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Cognition, Music and Hearing Aids

Research and Technology

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The hidden cognitive load of hearing loss

Hearing Loss

Questions:

- Does the Cello player have a beard?
- Does the Violin player wear shoes or boots?
- What chair is the Violin player sitting on?

Rönnberg et al 2013, Wendt et al 2015

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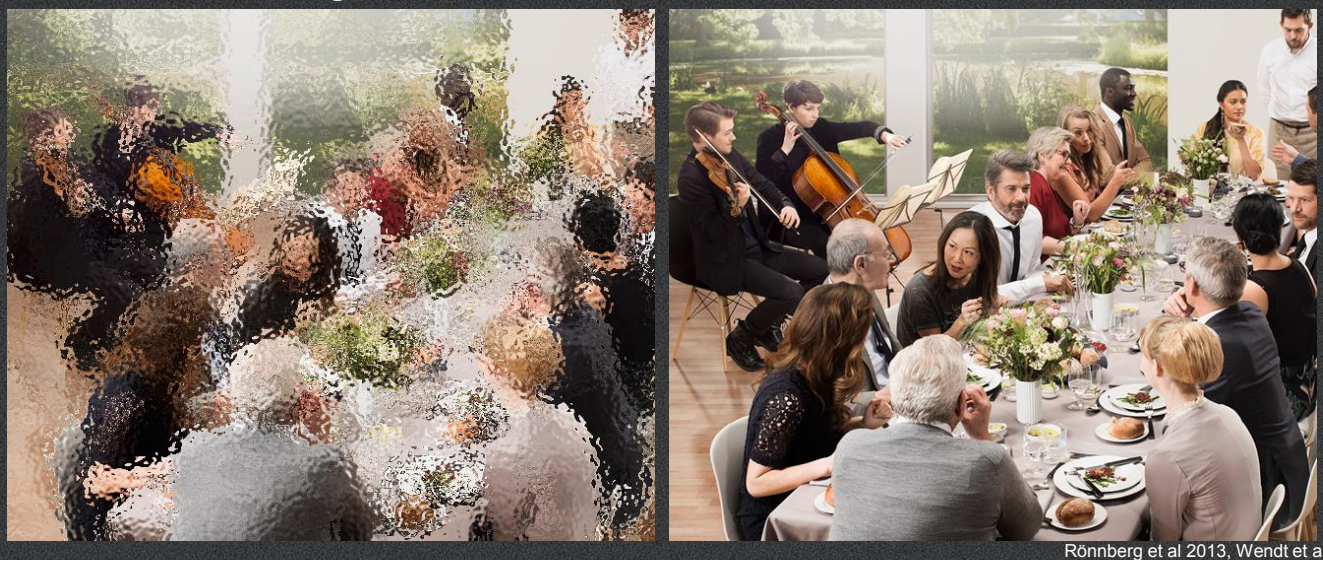
The hidden cognitive load of hearing loss

Hearing Loss | **Normal Hearing**



Rönnberg et al 2013, Wendt et al 2015

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The hidden cognitive load of hearing loss

