Learning Objectives

- After the course, participants will be able to explain why listening is more effortful for those with hearing loss.
- After the course, participants will be able to describe a few different ways of measuring the effort used to understand speech, and why this is relevant for real life situations.
- After the course, participants will be able to discuss the limitations of maximum output of bone anchored devices, and how this affects different users of these devices

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BrainHearing

The reason we develop the products we do

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Outline

- Part I
  - Hearing and cognition
  - Real world listening situations
  - How we can rethink out measurement methods to include cognition
  - Results using bone anchored devices and novel outcome measures including cognition
- Part II
  - Why maximum output of bone anchored devices affects all users
  - Should this influence how we counsel patients?
- Questions & comments

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Part I: Overview

- Hearing and cognition
  - Why is listening more effortful for those with hearing loss?
  - Does a hearing loss give raise to long-term issues?
- Real-world daily life (ecological) listening situations
  - In which situations do hearing impaired typically communicate?
- Cognitive measures beyond speech performance testing
  - Effect of technology on cognition
  - Advanced hearing aid technology

An example of processing

- You will be presented with two tasks to perform, then asked to compare your performance on each.

- Practice:

Red Purple …

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Task 1: Read the word that is written

Red Green Black Green

Green Red Purple Blue

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Task 2: Read the color of the text

Red Green Black Green

Green Red Purple Blue

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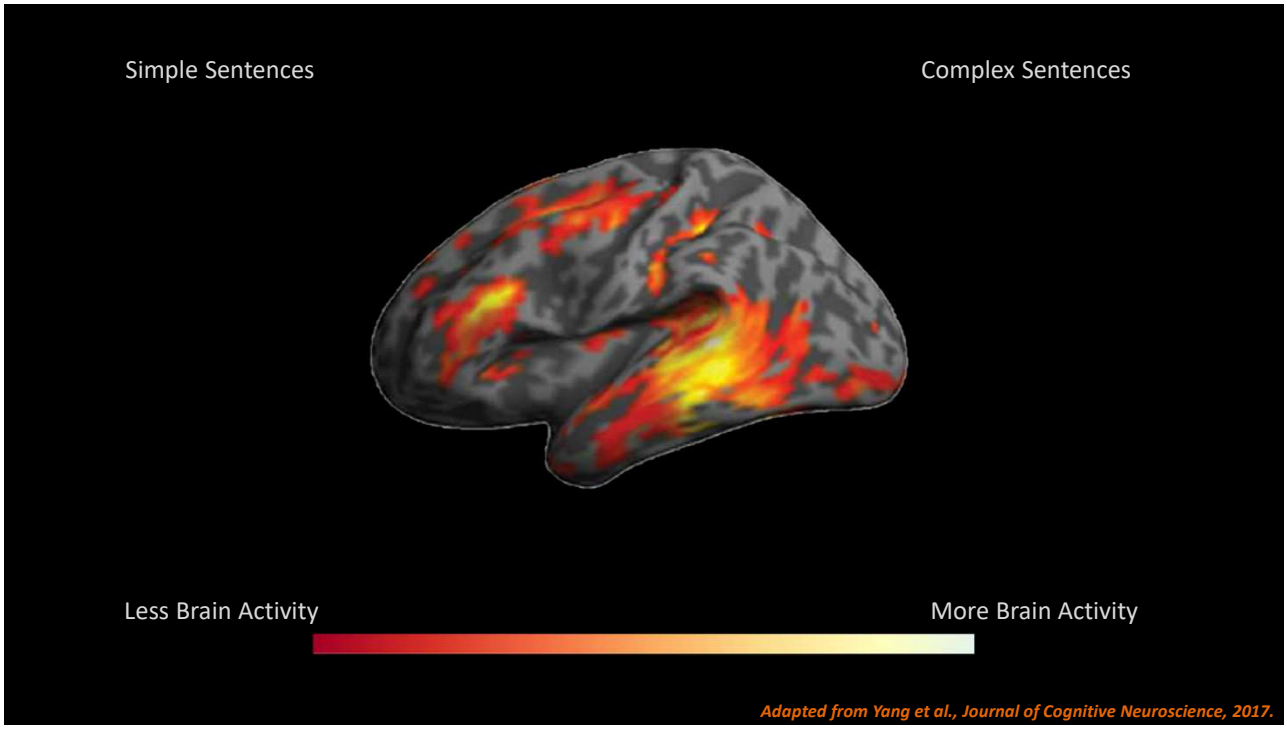
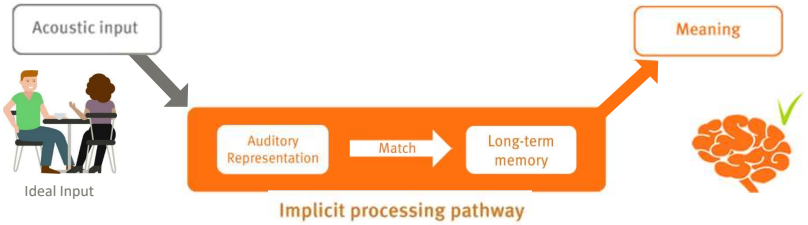


The Listening Effort Framework



The Ease of Language Understanding -ELU- model. Adapted from Rönnberg et al., 2013

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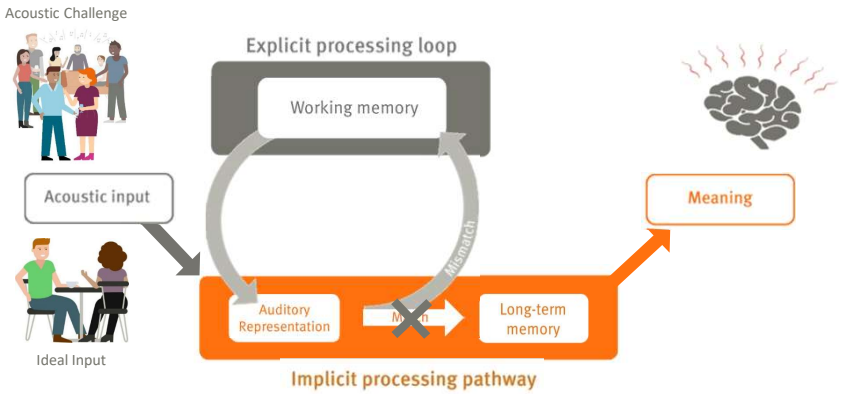
The Listening Effort Framework



The Ease of Language Understanding -ELU- model. Adapted from Rönnberg et al., 2013

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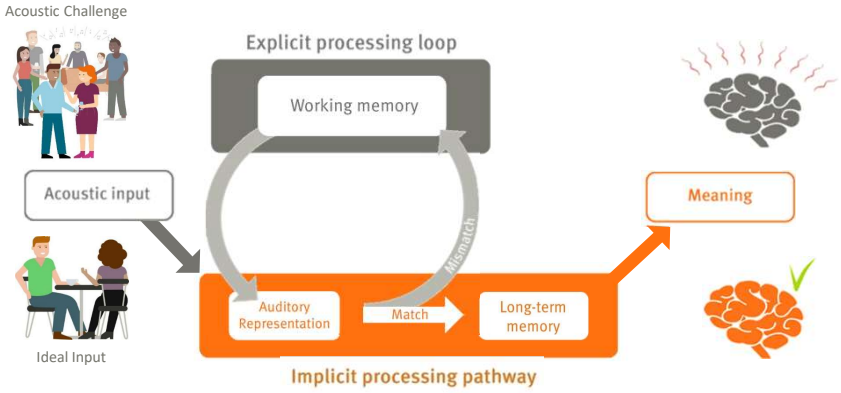
The Listening Effort Framework



The Ease of Language Understanding -ELU- model. Adapted from Rönnberg et al., 2013

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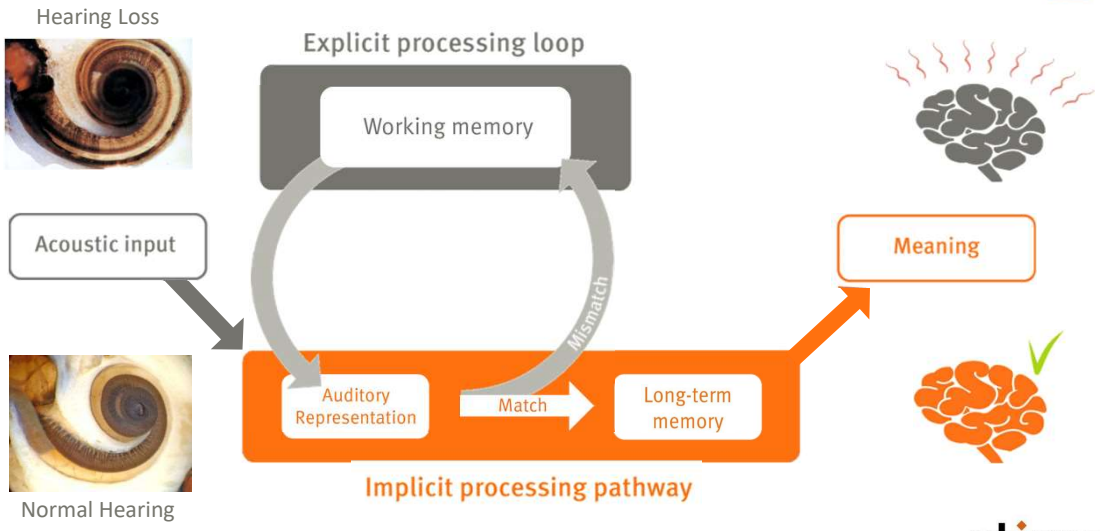
The Listening Effort Framework



