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Can we compare  
**Sound Quality of Noise Reduction**  
between commercial hearing aids?

A method to level the ground between devices



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# Introduction

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Speech in quiet



**NO PROBLEM**

Speech in noise



**PROBLEM**

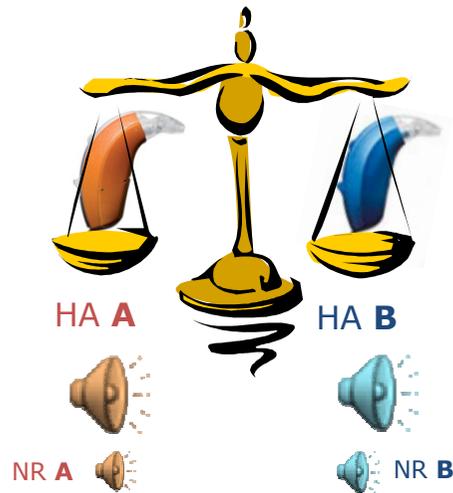
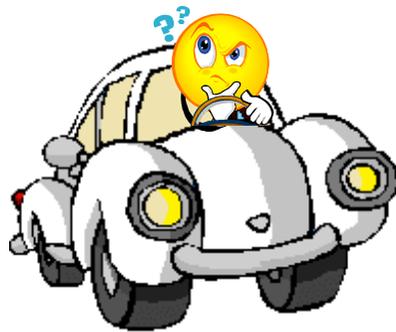
# Noise Reduction in Hearing Aids

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- Chosen principles unknown to clinician: “black box”
  - Selection of best NR for individual
  - Selection of best NR for situation
  - Selection of best NR for Hearing loss
  - Trial and error
- Technical properties differ between hearing aids
- Perceptual effects are unknown
- Direct comparison between NRs required

# Noise Reduction in Hearing Aids

Can noise reduction features of different hearing aids directly be compared?



**NO**

HA first fit  
Flat sensorineural 50 dB HL

- Direct comparison between NRs required
  - Problem: effect of hearing aid >> effect of noise reduction
  - Wanted: effect of hearing aid << effect of noise reduction

# Method – Hearing aids

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- Hearing aids (BTE)

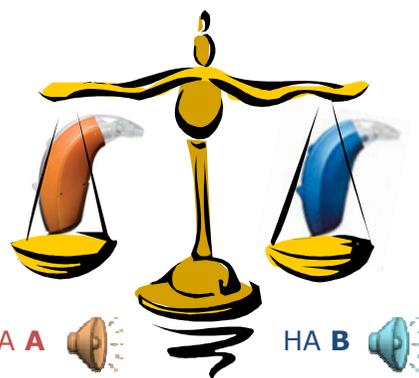
- 1 Oticon Vigo Pro
- 2 Phonak Exélia M
- 3 ReSound Azure AZ80-DVI
- 4 Widex Mind 440
- 5 Starkey Destiny 1200

- Programming

- Fine-tuning of first fit
  - Equal insertion gain (difference between aided and unaided response)
  - Compression ratio 1.0 (= no compression)
- Microphone omnidirectional
- All features OFF

# Method – Hearing aids

Is the fine-tuned fit (with insertion gain) good enough?