Hearing Loss | **Normal Hearing**

Rönnberg et al 2013, Wendt et al 2015

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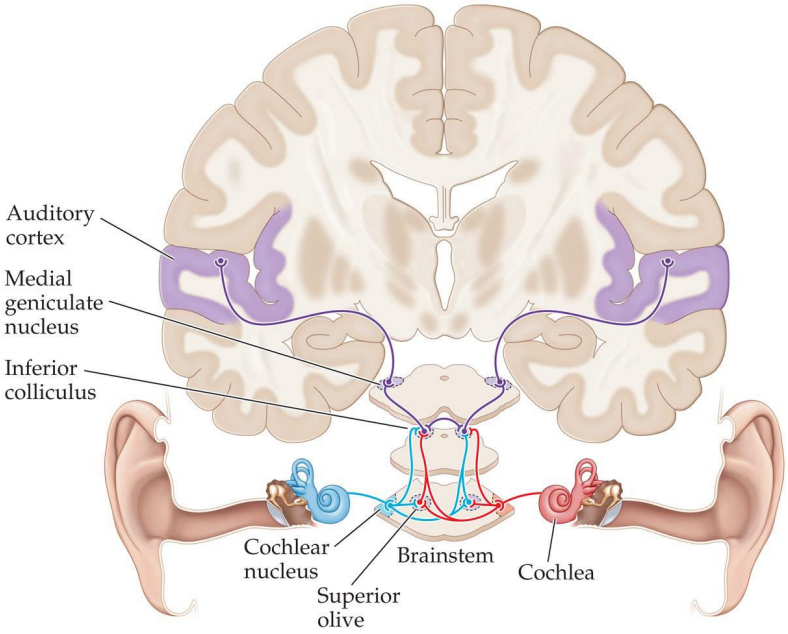
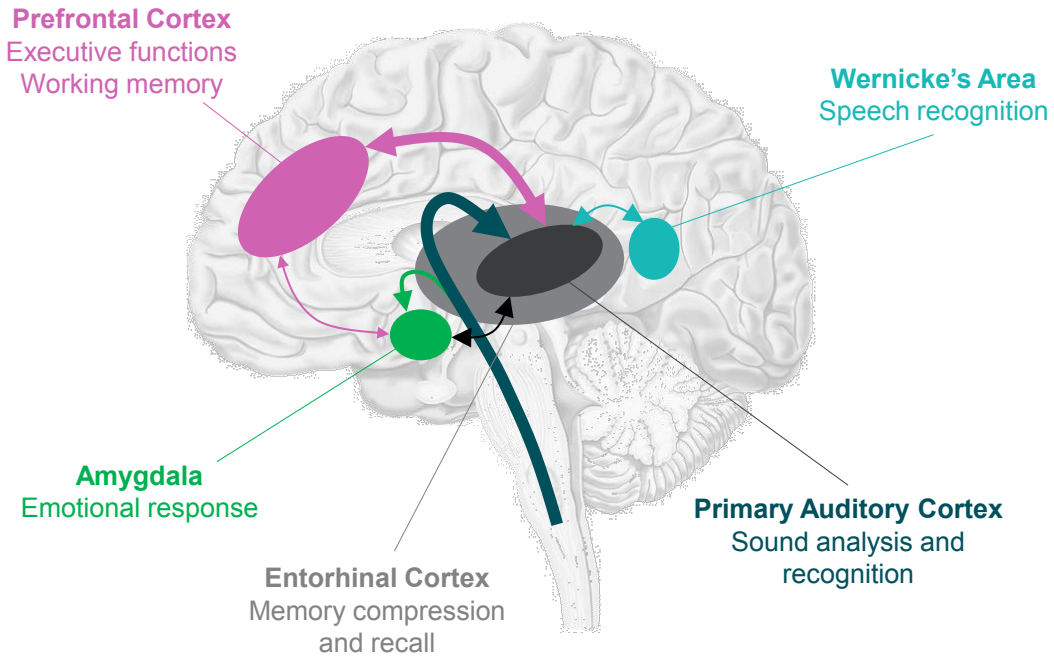
Turn sound into rich information in the Brain



Acknowledgement: Carina Graversen, Eriksholm

Make sense of information effectively



Acknowledgement: Carina Graversen, Eriksholm

Study: Listening effort for persons with HL

Participants:

- 30 normal-hearing, PTA < 20 dB HL from 500 Hz to 4 kHz
- 25 hearing-impaired, PTA between 35-65 dB HL from 500 Hz to 4 kHz
- Age matched groups (age range: 18-62 years, mean age: 47 years)

Stimulus:

- Everyday Dutch sentences: female speaker presented over headphones, hearing-impaired compensated with NAL-R.