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The Ease of Language Understanding -ELU- model. Adapted from Rönnberg et al., 2013

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Part I: Overview

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  - Why is listening more effortful for those with hearing loss?
  - Does a hearing loss give raise to long-term issues?
- Real-world daily life (ecological) listening situations
  - In which situations do hearing impaired typically communicate?
- Cognitive measures beyond speech performance testing
  - Effect of technology on cognition
  - Advanced hearing aid technology

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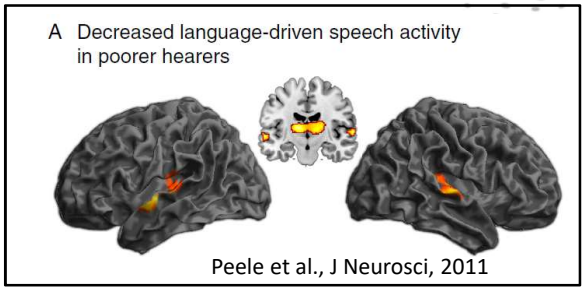
Hearing Loss & Cognitive Load

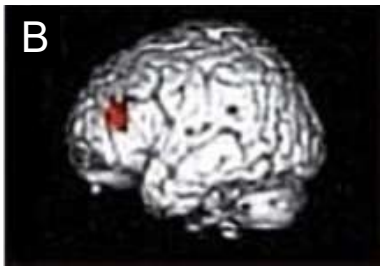
Poorer hearing is associated with:

A. Reduced language-driven activity in primary auditory pathways

B. Increased compensatory language-driven activity in pre-frontal cortical areas



Peele et al., J Neurosci, 2011



Grossman et al., Brain Lang, 2002

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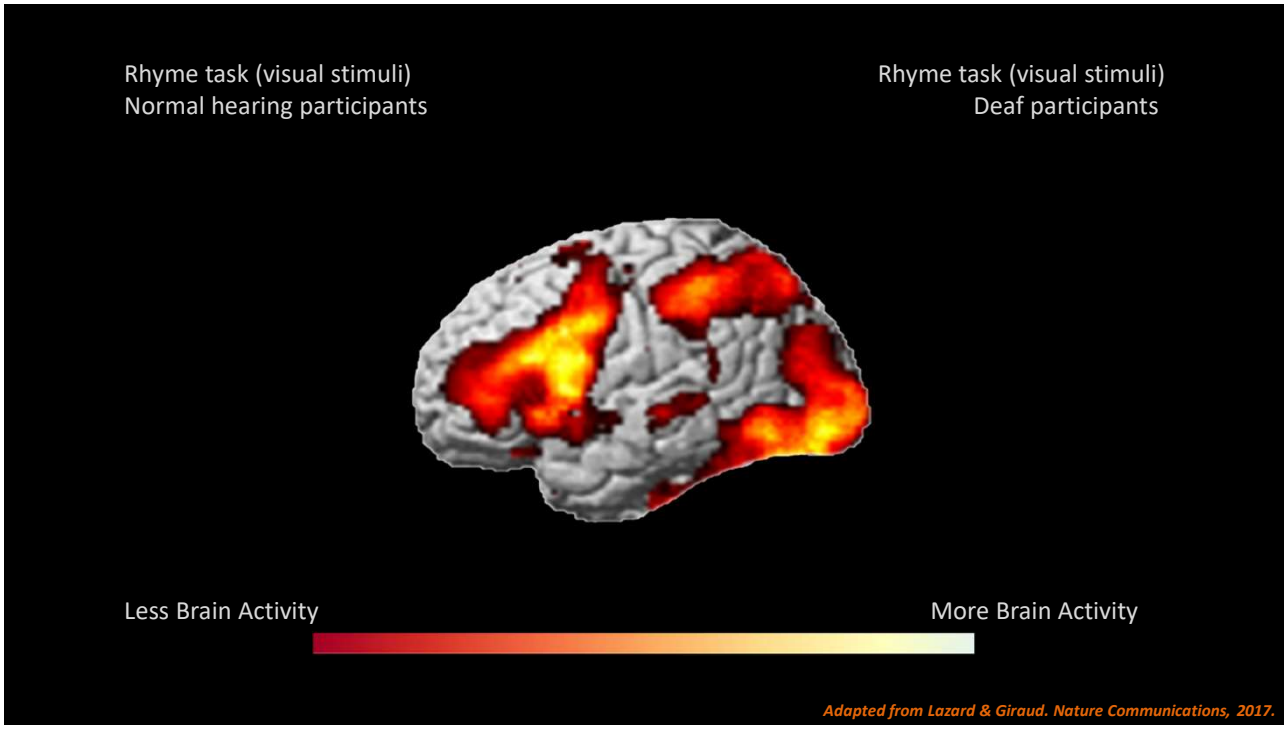

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Rönnberg et al.: *Hearing Loss and LTM*

Journal of Speech, Language, and Hearing Research • Vol. 54 • 705–726 • April 2011

Figure 1. Visualized structural equation modeling (SEM) for the hearing losses of the better ear (BE; see upper panel) and worse ear (WE; see lower panel) and their relation to episodic long-term memory (ELTM) performance when taking age into account. SPTs = subject-performed tasks; Rec = recall.

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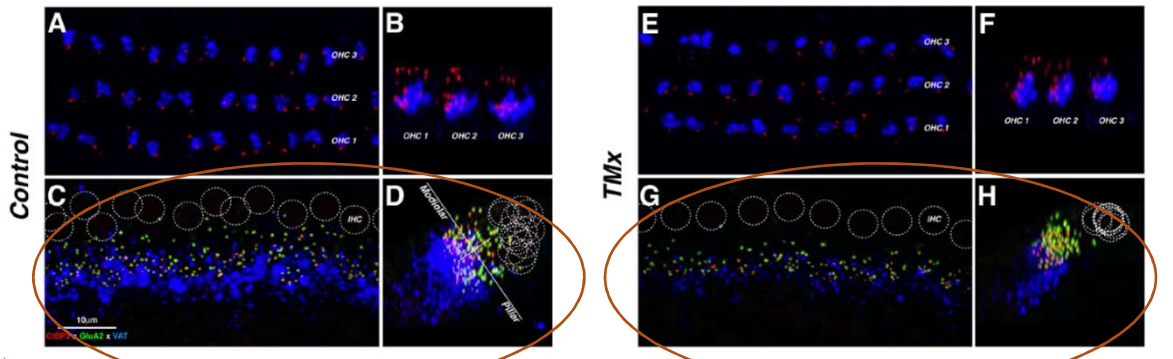
Conductive losses affect innervation already in the cochlea



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Liberman et al., PlosOne, 2015

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Summing up so far…

- Why is listening more effortful for those with hearing loss?
  - Less automatization compared to normal-hearing persons
  - More activation of working memory.
- Does the hearing loss give problems with memory and other long-term effects?
  - Yes, at least for untreated hearing loss
  - Work ongoing on the effect of different treatments

Part I: Overview

- Hearing and cognition
  - Why is listening more effortful for those with hearing loss?
  - Does a hearing loss give raise to long-term issues?
- Real-world daily life (ecological) listening situations
  - In which situations do hearing impaired typically communicate?
- Cognitive measures beyond speech performance testing
  - Effect of technology on cognition
  - Advanced hearing aid technology

Ecological communication situations

- In which situations are the hard of hearing people communicating in their daily life?
  - At which SNRs?
  - How much of the information is understood?

Work by Widex ORCA and Jade University of Applied Sciences, Oldenburg

Be
sou

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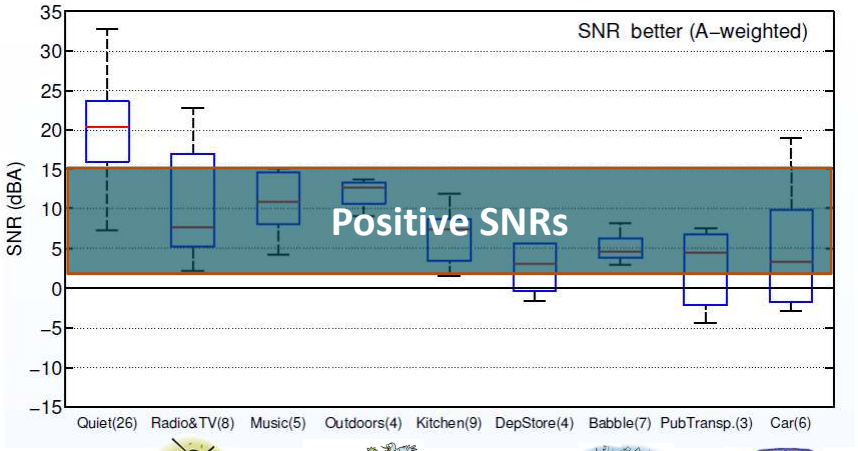
People who are hard of hearing ….communication situations in daily life



