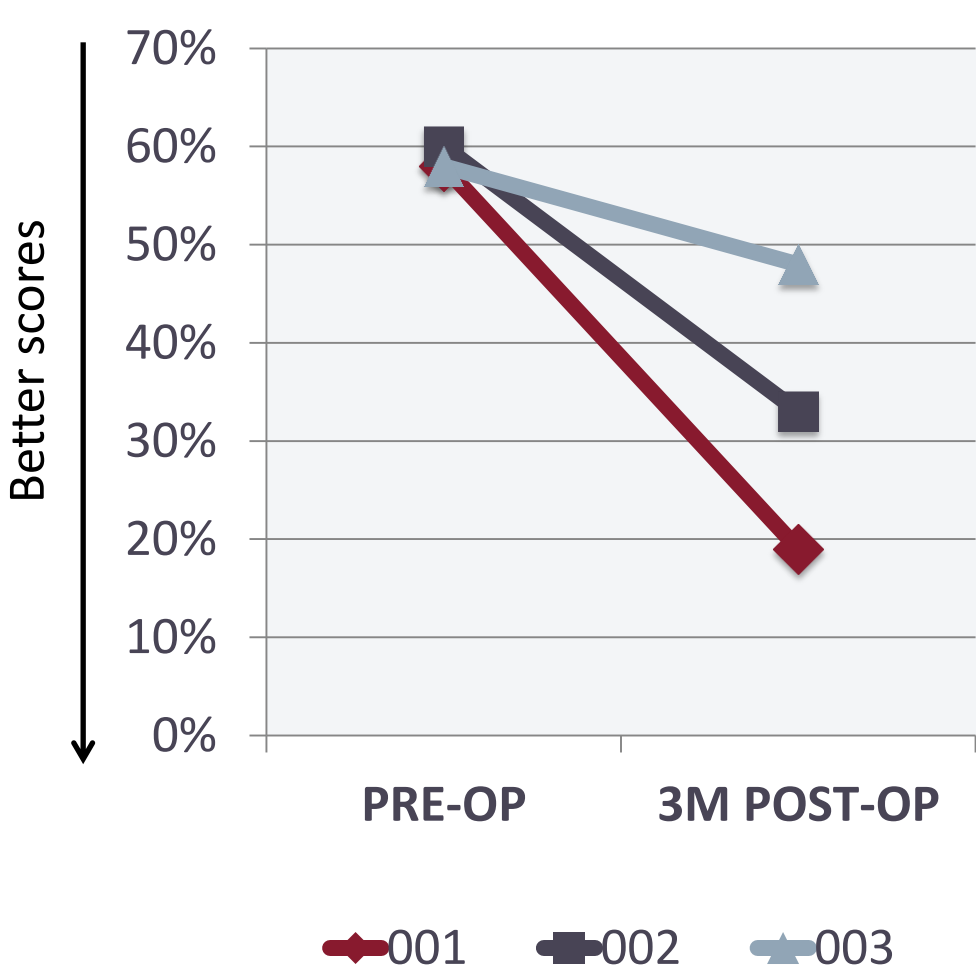

Amadé Audio Processor
Bone Conduction –
Floating Mass Transducer
Screw
attachment