Outcome measures:

- Peak Pupil Dilation [mm]
- Correct sentence recognition [%]

7 | Ohlenforst et al 2017

European Commission | VUmc VU University Medical Center Amsterdam | Eriksholm ResearchCentre PART OF OTICON

Pupillometry

Pupil react to changes in sympathetic nervous system (SNS)

- A reaction due to perceived stressful conditions

Pupillometry in audiology and hearing science

- More challenging task indicated by a larger pupil (*Kahneman,1973*)
- Pupil size can quantify effort required for speech recognition in noise *(e.g. Kramer et al., 1997, Koelewijn et al., 2012, 2014)*
- Pupillometry is a sensitive and valid cognitive load index (Zekveld et al 2012)

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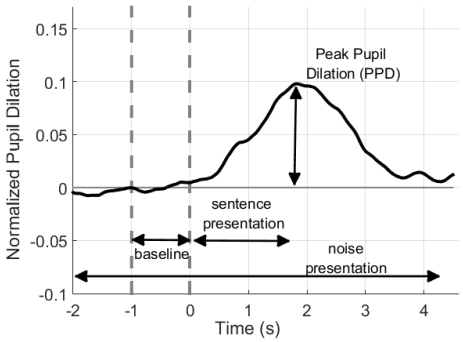
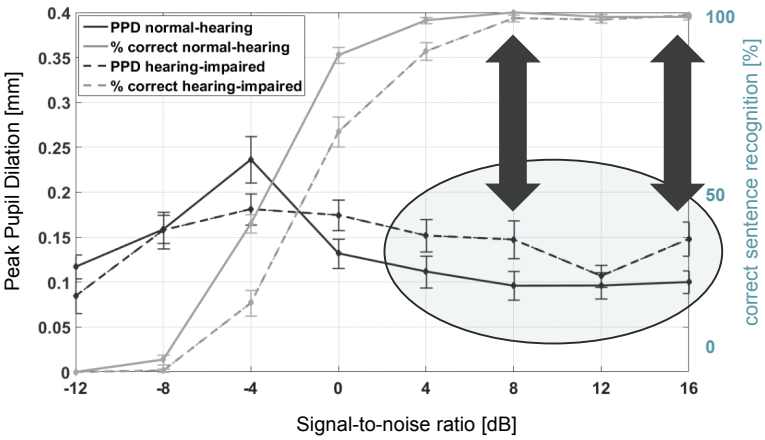
Pupil dilation and sentence recognition

stationary noise masker





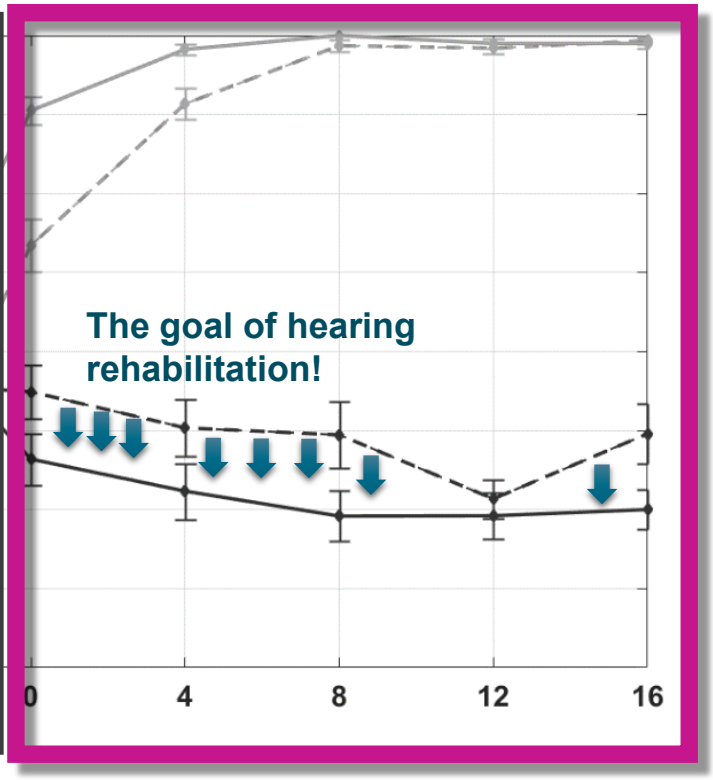
Mixed-model ANOVA: significant interaction effect between SNR and hearing-status

Focus on positive SNRs - real life situations & music has a signal that is louder than the noise.