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Smeds et al. (2015)

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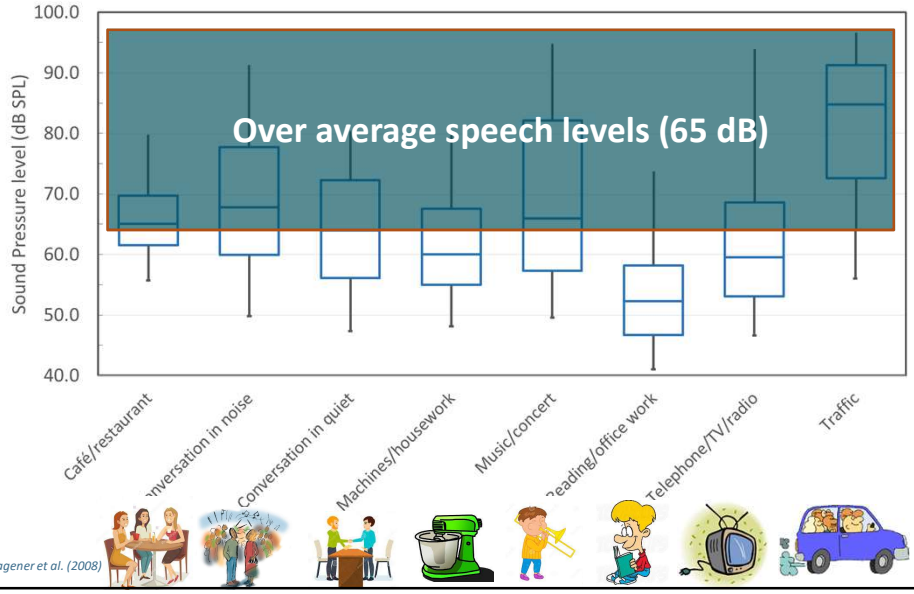
People who are hard of hearing ….sound level variation in daily life



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Wagener et al. (2008)

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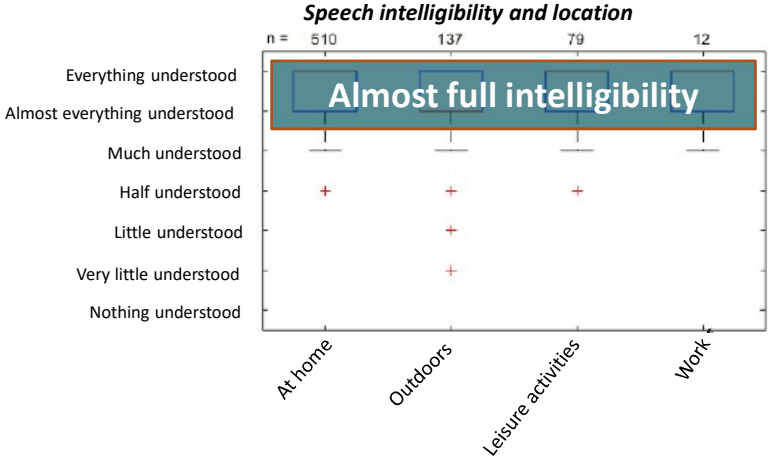
Subjective assessment of speech intelligibility under real life conditions

- Subjective intelligibility does not vary, mostly close to full intelligibility



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Haverkamp, Gabler, Kissner, Bitzer & Holube (2015), DGA

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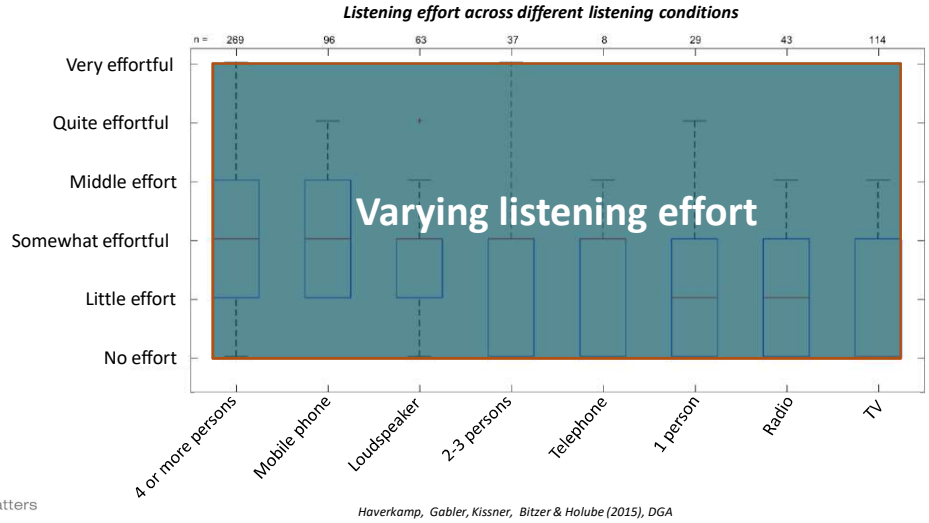
Subjective assessment of listening effort under real life conditions

- Subjective listening effort varies substantially



Haverkamp, Gabler, Kissner, Bitzer & Holube (2015), DGA

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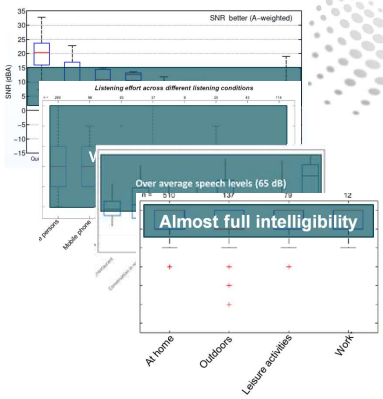
Summing up so far…



Ecological conditions (here):

- ***Positive SNRs*** (SNR + 5 dB or better)
- ***Subjective effort varies***
- ***Overall sound levels varies a lot***
- ***Successful perception*** (close to 100% correct performance).

- … effort may vary although having high speech intelligibility.

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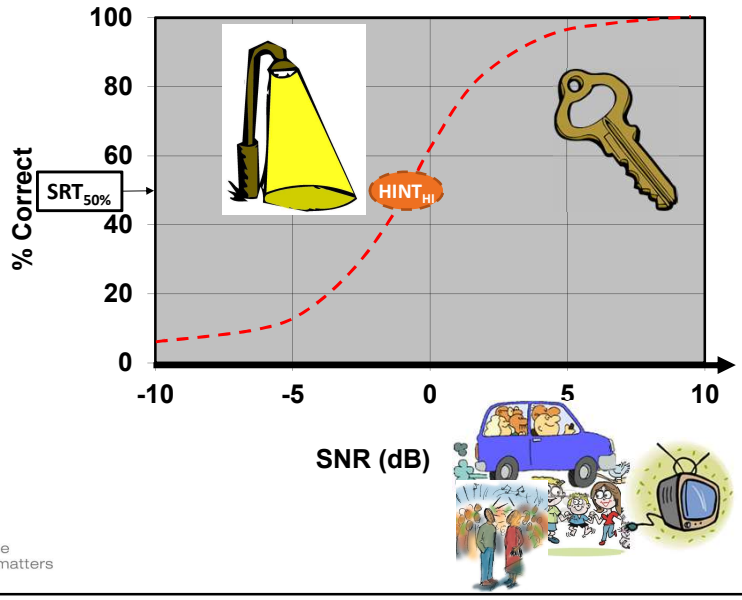
Speech in noise testing…



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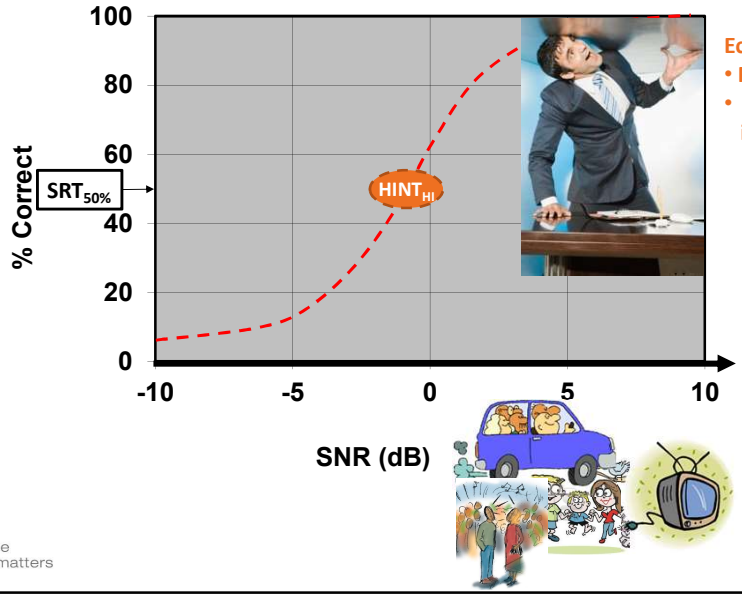
Speech in noise testing…



Ecological:
- Positive SNRs
- ~100% speech intelligibility

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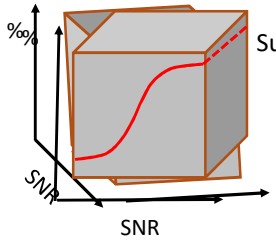
…a new axis with ~100% speech intelligibility