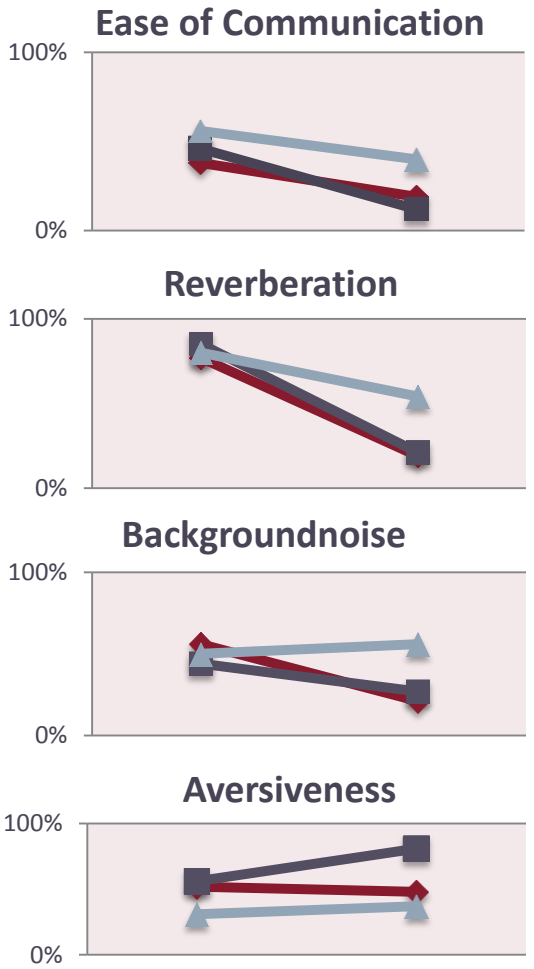
SPEECH IN NOISE



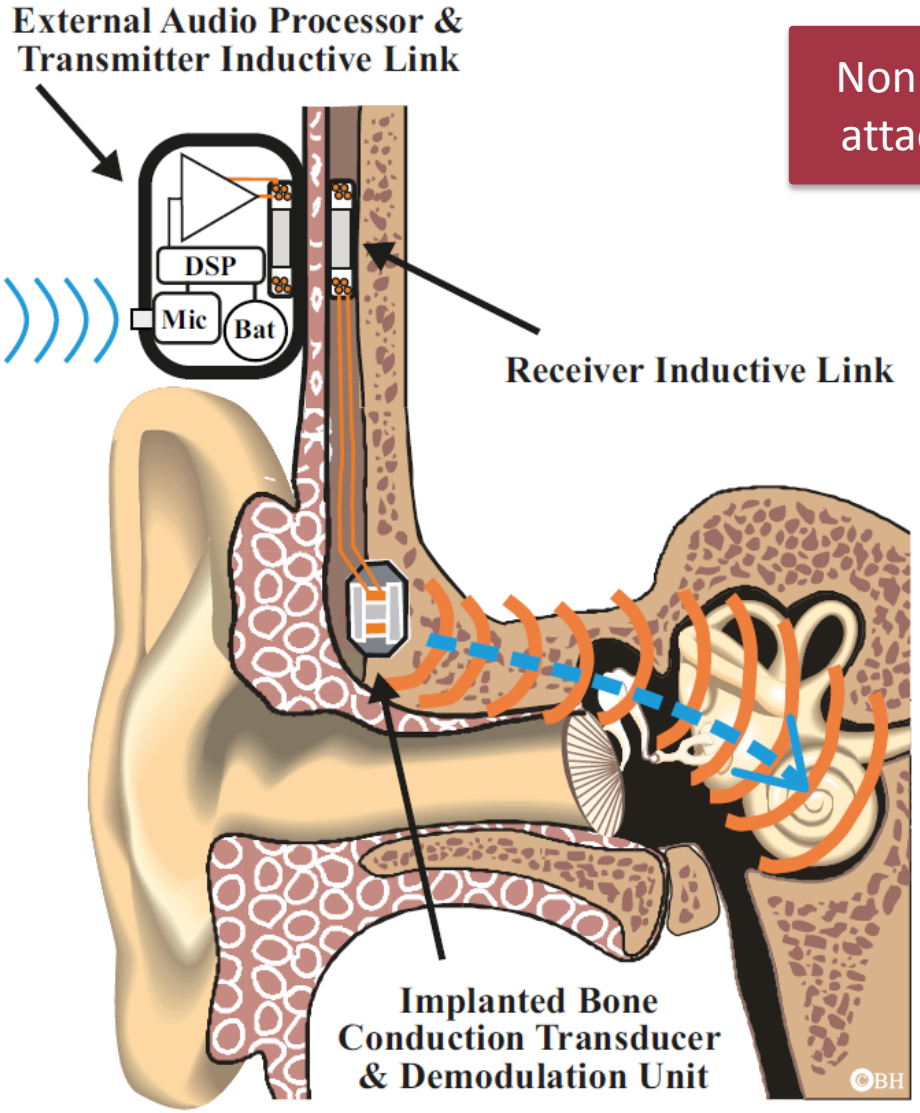
Mertens et al., 2013

SUBJECTIVE BENEFIT

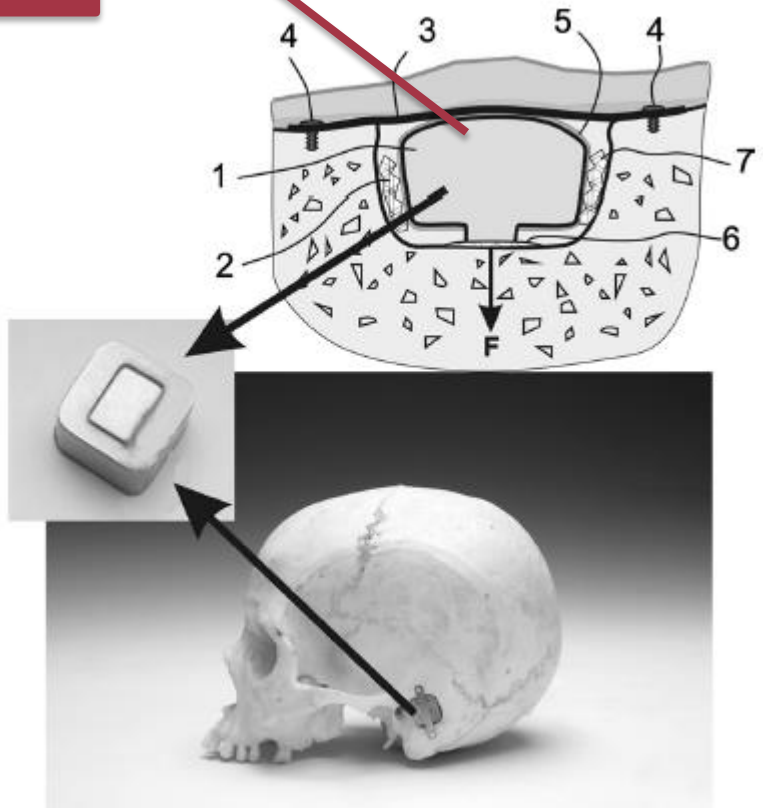




Mertens et al., 2013

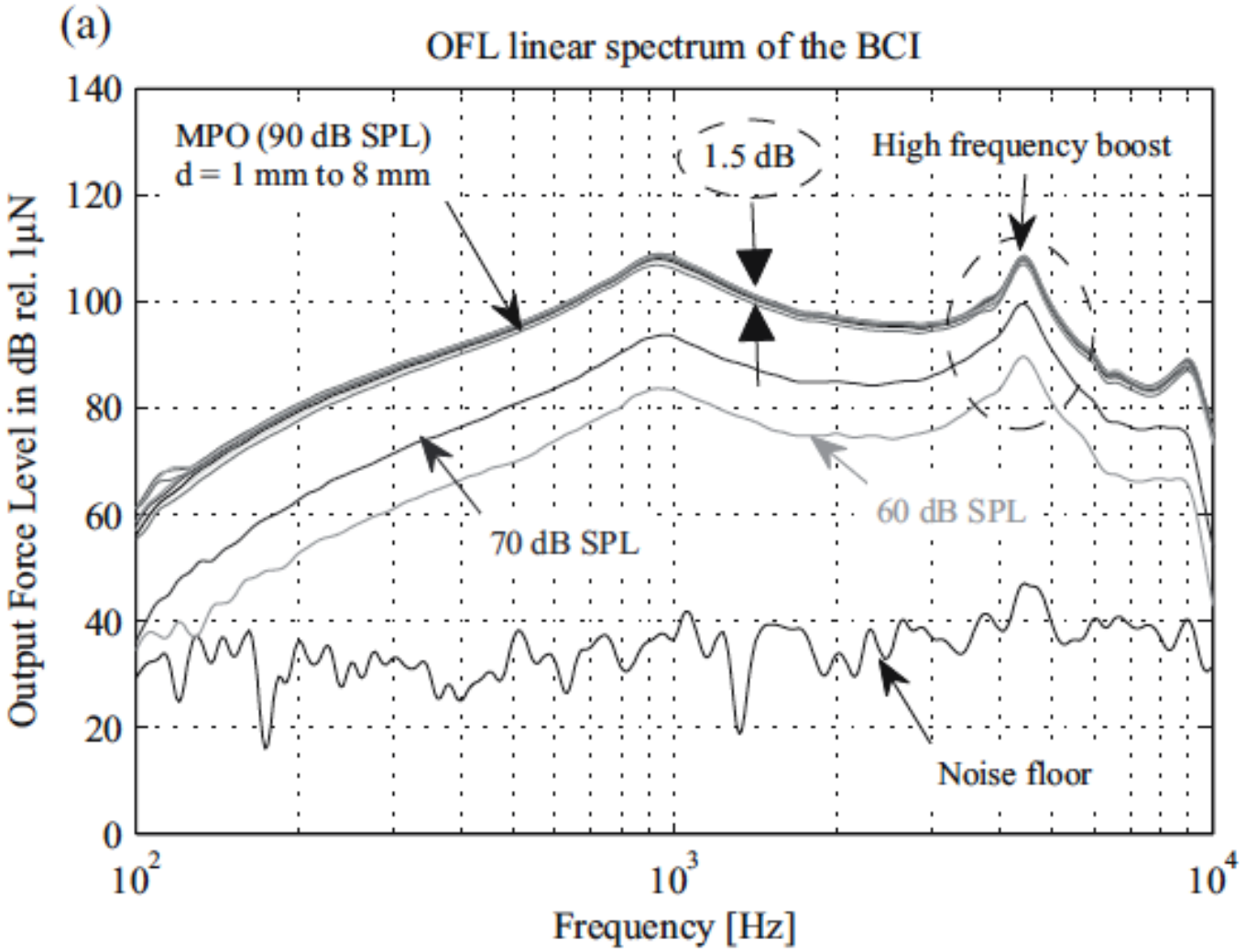


Non - Screw attachment



Taghavi et al. , 2012