Extra brain load of hearing loss, even when speech understanding is 98-100%

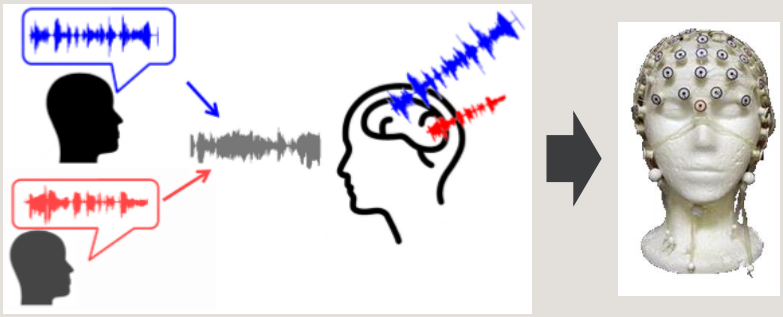
Ensuring good speech understanding is no longer enough to ensure high benefit in the real world!

Hearing aids must reduce this extra brain load!



“it sounds blurry”

- Study shows how speech is encoded in the brain of persons with normal hearing and persons with hearing loss, in complex environments.



Sound ← *compare* → EEG

Petersen et al., 2016, “Neural tracking of attended versus ignored speech is differentially affected by hearing loss”, *J. Neurophysiol*

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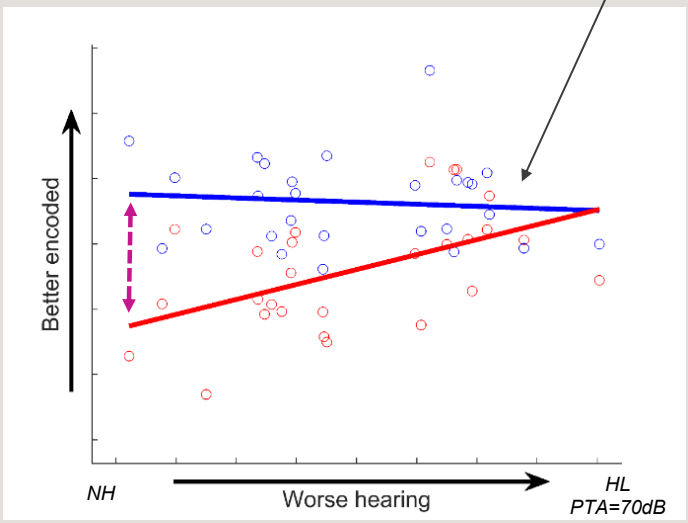
“it sounds blurry”

“muddy, blurry”

selective attention =“clear”



attended speech
unattended speech

In noise, patients have difficulties to organize complex sound scenes

Petersen et al., 2016, “Neural tracking of attended versus ignored speech is differentially affected by hearing loss”, *J. Neurophysiol*

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Discussion

- What is the consequence for music perception for people with hearing loss?
- If separating voices is difficult, what does it say about separating singers and instruments?

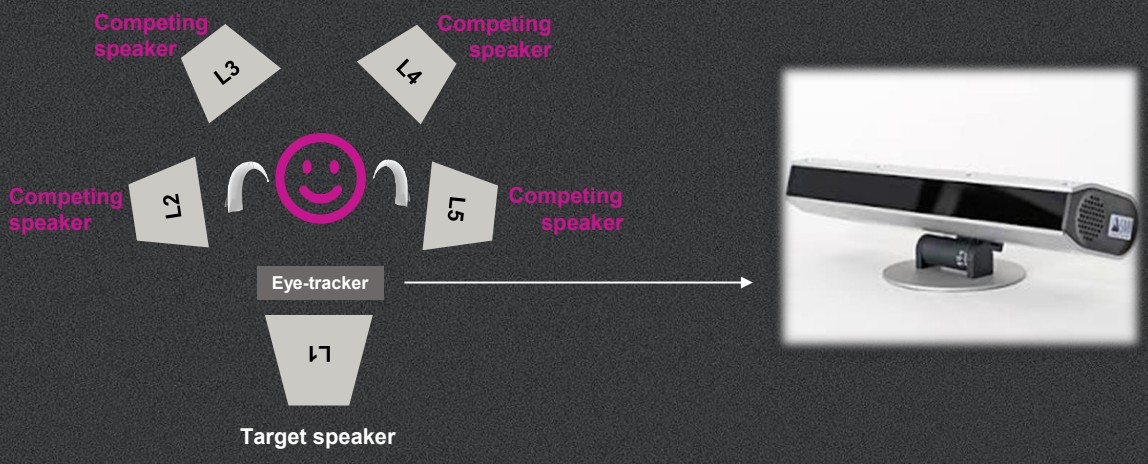
How do hearing aids classify music?