Successful word accuracy

? (Working) Memory

SNR

	Storage	Processing	
Person in quiet	■■■■■		Memory Score = 6
…same person in noise	■■■		Memory Score = 4
…and even more noise	■		Memory Score = 2
…effect of HA in even more noise	■ →		Memory Score = 4

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Inspired by Pichora-Fuller (2006)

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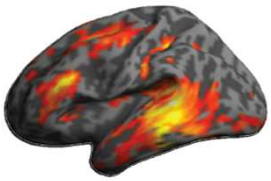
Some examples of cognitive measures

Brain Activity

- Neuroimaging: fMRI/PET
- EEG/ MEG
- Optical Imaging fNIRS



Behavioral Response

- Memory
- Response Time
- Dual tasks

Physiological Correlates

- Pupil dilation
- Skin conductance
- Stress hormones

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Adapted from: *Peelle, 2017, manuscript in preparation*

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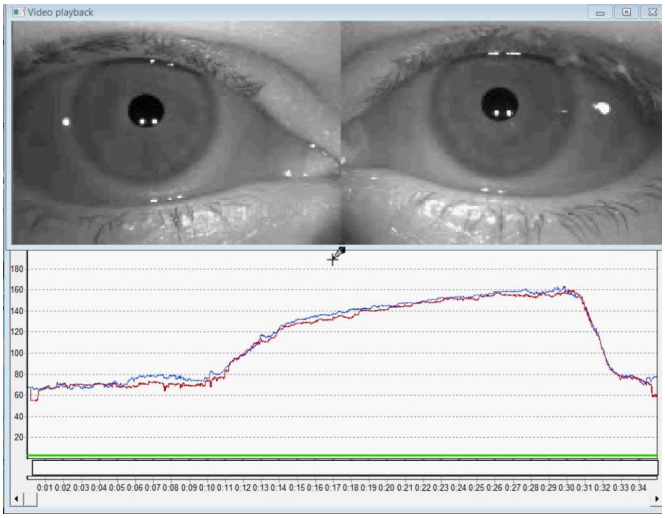
Example: Pupillometry
Algorithms for reduced listening effort



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Example: SWIR test
Sentence – final Word Identification and Recall

… at an SNR which allows 95-100% intelligibility
(typically +5 … +15 dB)

Ecological ✓

Task: **listen to speech in noise**

1. Her går alle med solbriller

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Method, SWIRL test

Task: **repeat** last word

1. Her går alle med **solbriller**

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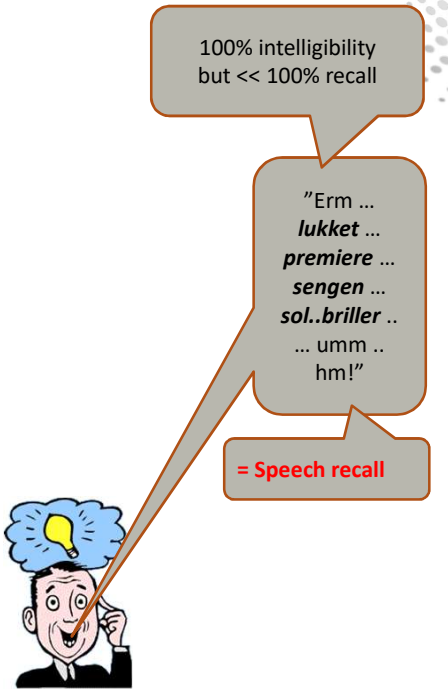
Method, SWIRL test

Task: **repeat** last word (of 7 sentences)

1. Her går alle med
2. Han ligger stadig i
3. Eleven skriver en lang
4. Hele byen kom til
5. Hans datter vil på
6. I går havde filmen
7. Fabrikkens port var ikke

?

Task: **recall** words



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Method, SWIRL test

Task: **repeat** last word (of 7 sentences)

1. Her går alle med **solbriller**
2. Han ligger stadig i **sengen**
3. Eleven skriver en lang **rapport**
4. Hele byen kom til **brylluppet**
5. Hans datter vil på **højskole**
6. I går havde filmen **premiere**
7. Fabrikkens port var ikke **lukket**

Task: **recall** words

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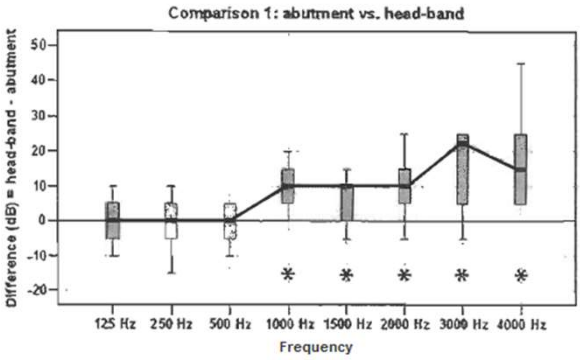
Experiment:

Sound quality of bone conduction devices

- Softband needs higher drive force above 1 kHz
  - => earlier into non-linear movement of transducer => sound quality/audibility issues
  - => effect on memory?

Abutment

Softband



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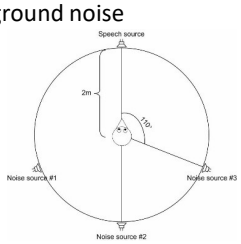
Experiment:

Sound quality of bone conduction devices

- 16 Ponto Plus Power patients (10 women)
- Conductive and mixed hearing losses

Procedure:

- **Prepare Experiment**
  - *Adjust SNR to ~95 %* correct HINT sentences for Softband in ISTS background noise
  - => *average SNR 10 dB* (SD = 4.8 dB)



- **SWIRL test**

  Contrast:

  Abutment versus softband, 10 repetitions, ramdomized order

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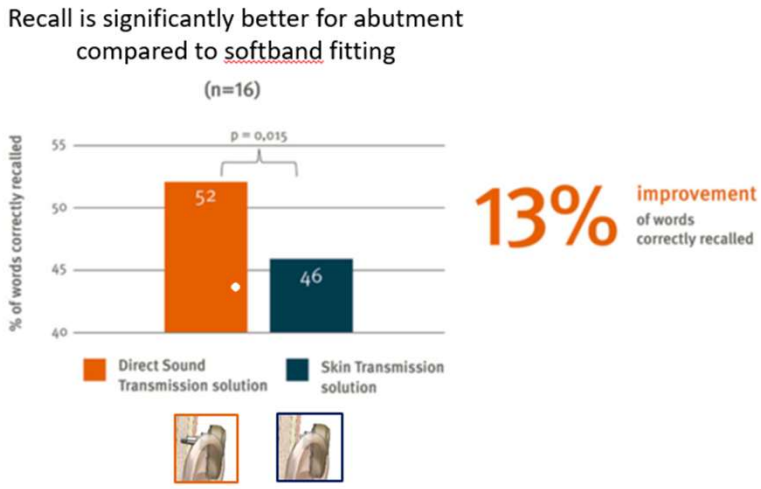
Experiment:

Sound quality of bone conduction devices



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Lunner et al. (2016) Using speech recall in hearing aid fitting and outcome evaluation under ecological test conditions. Ear & Haring, vol 37, supplement 1, 145S-154S

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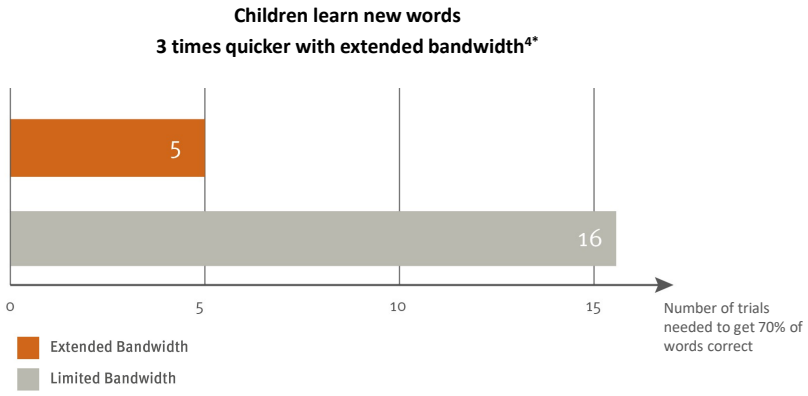
Direct drive & bandwidth:
Learning effects in children



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**The study included both normal hearing and hearing impaired children who were exposed to limited and extended bandwidth. No conclusion can be drawn from this study with regards to Ponto 3.*

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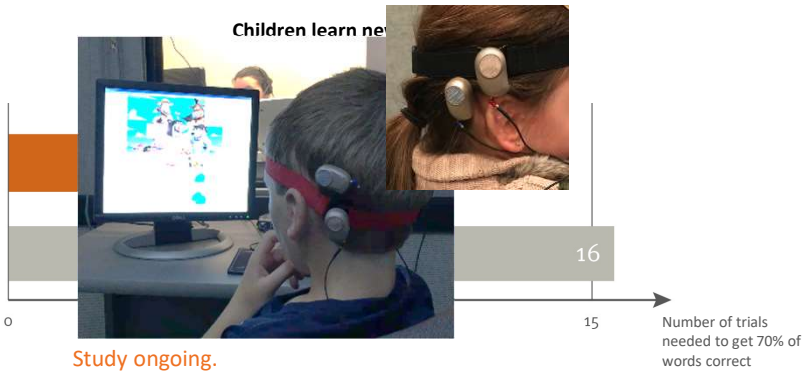
Direct drive & bandwidth: Learning effects in children