HA A   
NR A 

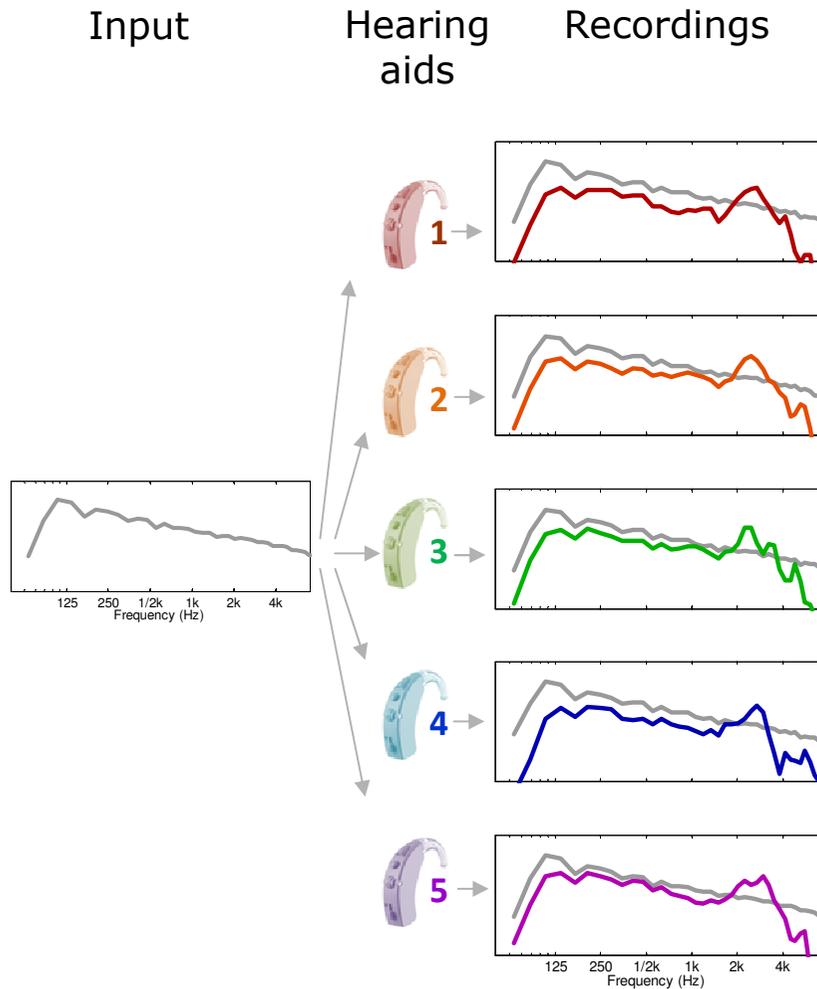
HA B   
HA B 



**NO**

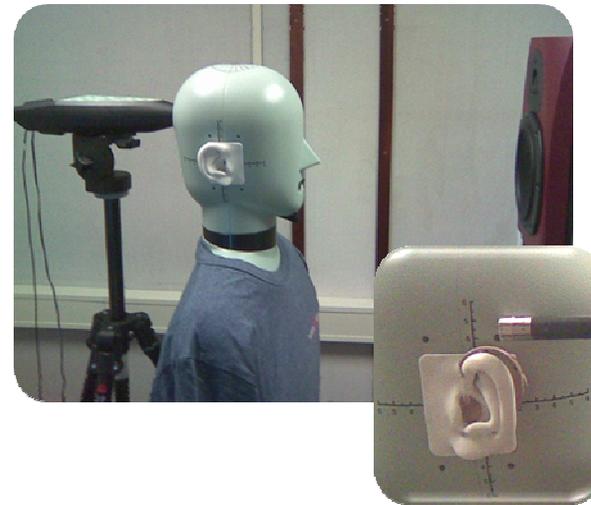
Linear fit  
Based on insertion gain

