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.
BrainHearing
The reason we develop the products we do

Outline

○ Part I
  - Hearing and cognition
  - Real world listening situations
  - How we can rethink 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

This course is presented in partnership with
Part I: Overview

- Hearing and cognition
  - Why is listening more effortful for those with hearing loss?
  - Does a hearing loss give rise 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  ...

This course is presented in partnership with
Task 1: Read the word that is written

Red  Green  Black  Green
Green  Red  Purple  Blue

Task 2: Read the color of the text

Red  Green  Black  Green
Green  Red  Purple  Blue

This course is presented in partnership with
This course is presented in partnership with

The Listening Effort Framework

Adapted from Yang et al., Journal of Cognitive Neuroscience, 2017.

The Listening Effort Framework

Adapted from Rönnberg et al., 2013.

The Ease of Language Understanding (ELU) model. Adapted from Rönnberg et al., 2013.
This course is presented in partnership with
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?
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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

Rhyme task (visual stimuli)
Normal hearing participants

Deaf participants

Less Brain Activity
More Brain Activity

Conductive losses affect innervation already in the cochlea

Liberman et al., PlosOne, 2015
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?
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  - 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

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

This course is presented in partnership with
People who are hard of hearing
....sound level variation in daily life

Subjective assessment of speech intelligibility under real life conditions
- Subjective intelligibility does not vary, mostly close to full intelligibility

This course is presented in partnership with
Subjective assessment of listening effort under real life conditions

- Subjective listening effort varies substantially

![Listening effort across different listening conditions](image)

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.

This course is presented in partnership with
Speech in noise testing...

Ecological:
- Positive SNRs
- ~100% speech intelligibility

This course is presented in partnership with
Part I: Overview

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

...a new axis with ~100% speech intelligibility

Inspired by Pichora-Fuller (2006)
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

---

**Example: Pupillometry**
Algorithms for reduced listening effort

---

This course is presented in partnership with
Example: SWIR test
Sentence – final Word Identification and Recall

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

Task: listen to speech in noise
1. Her går alle med solbriller

Method, SWIRL test

Task: repeat last word
1. Her går alle med solbriller

This course is presented in partnership with
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

"Erm ... lukket ... premiere ... sengen ... sol...briller ... umm ... hm!"

Task: recall words

This course is presented in partnership with
**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?

---

**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, randomized order
Experiment:
Sound quality of bone conduction devices

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

Direct drive & bandwidth:
Learning effects in children

*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.

This course is presented in partnership with
Direct drive & bandwidth: Learning effects in children

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

*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.

This guides what products we bring to the market

This course is presented in partnership with
BrainHearing guides what products we bring to the market

Bone Conduction Devices

- Direct Sound Transmission
- Direct contact Transducer - Bone
  - Implanted Transducer
  - Transducer in Processor
- Skin Drive
  - No direct contact Transducer - Bone
  - Headband or Softband
  - Transducer held by Implanted magnet

Reinfeldt et al., 2015

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Ponto 3 – The world’s most powerful family of abutment-level processors

Ponto 3 45 dB HL  Ponto 3 Power 55 dB HL  Ponto 3 SuperPower 65 dB HL

This course is presented in partnership with
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?
The users are our starting point

Patients deserve a safe treatment process
Modern life requires new communication solutions
Promoting healthy skin is a guiding principle
Everyday hearing challenges can be overcome

Understanding speech in difficult situations
Unclear sound
Distortion of sounds

Users’ challenges

Patients’ prioritization of challenges as seen from their point of view

Understanding speech in difficult listening situations
Unclear sound
Distortion of sounds

This course is presented in partnership with
Challenge in BAHS
Maximum output is low

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?

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

Device | Measured MPO | Reference | Manufacturer
--- | --- | --- | ---
Sophono Alpha 1 | 56-88 HL | Hul et al., 2015 | Sophono, Boulder, US
Soundbridge | 50-69 HL | Metter et al, 2014 | Med e. Innsbruck, Austria
Baha Cochlea, Baha 3 SuperPower®, Ponto 3 SuperPower® | 80-85 dB HL | Mehr | Cochlear BAH, Goteborg, Sweden/Oticon Medical, Åk ön, Sweden

1) http://www.snikimplants.nl

This course is presented in partnership with
Sound environments are dynamic

Bone anchored users benefit from higher max. output

This course is presented in partnership with
Bone anchored users benefit from higher max. output

Input

Output

Max. output

Amplification

This course is presented in partnership with
Bone anchored users benefit from higher max. output

Input

Output

Distortion

Max. output

Sound above saturation level are not naturally reproduced

Saturation @ this input level

Outdoors
in traffic

Conversation
in background
noise

Concert/
Lecture/
Theater

Input

Max. output

Distortion

Saturation @ this input level

Outdoors
in traffic

Conversation
in background
noise

Concert/
Lecture/
Theater

Dynamics in the sound environments and speech are reproduced

This course is presented in partnership with
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

Bone anchored users benefit from higher max. output

Saturation @ this input level

This course is presented in partnership with
Bone anchored users benefit from higher max. output

A larger proportion of the dynamics are reproduced without being limited.

This course is presented in partnership with
This course is presented in partnership with
The higher gain, the lower saturation level

saturation at this input level

saturation at this input level

max. output devices with 45 dB HL fitting range

the higher gain needed, the lower saturation level

saturation at this input level

saturation at this input level

max. output devices with 45 dB HL fitting range

This course is presented in partnership with
Part II: Outline

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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

This course is presented in partnership with
Ponto 3 SuperPower
Optimal audiological solution for all patients

- 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

Will I be overfitting the patients?

Associations to ‘SuperPower’ terminology

This course is presented in partnership with
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

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”

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


This course is presented in partnership with
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

Patients’ who are used to devices with lower MFO
Example: MFO as in Ponto 3

- Device is in saturation
- Distortion
- Sounds loud

This course is presented in partnership with
Patients’ who are used to devices with lower MFO

Example: now fitted with P3SP

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

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
  • comor mortis
  • age < 60 years (22-80 yrs; avg: 63.0 yrs)
  • substantial air-bone gap
  • BC-thresholds > 30 dB HL
• follow-up (N=17)
  • tests too complex/long (N=1), brain infarct (N=1)
  • appointment pending

Some comments ...

- calm, even sound
- less sound by sudden loud sounds
- more natural sound
- better in noisy hours
- sound better in noisy environments
- no reverberation in car
- more calm, even sound
- more natural sound

Pure-tone audiometry (N=20)

This course is presented in partnership with
Part II: Outline

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  • What will patients likely report back?

• Should this influence how we counsel patients?

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

This course is presented in partnership with
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

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)

This course is presented in partnership with
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

- 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.

All bone anchored users benefit from higher maximum output!

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.

This course is presented in partnership with