PRELIMINARY RESULTS



Taghavi et al. , 2012

✓ Advantages

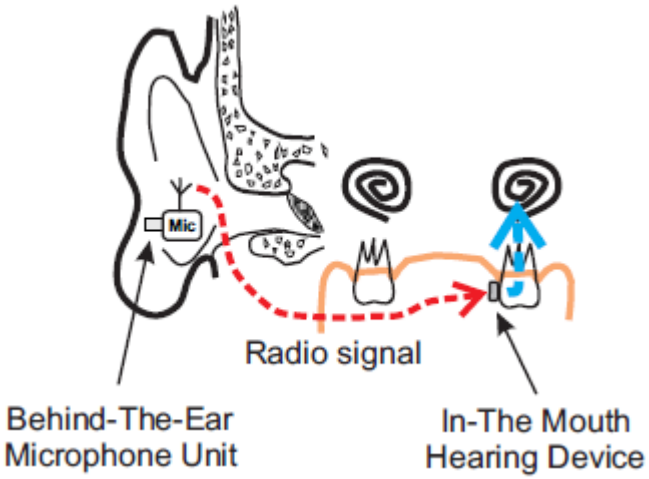
- Aesthetics: no skin penetration
- No skin problems / Extrusion
- Wearing comfort (↔ conventional transcutaneous system)
- Increased gain in the high frequencies (BCI)
- Transducer is closer to the cochlea

✓ Disadvantages

- Not as much gain as the percutaneous system
- MRI compatible BUT large amount of distortion (around 10cm)
- Beneficial for SSD?

SOUNDBITE

1. Functioning
2. Results
3. Advantages & Disadvantages



Behind The Ear component (BTE)

In The Mouth component (ITM)