# Method - Recordings

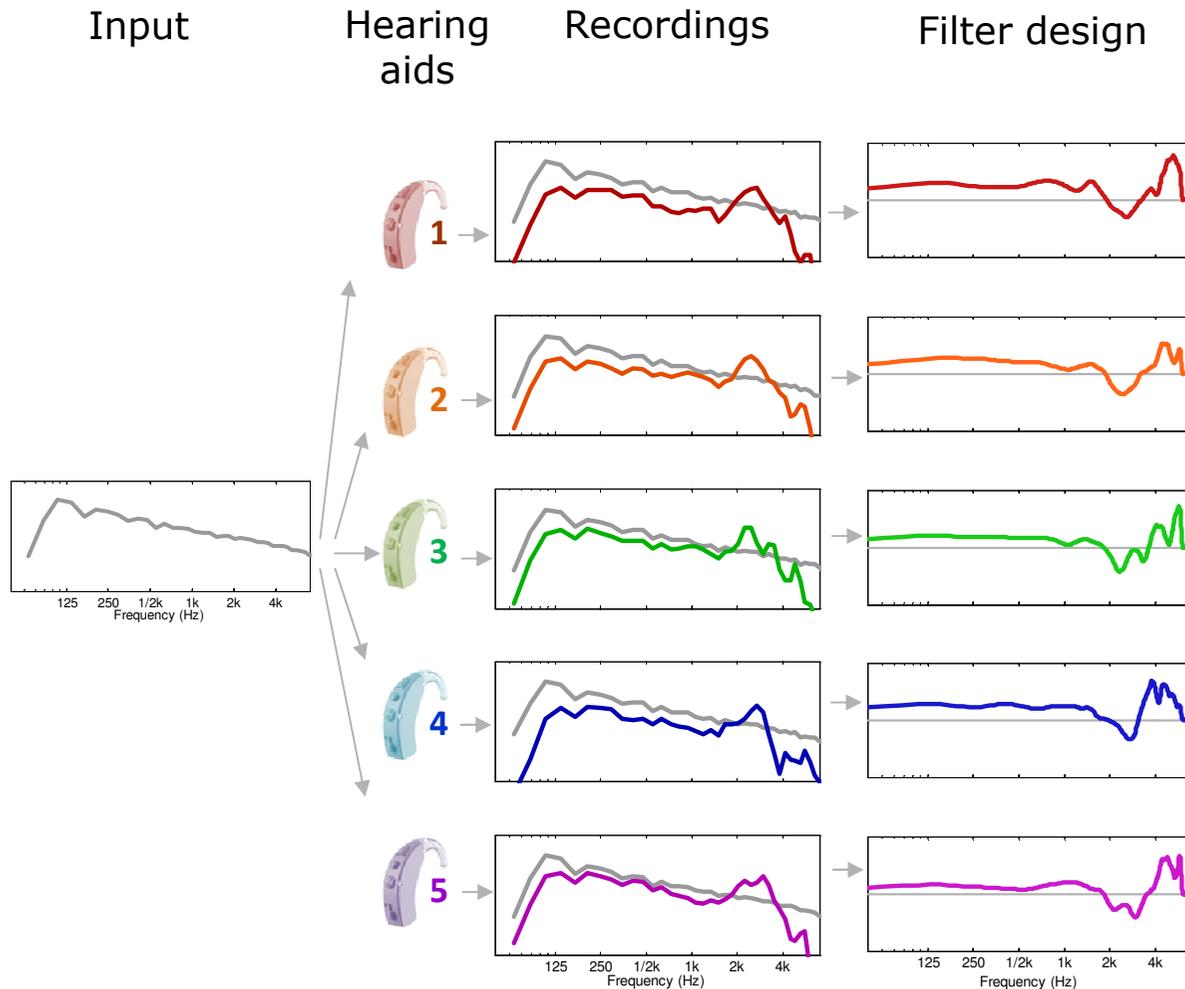


## Recording

- Input: pink noise at 70 dB SPL
- Hearing aid on Head and Torso Simulator



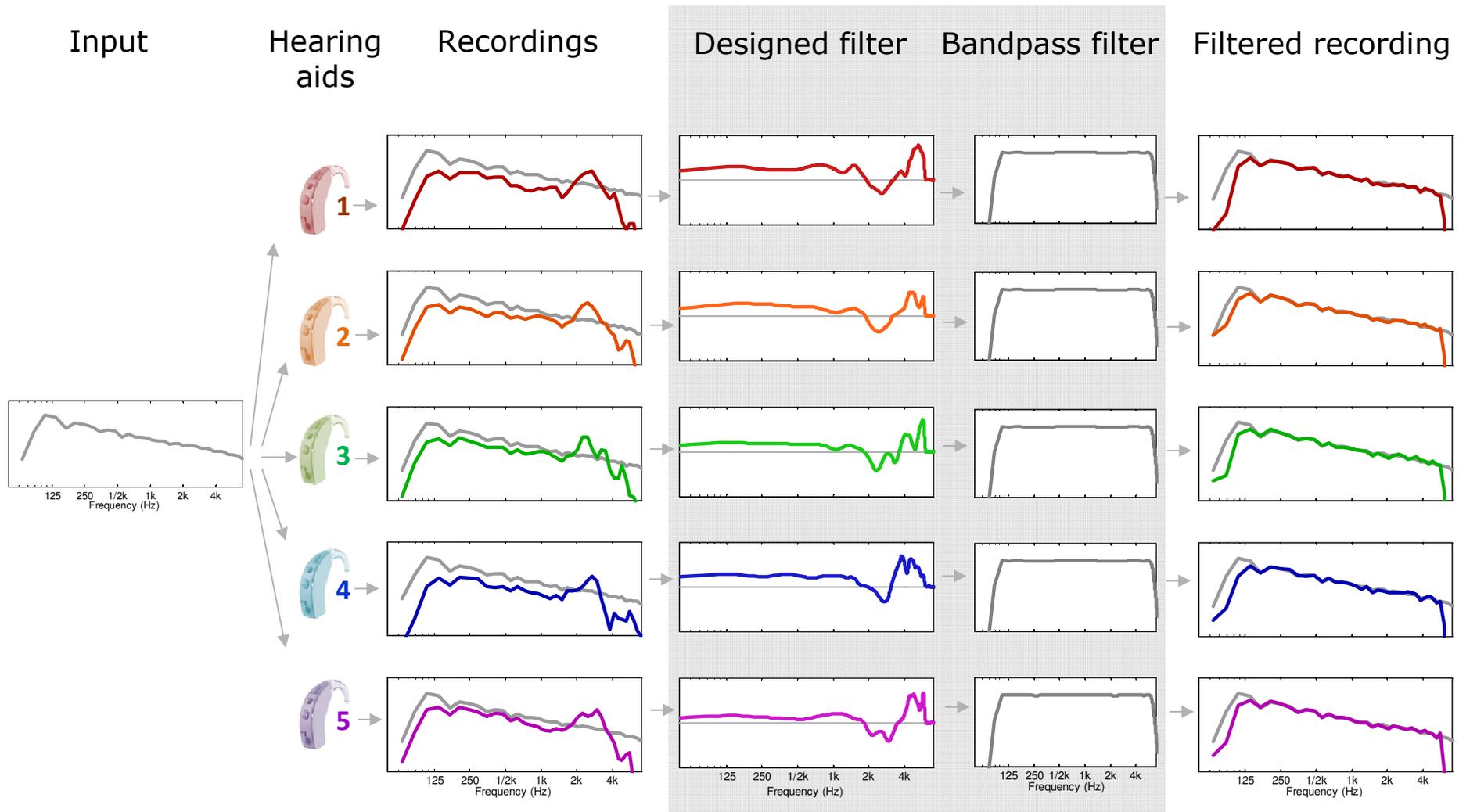