- Type of music?
- Live or recorded?
- Compressed during production?
- Listening conditions
  - Focused listening in quiet surroundings
  - Casual listening, for instance when driving a car or in public transport

Research into the benefits of reducing the cognitive load

Setup to mimic complex listening environment

24 people with hearing loss tested in the Cognitive Hearing Science lab at Eriksholm



Wendt et al., 2016

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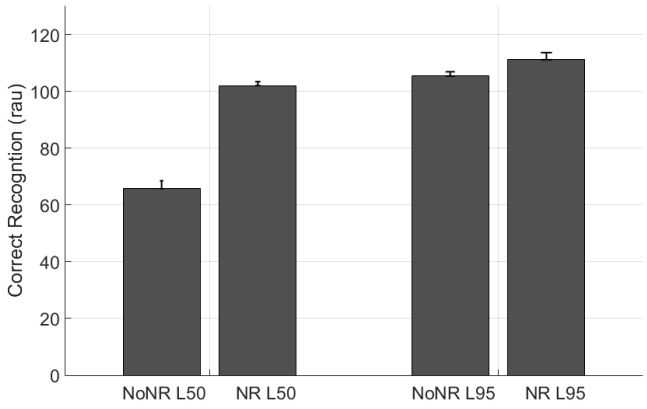
Pupillometry Study with Opn Hearing aids

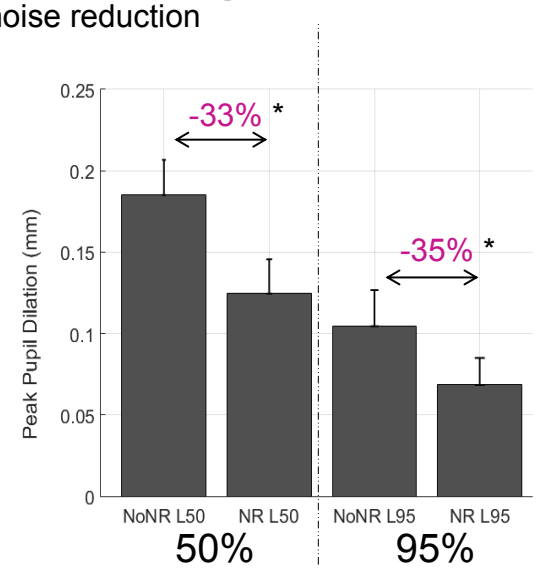
Hearing aids with and without advanced directional noise reduction