Miller et al. , 2010

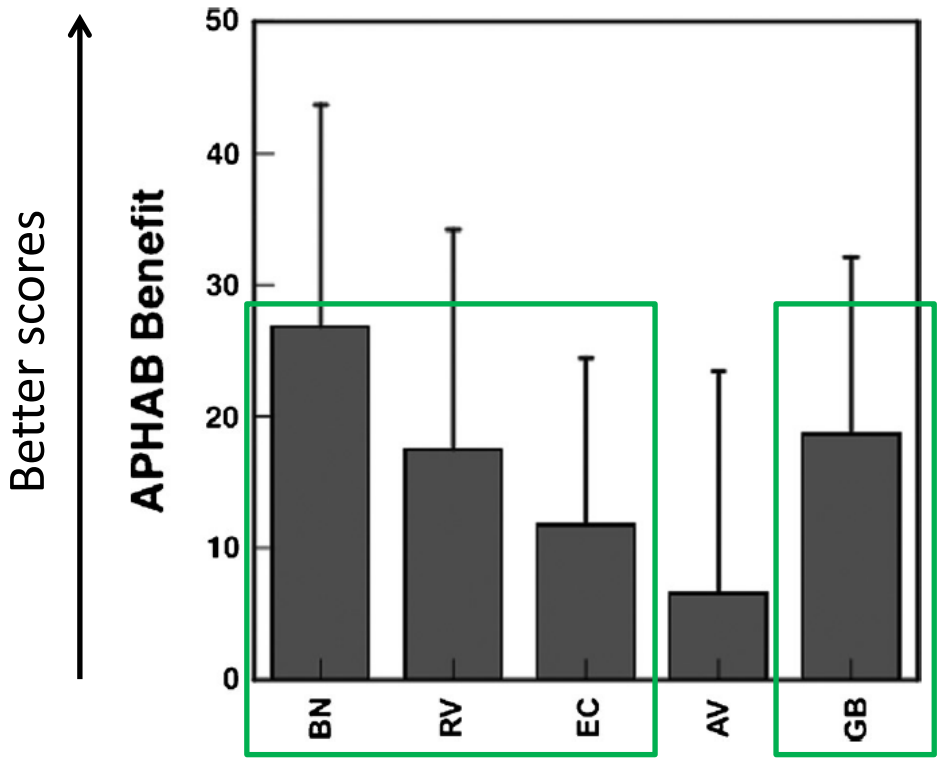
SPEECH IN NOISE

Site	Day	HINT (dB) mean (SD) no noise	HINT (dB) mean (SD) noise front	HINT (dB) mean (SD) noise poorer	HINT (dB) mean (SD) noise better
A	1	0.6 (3.00)	0.6 (1.17)	1.7 (1.33)	−1.5 (1.31)
B	1	−0.6 (4.58)	0.1 (1.43)	2.5 (1.52)	−1.8 (0.67)
Total	1	−0.2 (4.00)	0.2 (1.53)	2.1 (1.57)[a]	−1.7 (0.97)[a]
A	30	0.2 (2.51)	0.4 (1.02)	2.0 (1.39)	−2.2 (0.92)
B	30	−2.1 (5.56)	−0.3 (1.75)	2.6 (1.12)	−2.8 (0.98)
Total	30	−1.1 (4.59)	0.0 (1.50)	2.3 (1.26)[a]	−2.5 (1.00)[a]

(p < 0,001)

Murray et al. , 2011, n = 28 SSD patients

SUBJECTIVE BENEFIT



Statistically significant improvement; *p < 0,05*

Murray et al. , 2011, n = 28 SSD patients

✓ Advantages

- No surgery needed – completely non-invasive
- Placement microphone in the external ear canal (pinna-effects)

✓ Disadvantages

- Acoustic feedback is often reported
- 36% reports eating problems - 35% of the users eat with the ITM part in place
- Orthodontic treatment is sometimes necessary
- Relatively low power-output < 1 kHz → up to now only in SSD
- Batteries ITM last only 6-8h

WHICH BC SOLUTION?

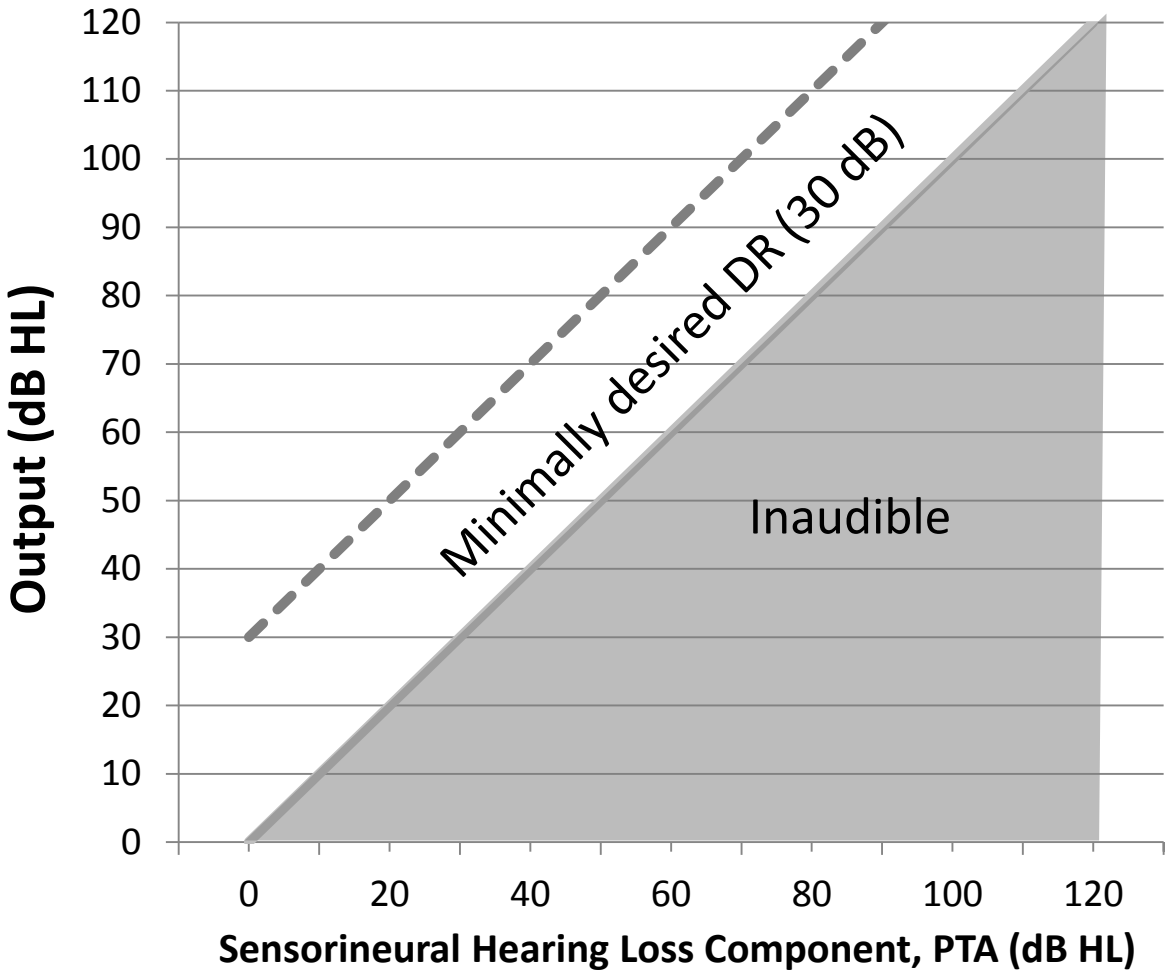
1. Classification of amplification options based on Maximum Output
2. Maximum output of BC devices
3. Conclusion