# Method – Filter design



## Filter design

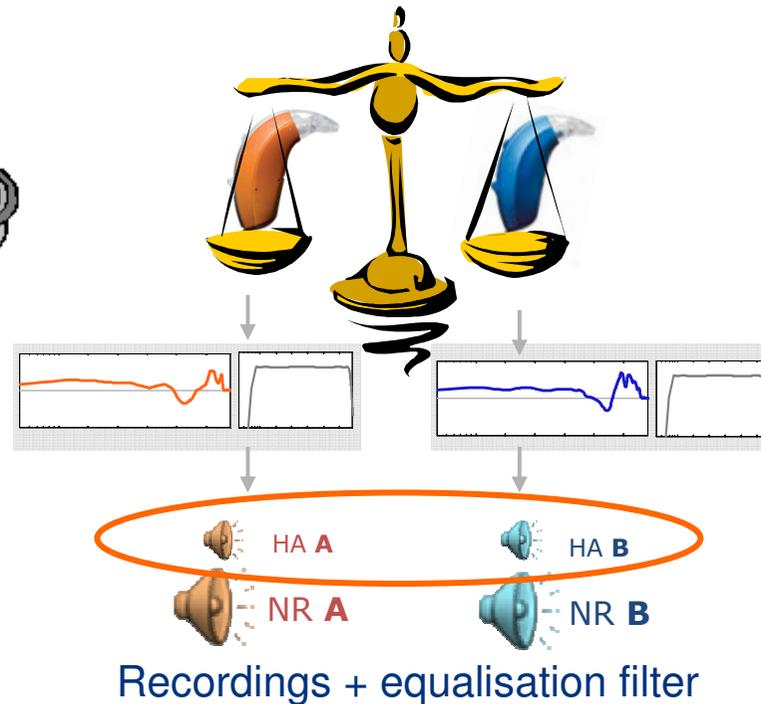
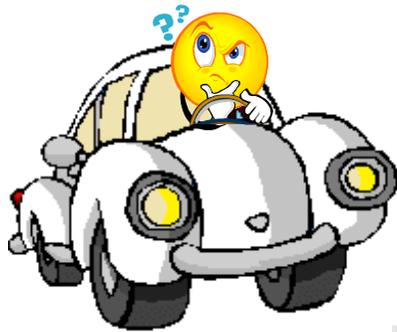
- Linear system analysis
- Dividing output spectrum by input spectrum