Study ongoing.
Preliminary data presented at Osseo
Pittman (2017), Osseo, Nijmegen, The Netherlands

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**The study included both normal hearing and hearing impaired children who were exposed to limited and extended bandwidth. No conclusion can be drawn from this study with regards to Ponto 3.*

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This guides what products we bring to the market

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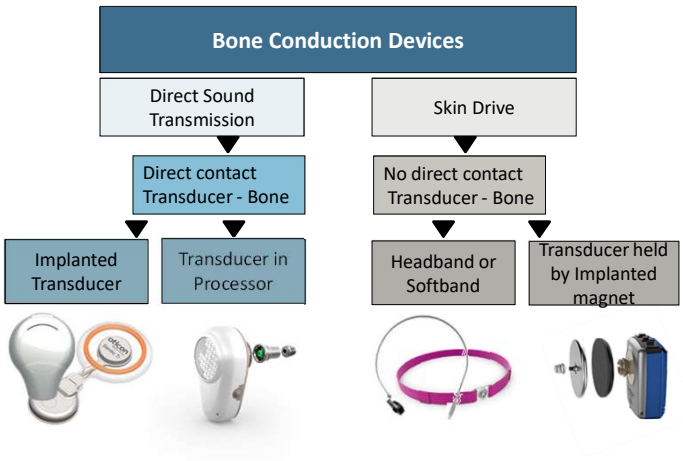
BrainHearing guides what products we bring to the market



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Reinfeldt et al., 2015

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Part II: Outline

- Why all users benefit from higher maximum output
  - Technical limitations
  - Maximum output, gain, dynamic range, distortions – how does it all relate?
  - What will patients likely report back?
- Should this influence how we counsel patients?

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Part II: Outline

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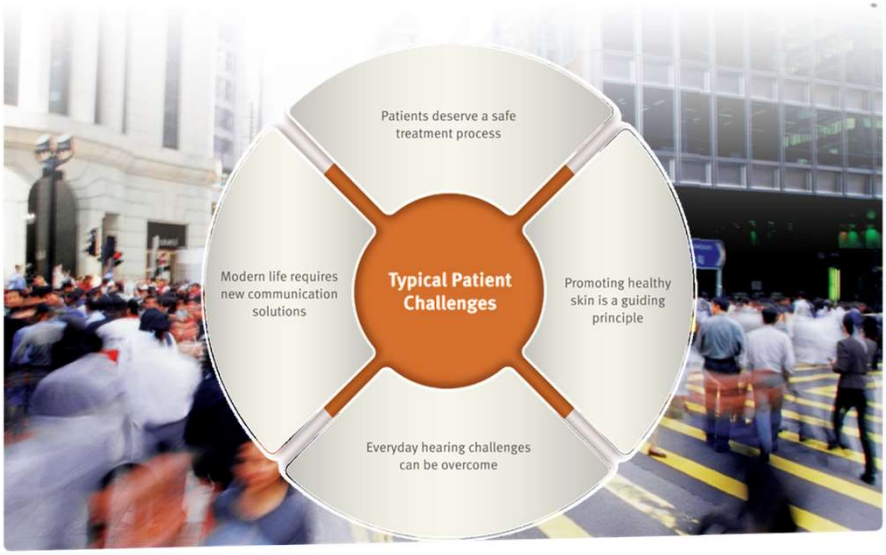
The users are our starting point



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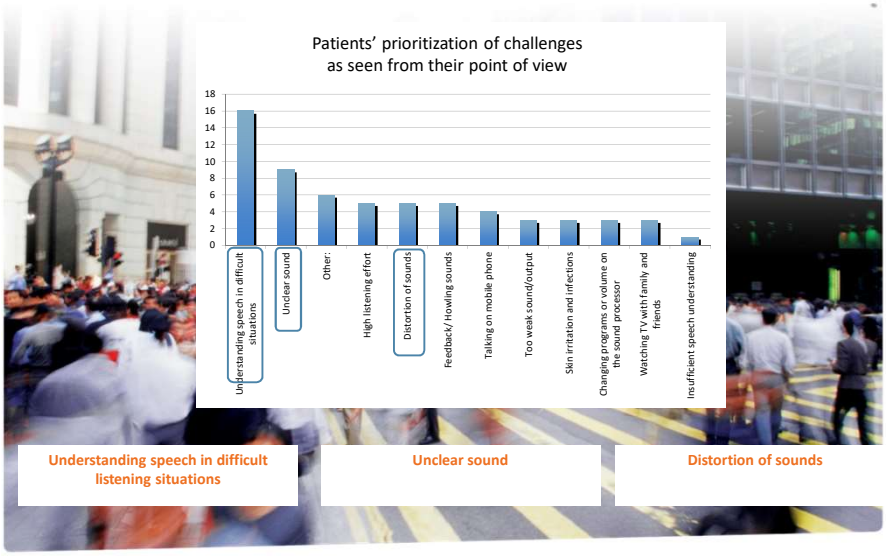
Users' challenges



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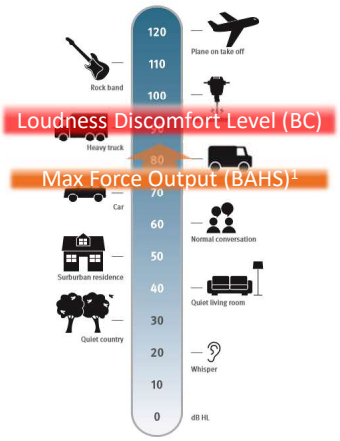
Challenge in BAHS
Maximum output is low



Device	Measured MPO	Reference	Manufacturer
Sophono Alpha 1	56 dB HL	Hol et al., 2013	Sophono, Boulder, US
Bonebridge	65 dB HL	Mertens et al, 2014	Med-El, Innsbruck, Austria
Standard Baha Divino/BP100	67-69 dB HL	Carlsson & Hakansson, 1997 Zwartenkot et al. 2014	Cochlear BAS, Goteborg, Sweden
Standard Ponto	67-69 dB HL	Zwartenkot et al. 2014	Oticon Medical, Askim, Sweden
Baha Cordelle, Baha 5 SuperPower*; Ponto 3 SuperPower*.	80-85 dB HL	Idem	Cochlear BAS, Goteborg, SwedenOticon Medical, Askim, Sweden

Objective measurement of the MPO of several hearing devices[1]
*(*updated spring 2017)*

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1) http://www.snikimplants.nl

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Part II: Outline

- Why all users benefit from higher maximum output
  - Technical limitations
  - Maximum output, gain, dynamic range, distortions – how does it all relate?
  - What will patients likely report back?
- Should this influence how we counsel patients?

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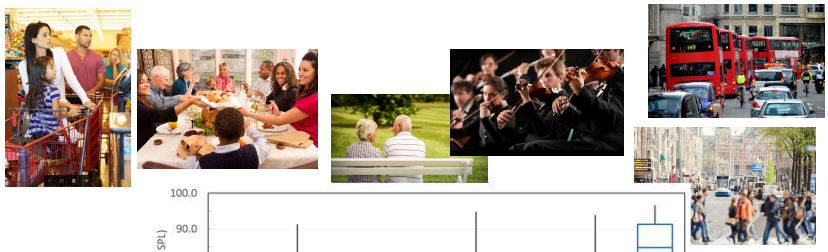
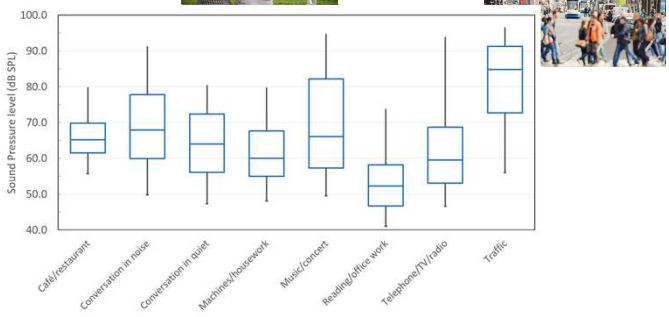
Sound environments are dynamic





Wagener et al. (2008)

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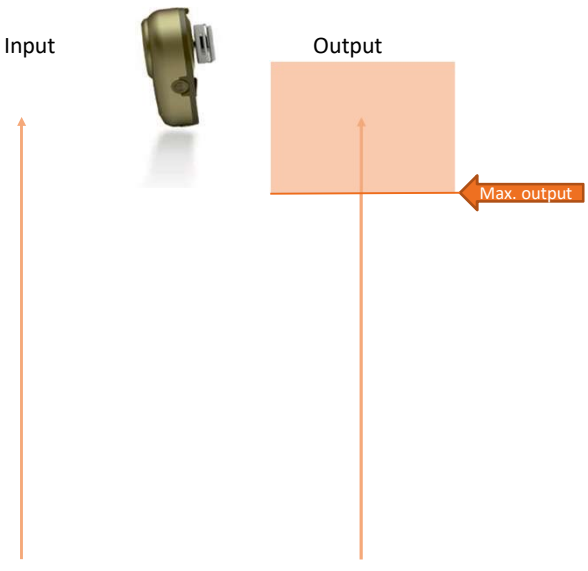
Bone anchored users benefit from higher max. output