50% SNR = 1.3 dB

95% SNR=7.1dB

Intelligibility



50% SNR = 1.3 dB

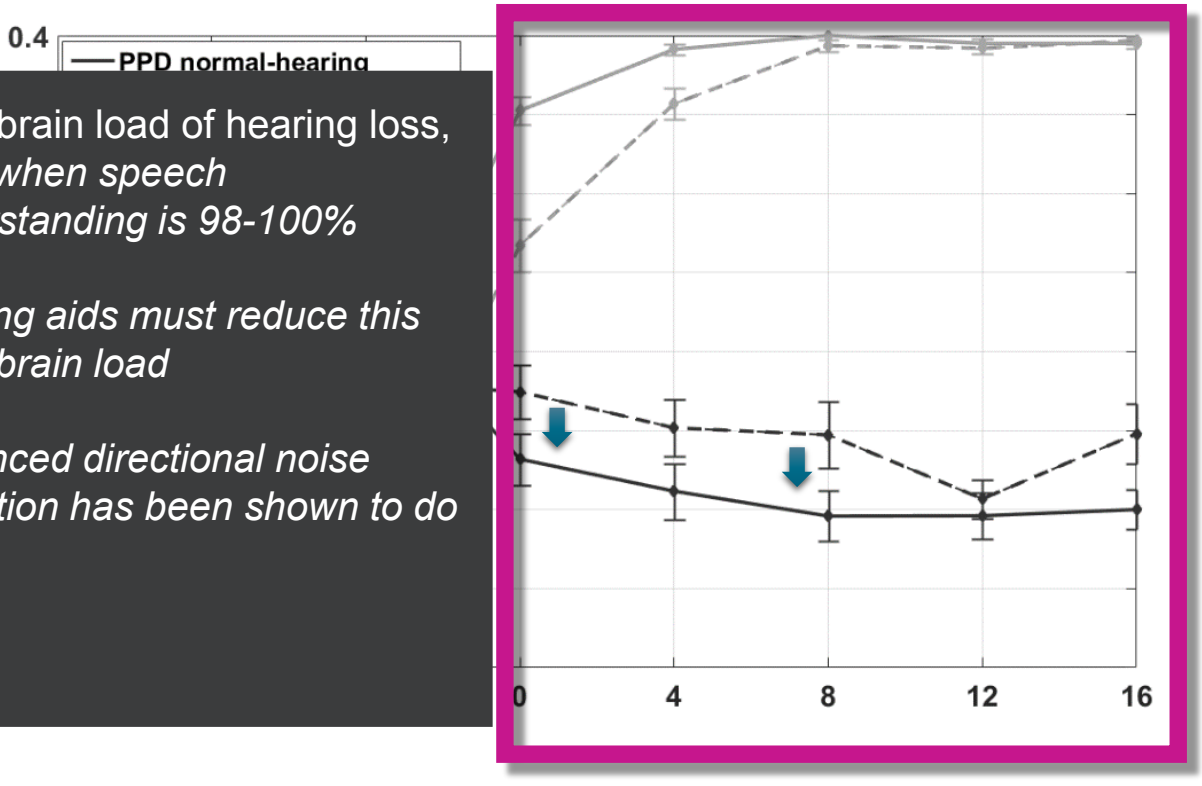
95% SNR=7.1dB

Listening effort

Extra brain load of hearing loss, *even when speech understanding is 98-100%*

Hearing aids must reduce this extra brain load

Advanced directional noise reduction has been shown to do this!



Recall study
Linköping University

First study showing noise reduction can improve recall

26 people with hearing loss tested

- Test conditions representing everyday communication
- Two types of situations tested:
  - Medium difficulty (95% speech recognition)
  - Increased difficulty (70% speech recognition)
- OpenSound Navigator on versus off

Ng et al, 2016, manuscript under preparation

Testing for recall from memory

SWIR – Sentence-final Word Identification and Recall

- Listen to HINT sentence in background speech
- Repeat back what you heard
- 7 sentences in total
- Remember last word
- Recall as many last words as you can

Number	Word	Recalled from	Used for outcome
1	Garden	Long term memory	Yes
2	Mirror	Long term memory	Yes
3	Lunch	In transfer	?
4	Sister	In transfer	?
5	Train	In transfer	?
6	Box	Short term memory	Yes
7	Driver	Short term memory	Yes

Ng et al., 2013 + Ng. et al., 2015

Results: OpenSound Navigator on versus off

25% improvement in long term memory and 5% improvement in short term memory

25%
(70% condition, less for the 95% condition)