- FIR filter with 500 taps

# Method - Filtering



# Results

Is the equalized recording good enough?



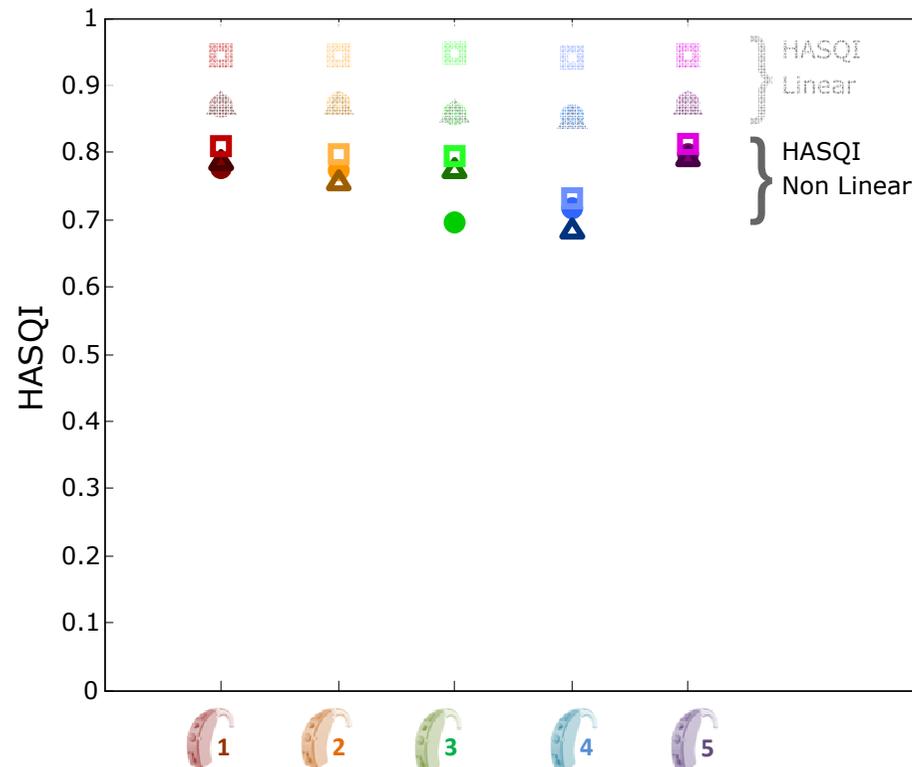
It seems so!