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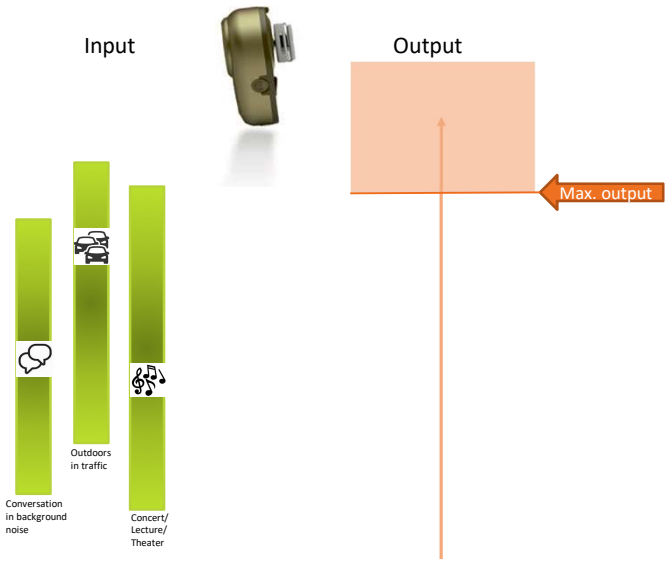
Bone anchored users benefit from higher max. output



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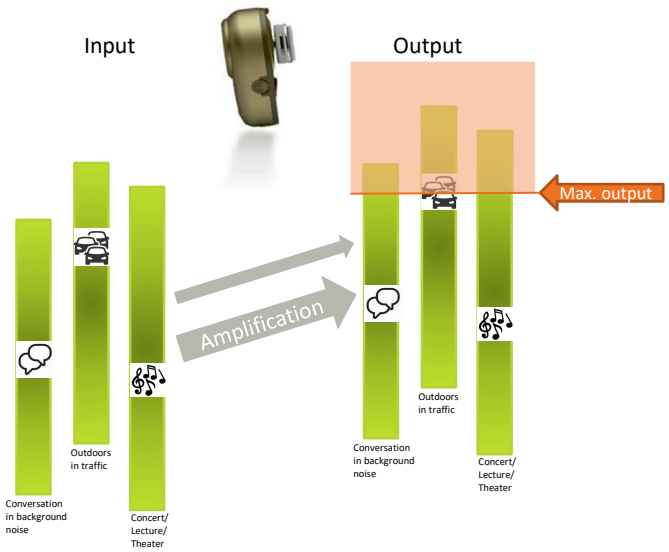
Bone anchored users benefit from higher max. output



Because sound matters

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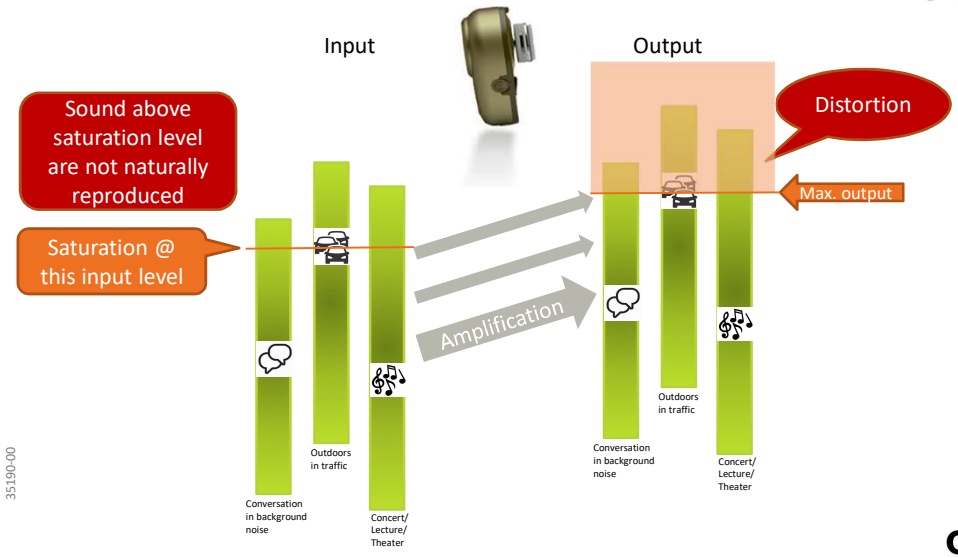
Bone anchored users benefit from higher max. output



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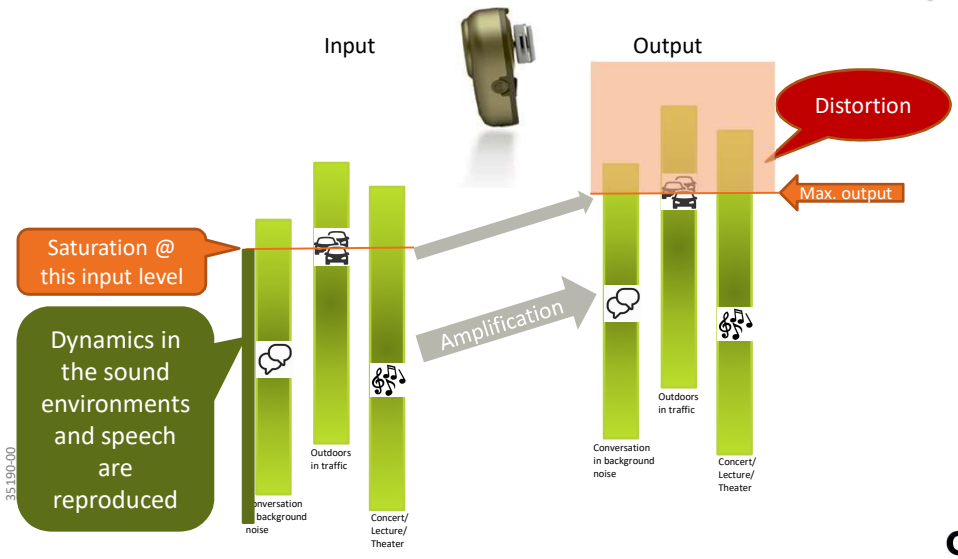
Bone anchored users benefit from higher max. output



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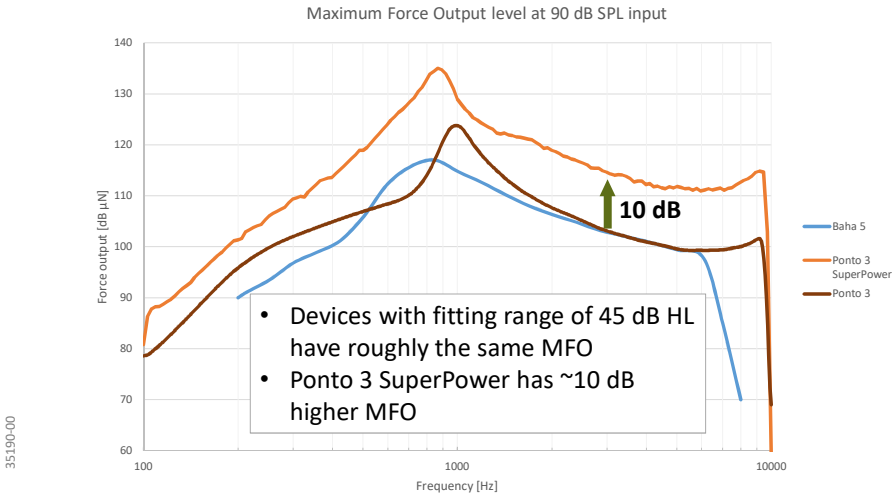
Max. output in devices with 45 dB HL fitting range and Ponto 3 SuperPower



- Devices with fitting range of 45 dB HL have roughly the same MFO
- Ponto 3 SuperPower has ~10 dB higher MFO

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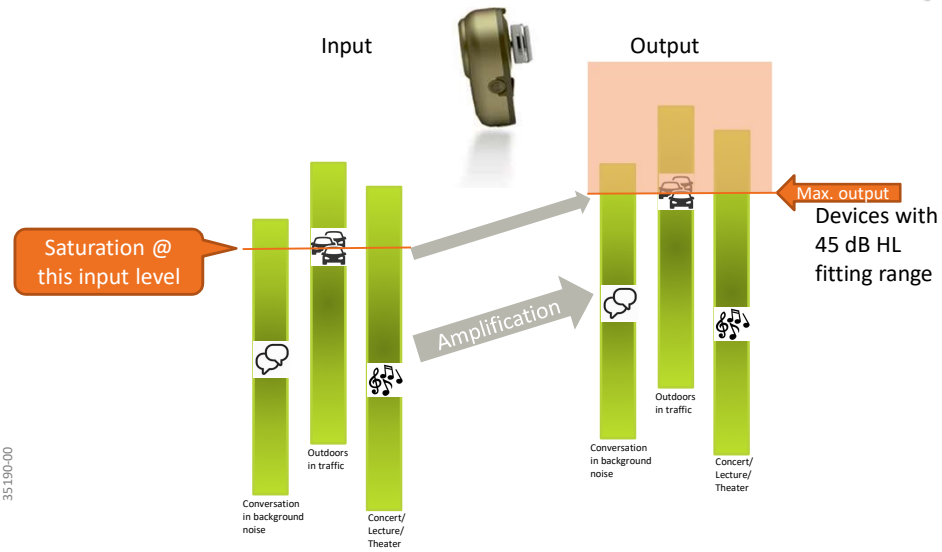
Bone anchored users benefit from higher max. output