- ✓ Maximum Output = the highest sound level that can be produced without distortion
- ✓ Non-linear behavior: clipping/saturation of the device
- ✓ Maximum output is device specific
- ✓ Directly related to the device's application range (dB HL)
- ✓ Normally measured using ear/skull simulators

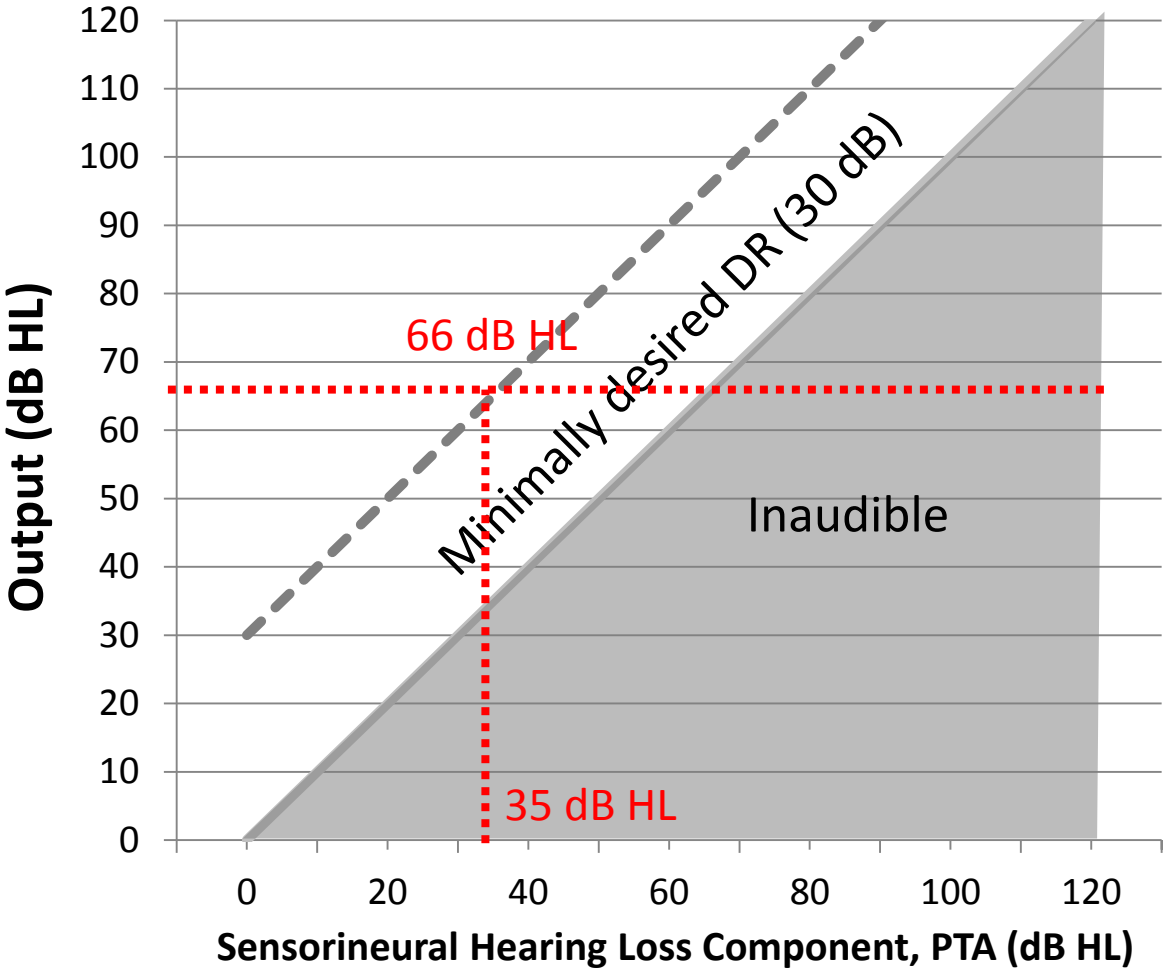
- ✓ MO (OFL80) for percutaneous **bone conductors**, measured on skull simulator, expressed in dB FL (force level); transferred to dB HL**