- Evaluation of equalisation filter: comparison of corrected recordings *without noise reduction*

# Objective evaluation



- Hearing-aid speech quality index (Kates and Arehart, 2009)**
  - HASQI linear: changes in long-term spectral shape
  - HASQI non-linear: changes in signal envelope modulations



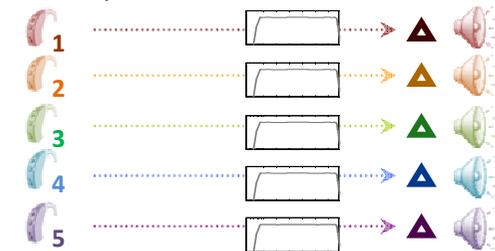
Reference signal (input)



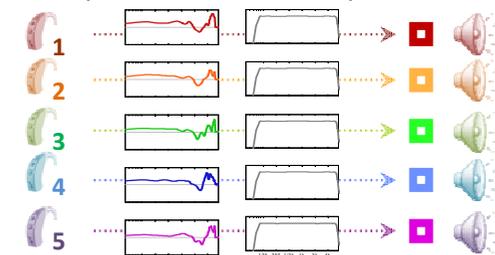
Unfiltered recording



Band-pass filtered



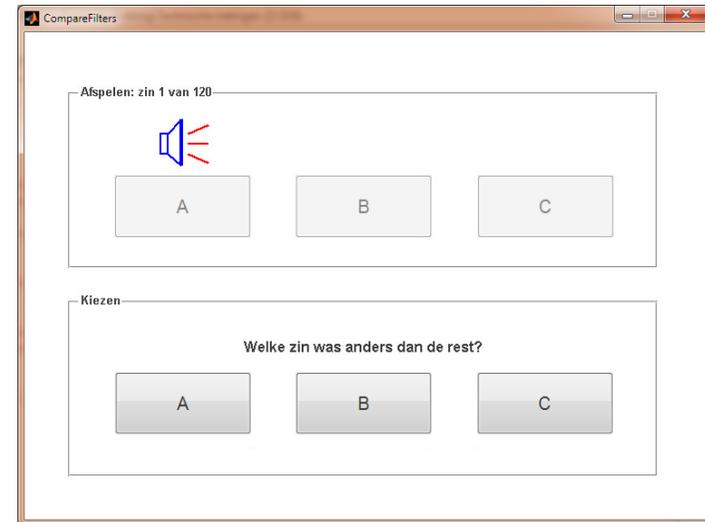
HA specific filter + bandpass filter



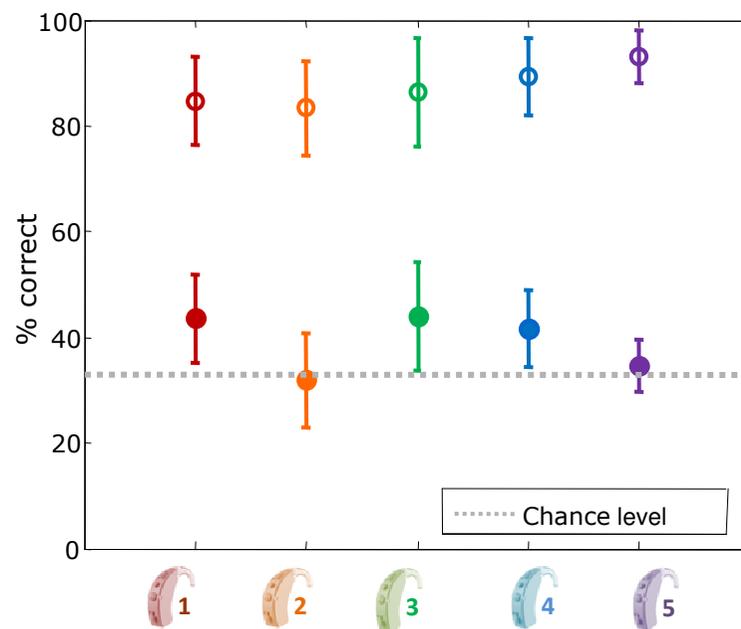
# Subjective evaluation



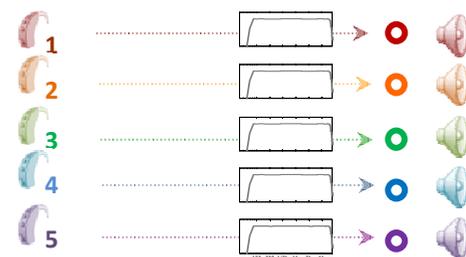
- 6 normally hearing subjects
- Detection task
  - Identify odd stimulus from set of three
- Test sets (not mixed):
  - Recordings with bandwidth limitation
  - Recordings with correction for hearing aid + bandwidth limitation
- Three runs, 60 trials per test set; 120 trials per subject



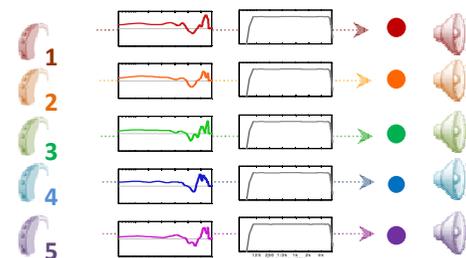
# Subjective evaluation



Band-pass filtered