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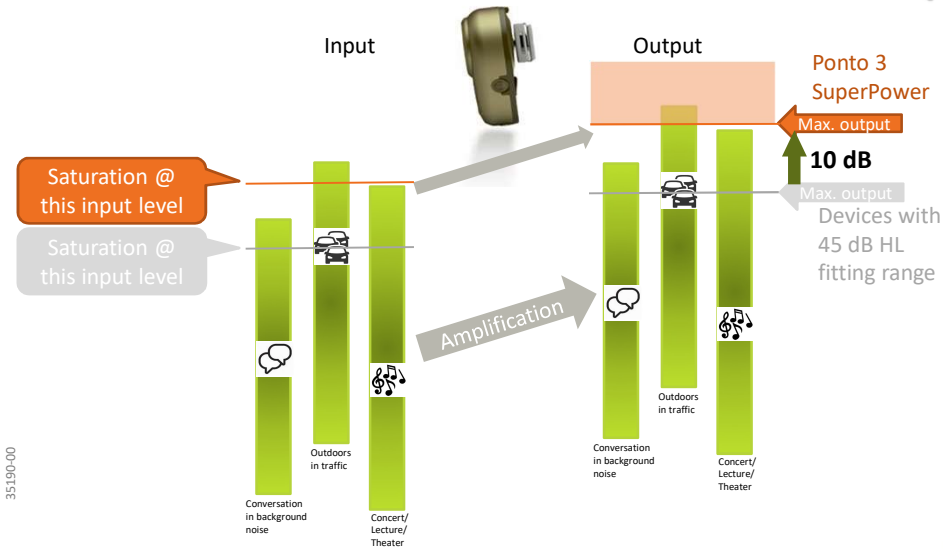
Bone anchored users benefit from higher max. output



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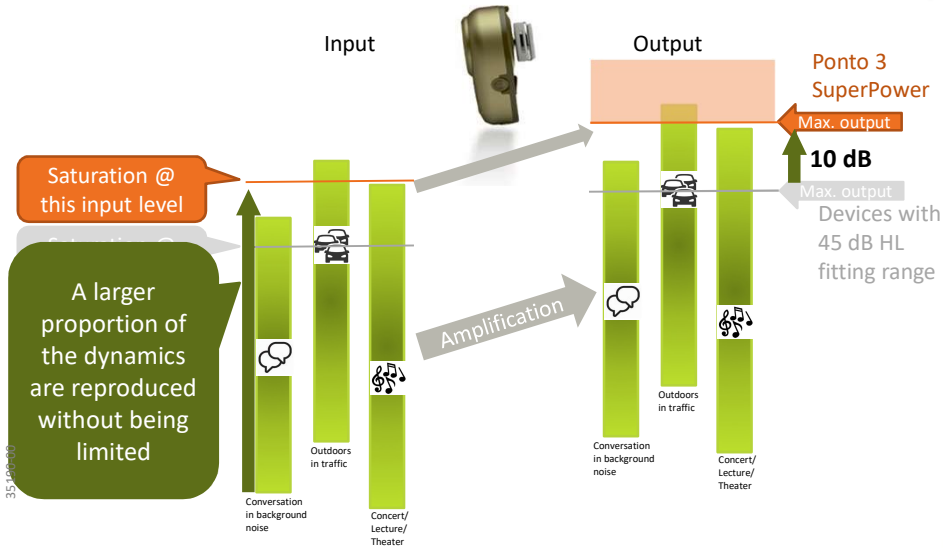
Bone anchored users benefit from higher max. output



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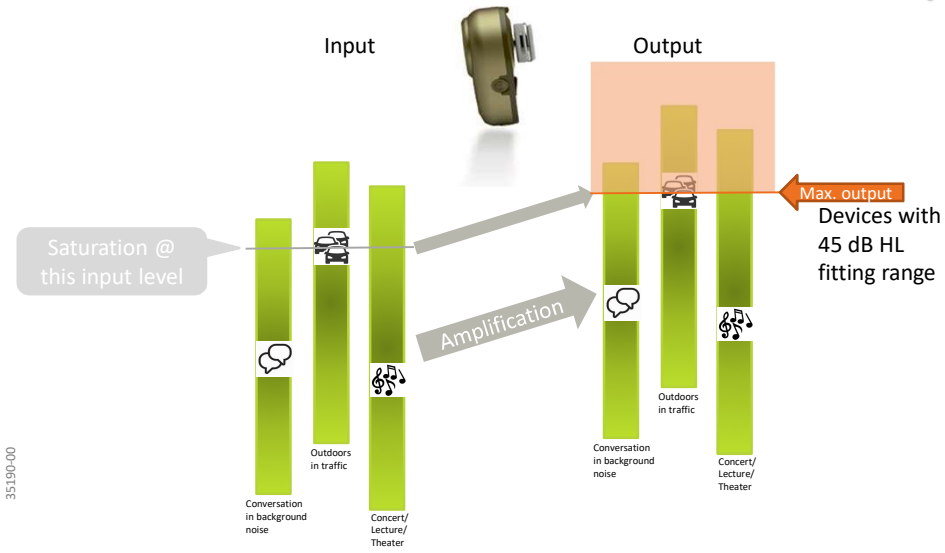
The higher gain, the lower saturation level



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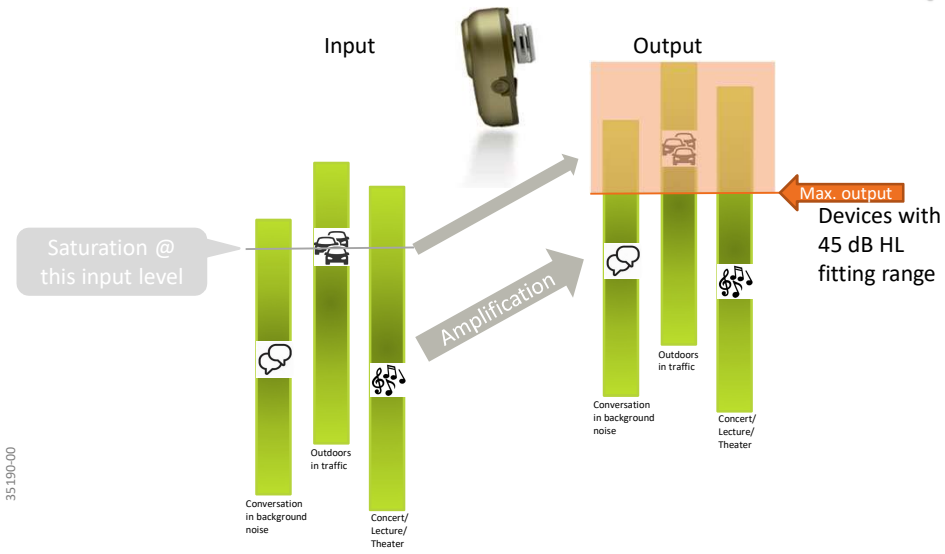
The higher gain, the lower saturation level



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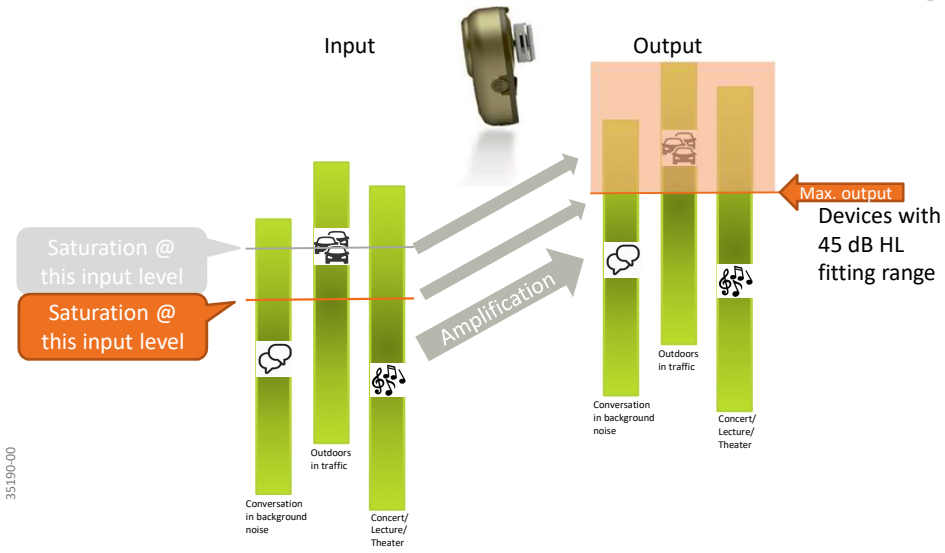
The higher gain, the lower saturation level