* A. Snik, J. Zwartenkot, J. Noten, E. Mylanus; Radboud University Medical Center Nijmegen, ENT department
** Using RETFLdbc (Reference equivalent threshold force level for direct bone conduction, Carlsson et al., 1997)

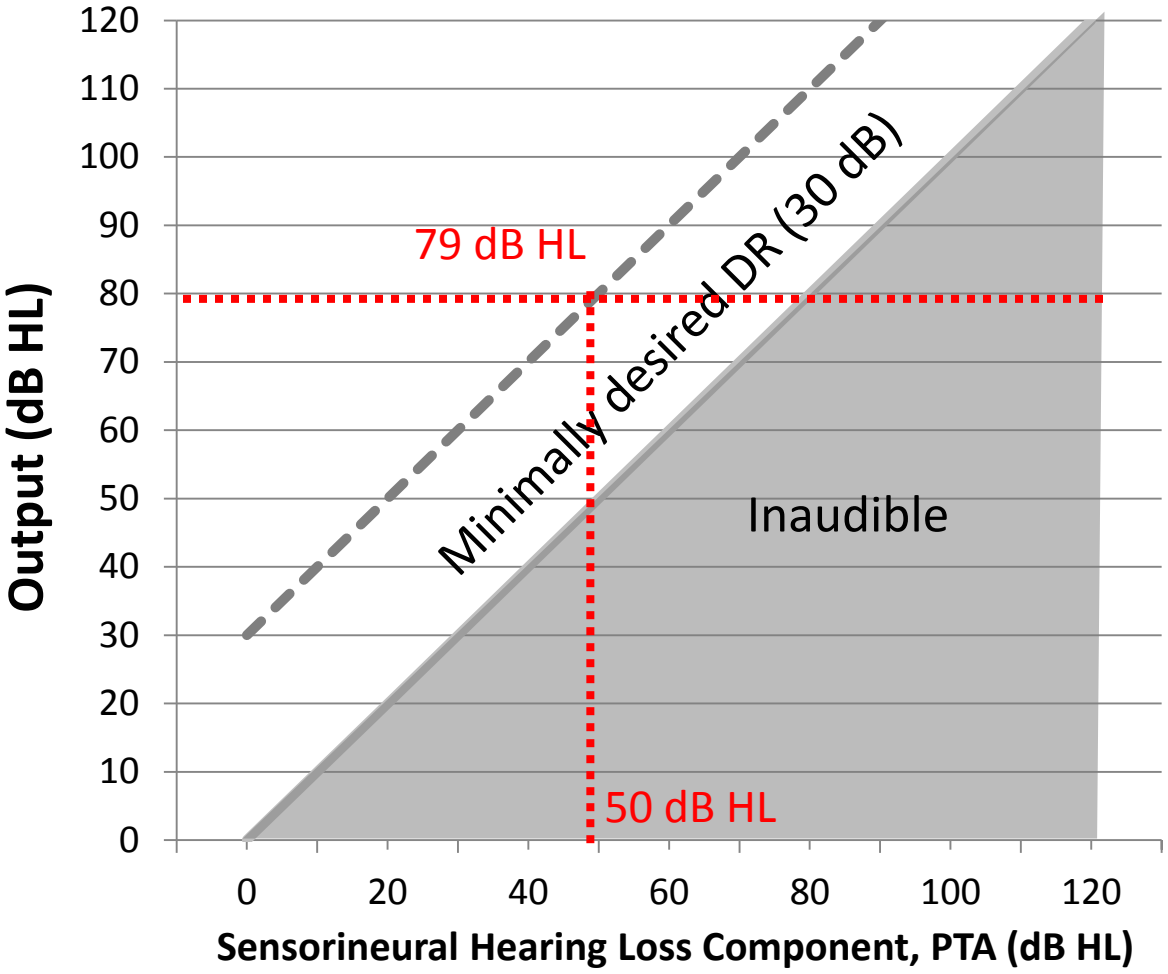
MAXIMUM OUTPUT



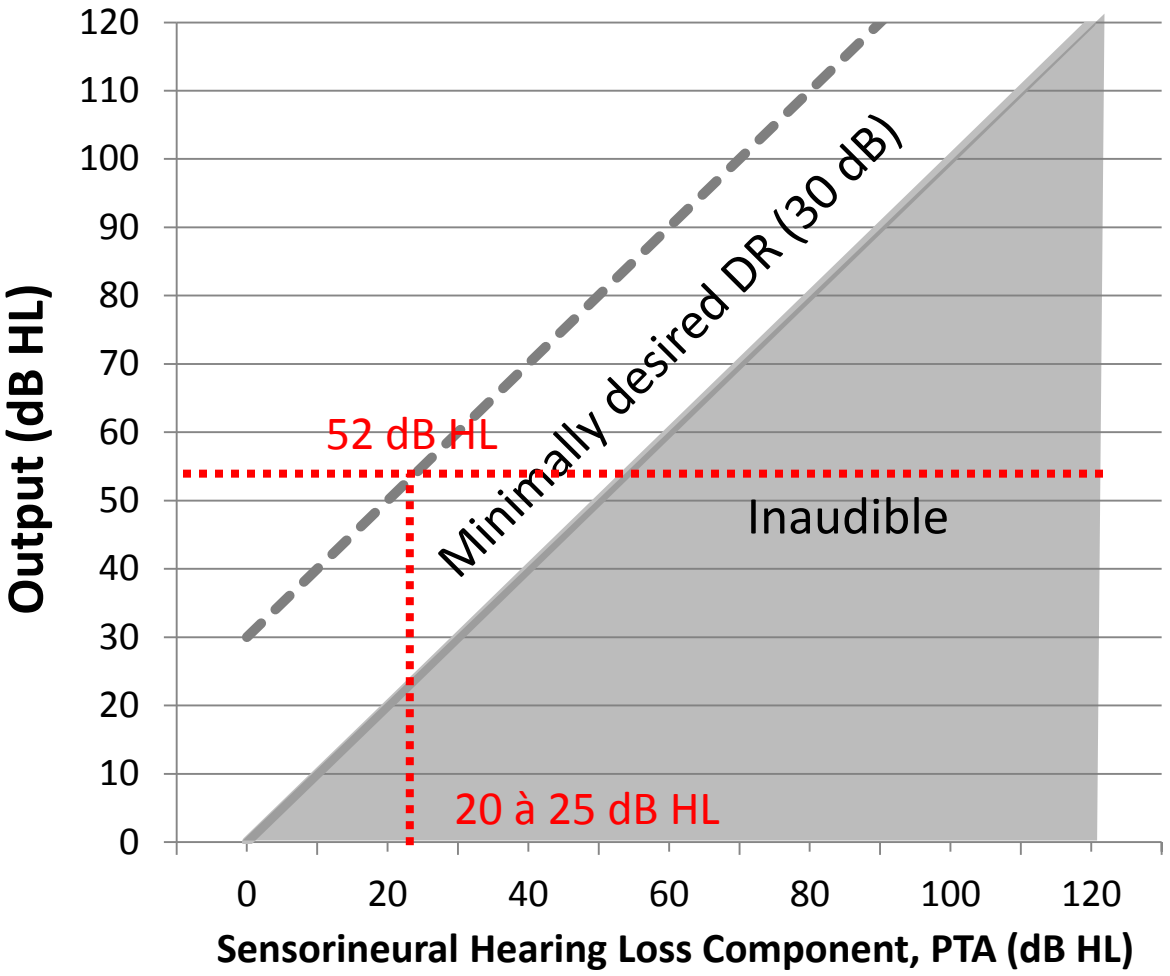
BAHA CLASSIC



BAHA CORDELLE



SOPHONO


120
110
100
90
80
70
60
50
40
30
20
10
0
Output (dB HL)
52 dB HL
Minimally desired DR (30 dB)
Inaudible
20 à 25 dB HL
0
20
40
60
80
100
120
Sensorineural Hearing Loss Component, PTA (dB HL)

OVERVIEW

Device	Max. output In dB HL	Upper SNHL appl. border
Baha Classic/ Divino	66*	35
Baha Cordelle	79*	50
Otomag Sophono	52 dB HL **	20-25 dB HL
Baha Attract	?	?
Medel Bonebridge	?	?
BCI	?	?

Upper appl. Border refers to the maximum sensorineural hearing loss component

* Measurements skull simulator; Snik et al.
* Published; Hol et al., 2013

- ✓ Bone conduction devices are a great solution for different groups of patients
- ✓ Different solutions for different types of hearing losses, aetiologies, patients!
- ✓ Choice for a certain system not only based on datasheets

THANK YOU FOR BEING “ALL EARS”!

Jolien.desmet@uza.be

@JDesmet_UZA

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