5%

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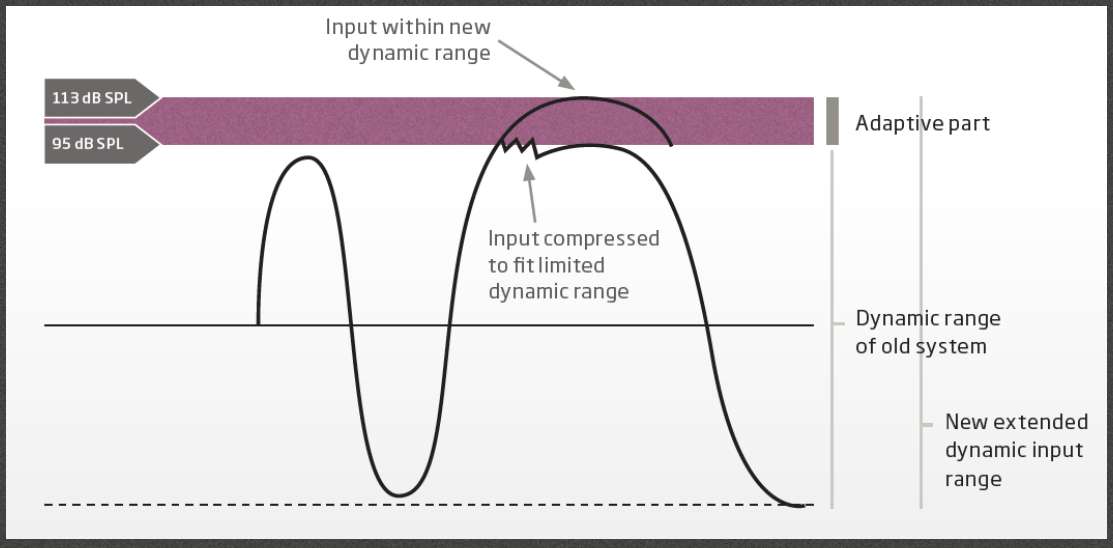
Other hearing aid technology to improve music listening…

Preserving Dynamic Range in Music

Music - high dynamic range - can have high level even at moderate loudness levels



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Benefits of Extended Dynamic Range?

Study by Marshall Chasin and colleagues in collaboration with Oticon in 2016/2017

- Conducted at Musicians Clinics of Toronto
- Experimental contrast: Oticon OPN w. Clear Dynamics on/off
- Double-blinded fitting of the feature on/off
- Field testing for 4 weeks, 2 weeks on and 2 off in random order
- Participants: 10 Musicians and 10 Non-musicians
- Outcome measures
  - Device-Oriented Subjective Outcome
  - Preference ratings for different types of recorded music

Benefits of Extended Dynamic Range?

Study done by Marshall Chasin in collaboration with Oticon in 2016/2017

Musicians:

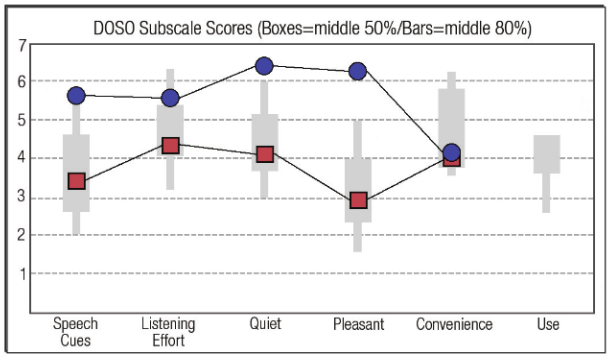

Figure 1a. Averages for the 10 musicians using the "old" (red squares) and the "new" Oticon Opn (blue circles) technologies of the on the DOSO subscales.

Non-musicians:

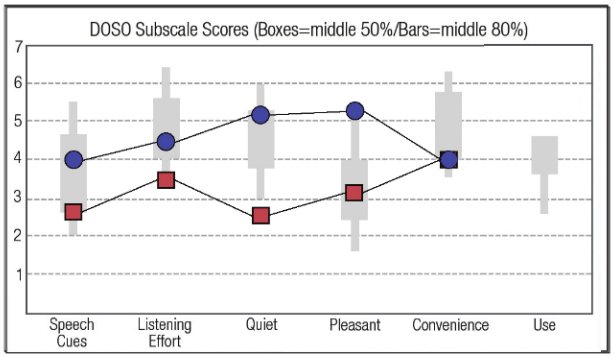

Figure 1b. Averages for the 10 non-musicians using the "old" (red squares) and the "new" Oticon Opn (blue circles) technologies on the DOSO subscales.

Benefits of Extended Dynamic Range?