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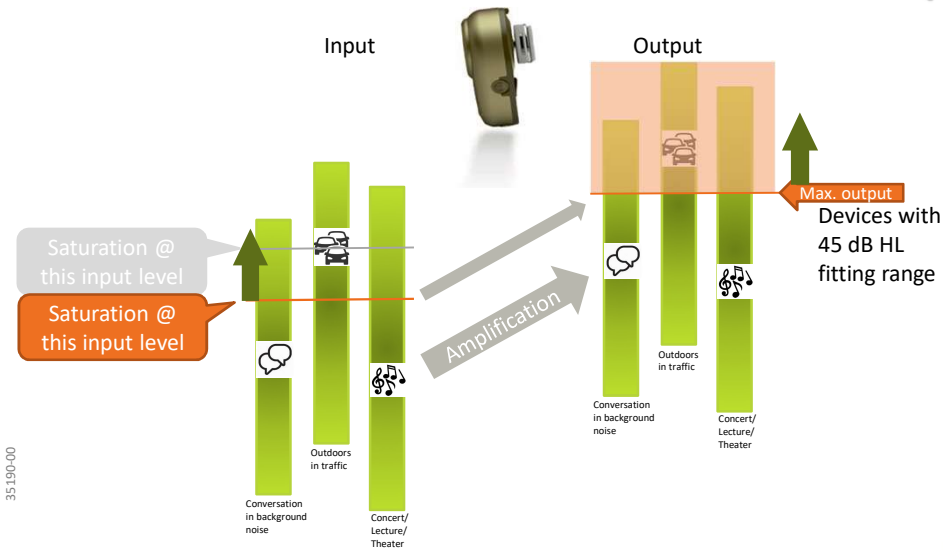
The higher gain needed, the lower saturation level



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Part II: Outline

- Why all users benefit from higher maximum output
  - Technical limitations
  - Maximum output, gain, dynamic range, distortions – how does it all relate?
  - What will patients likely report back?
- Should this influence how we counsel patients?

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Everyone deserves the best Sound Quality

Bone anchored users benefit from higher maximum output

Patients with
- Conductive hearing losses
- Mixed hearing losses
- SSD
- Softband fitting

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Ponto 3 SuperPower
Optimal audiological solution for all patients

Ponto 3 SuperPower

- Higher MFO -> Increased dynamic range / headroom in the device
- **Patients with conductive or mixed hearing losses**
  - The patient's auditive dynamic range are better utilized
  - More sounds are reproduced naturally without being limited
- **Patients using softband and head band**
  - Higher gain is provided to adress skin attenuation -> smaller dynamic range. SP enlarges the dynamic range.
- **SSD patients**
  - Better ability to loudness match sounds from the device to the normal hearing ear

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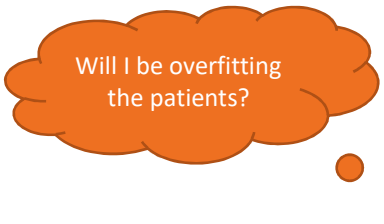

Associations to 'SuperPower' terminology

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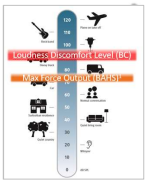
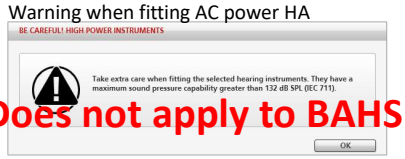
Using a SuperPower device, will it sound too loud/powerful?

1) BAHS's **MFO** is below patients' LDL

➢So no risk of "over-fitting" by using a BAHS SuperPower device



Warning when fitting AC power HA



Does not apply to BAHS

2) **Gain** is prescribed to HL and can be prescribed low enough

○ Patient can maximum turn up the volume control by 10 dB

➢So no risk of "over-amplification"

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Using a SuperPower device, what about annoyance to sounds

○ Patients report same degree of aversiveness to sounds when fitted with Ponto 3 SuperPower compared to Ponto Pro Power (AV parameter in APHAB-questionnaire).[1]

○ Loudness discomfort levels were estimated (extrapolated) to be 82.8, 92.1 and 89.3 dB HL at 1, 2, and 4 kHz, respectively, for bone conduction thresholds ≤ 40 dB(HL).[1]

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1) Bosman et al (2017) On Maximum Force Output in Bone-Anchored Devices. Poster at Osseo2017 conference.

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Will I be overfitting the patients?

Associations to 'SuperPower' terminology

Patients' reactions: do patients tell that it sounds louder when fitted with SuperPower?

Patients' reactions
are related
to their previous experience

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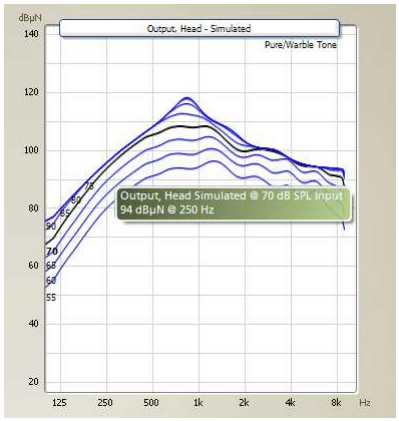
Patients' who are used to devices with lower MFO

Example: MFO as in Ponto 3



- Device is in saturation
- Distortion
- Sounds loud

Ponto 3

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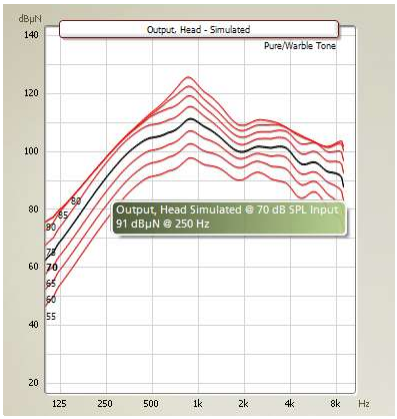
Patients' who are used to devices with lower MFO

Example: now fitted with P3SP



- Less often in saturation
- Less distortion
- Sounds quieter, more calm

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Immediate reactions to the sound in Ponto 3 SP

Nijmegen study – Ponto 3 SP

- subjects
  - BAHS experiences: 5-year replacements
  - Ponto Pro Power (N=19), Baha Intenso (N=1)
  - unilateral (N=14), bilateral (N=6)
- inclusion criteria
  - compos mentis
  - age < 80 years (22-80 yrs; avg: 63.0 yrs)
  - substantial air-bone gap
  - BC-thresholds > 30 dB HL
- follow-up (N=17)
  - tests too complex/tiring (N=1), brain infarct (N=1)
  - appointment p

Some comments …

Geluid is rustiger — calm, even sound

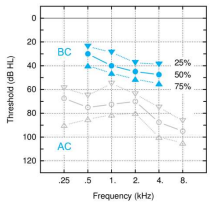
1. mijn gehoor is beter — my hearing is better
2. Ik schrik minder by plotseling harde geluiden — less startled by sudden loud sounds
3. Ik krijg complimenten van mensen — gets compliments on his hearing

1. Geluid is natuurlijker — more natural sound
2. Versta beter in rumoerige omgeving — understands better in noise
3. hoor beter wat en achter mij gebeurt — hears rear sounds better

a. Geen galmend geluid in auto.....bij vorige wel.
b. Geeft over het algemeen een rustigere hoorervaring.
c. Alles klink natuurlijker...dit in vergelijking met het blikkerige geluid van vorige toestel — no reverberance in car / more calm, even sound / more natural sound
d. Opvallend de andere draairichting van het volume-wieltje.
e. Bij volume verhogen geen galm.....
f. Batterijen hebben opvallend korte levensduur.....????

?

Pure-tone audiometry (N=20)



Bosman et al. (2017) Ponto 3 SuperPower test results. Radboud University, Nijmegen. Presented at Osseo2017

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Part II: Outline

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Choosing a sound processor

Patients don't ask for a SuperPower device

It is our joint task to make sure
the patients make an informed choice

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Choosing a sound processor
Test BAHS in dynamic listening environments

Tangible
- Cosmetic
- Handling
- Wireless
- …

Not tangible
- Sound quality
- Speech understanding
- Reliability
- …

Let the patient experience the sound quality

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Test BAHS in dynamic listening environments
A guide to help collecting experiences

- A test guide & note for the patient

  - to fill in during test at the hospital or at home.

  - it guides him/her to go to dynamic listening situations (e.g hospital café, outdoor)

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Summary

- Fitting a product with higher max output ->
  - less distortion of sounds
  - the dynamic range of listening environments being naturally reproduced is enlarged
- Ponto 3 SuperPower has the highest MFO in any abutment level device, though its' MFO is below patient's Loudness-Discomfort-Level, therefore

All bone anchored users benefit from higher maximum output!

- Higher max output leads to better sound quality which has a positive effect on e.g. listening to speech in noisy environments and music.
- Let patients test Ponto 3 SuperPower in dynamic environments.
- Our aim is to take the effort out of listening supporting BrainHearing.

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Brain Hearing™ for Oticon Medical

Technology for Hearing Implants to reduce Listening Effort

Improved speech recognition
In all listening situations.
Technology that makes sense.

Reduced Listening Effort
More understanding with less effort.
Technology for intense living.

Increased recall abilities
Empowered cognition for enriched
Social Interactions and faster learning.

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