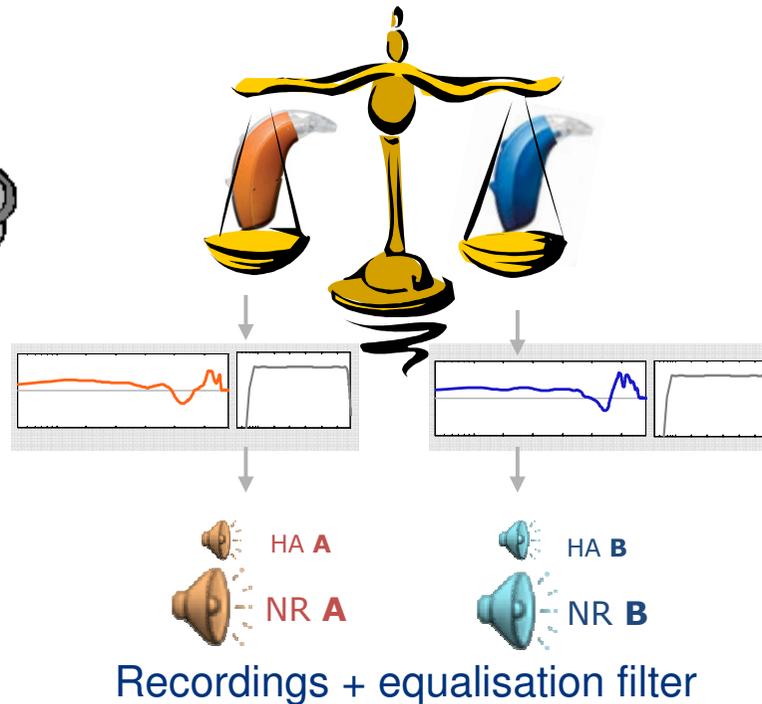
HA specific filter + bandpass filter



- Band-pass limited signals were detectable (average 87%)
- Detection of fully filtered signals was much more difficult (average 39%)
- Detection of individual recordings did not deviate from chance

# Conclusions & Application

Is the equalized recording good enough?



# Conclusions & Application

- The equalisation filter levels the ground between devices
  - Differences in HASQI quality index are reduced
  - Detection rate of differences is reduced to about chance level
- This opens the way for future perceptual comparisons
  - The equalisation filter can be applied with noise reduction ON
  - The filter does not influence hearing aid or noise reduction processing in any way
    - Equalization filtering on *output* of hearing aids (*after* HA processing)
  - Differences between aids then originate from noise reduction only
- Perceptual A-B comparison of hearing aid signal processing possible