Study done by Marshall Chasin in collaboration with Oticon in 2016/2017

Musicians:

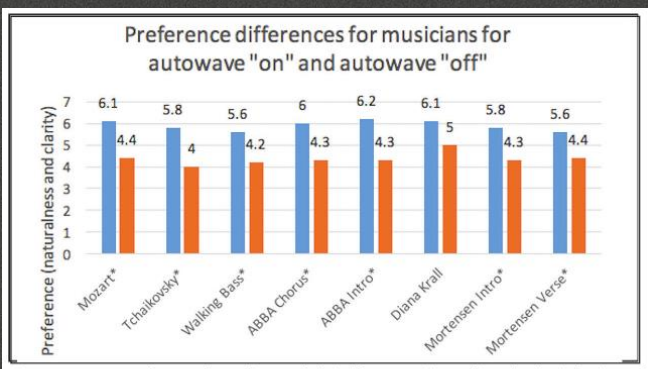

Figure 2a. Average preferences (naturalness and clarity) for 10 musician subjects for the eight pieces of recorded music with the astrisk (*) showing whether the differences between the "autowave on" (blue bars) and the "autowave off" (orange bars) achieved statistical significance at $\alpha = 0.05$.

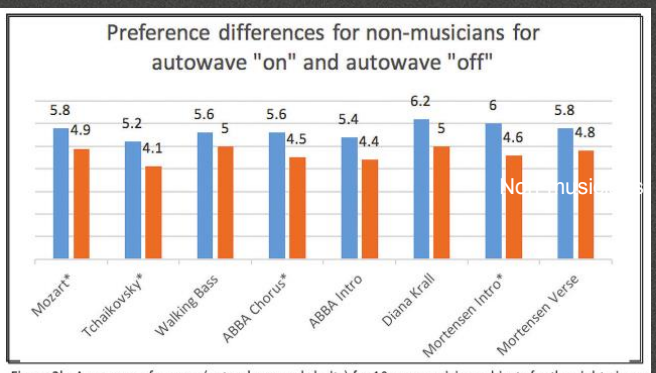

Figure 2b. Average preferences (naturalness and clarity) for 10 non-musician subjects for the eight pieces of recorded music with the astrisk (*) showing whether the differences between the "autowave on" (blue bars) and the "autowave off" (orange bars) achieved statistical significance at $\alpha = 0.05$.

- Autowave = automatic waveform preservation / extended dynamic range

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Benefits of Extended Dynamic Range?

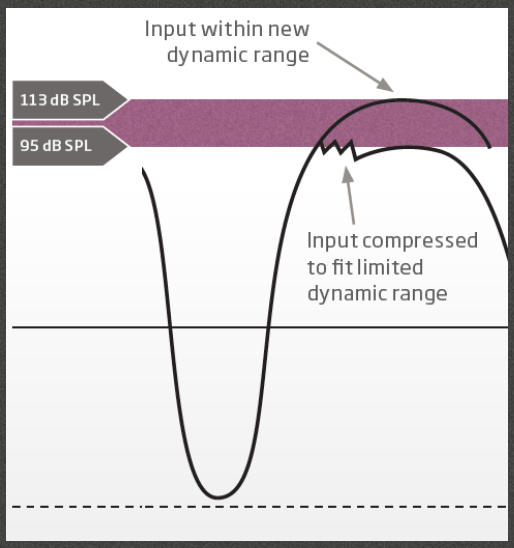
Study done by Marshall Chasin in collaboration with Oticon in 2016/2017

Conclusions – recorded music

- Improved naturalness and clarity for both musicians and non-musicians

Conclusions – field test DOSO

- Speech cues are easier to hear
- Listening effort is lower
- Speech in quiet is better
- Sound is more pleasant



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Final discussion

Cognition, Music and Hearing Aids

- The added cognitive load (WM) from hearing loss may make detailed music perception (Selective attention) difficult
- Separating voices is increasingly difficult with increasing hearing loss even with amplification
  - Distortion component of hearing loss…TFS…
- For casual music listening, at least one type of noise reduction may help by lowering the processing load
- Hearing aids that preserve a high input dynamic range is strongly preferred by musicians and preferred by non-musicians
- Other factors: Bandwidth, Compressor/Adaptive Gain, Maximum Output Settings, Output Range