

# Rerouting signal in single side deafness

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Inserm U1008: Controlled drug delivery to the inner ear



# Stereophony

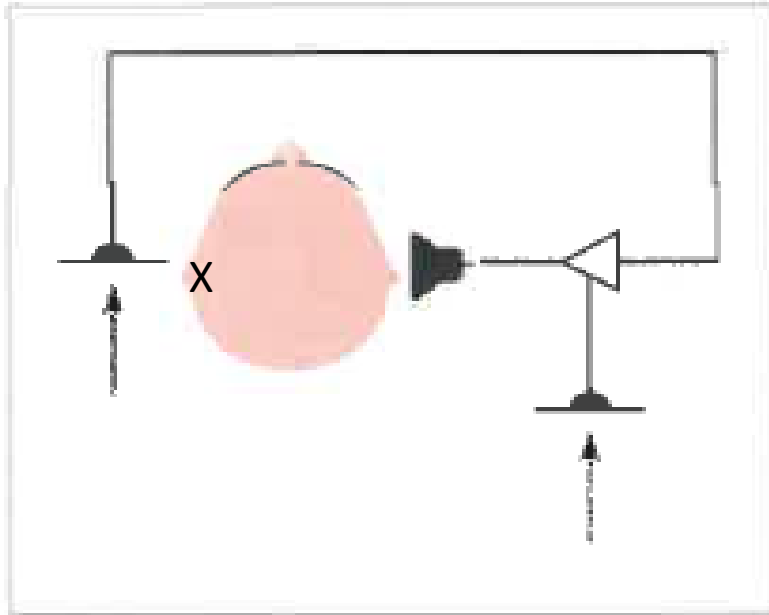
- augmentation of subjective threshold
- better sound localization
- better speech intelligibility in noise

# SSD

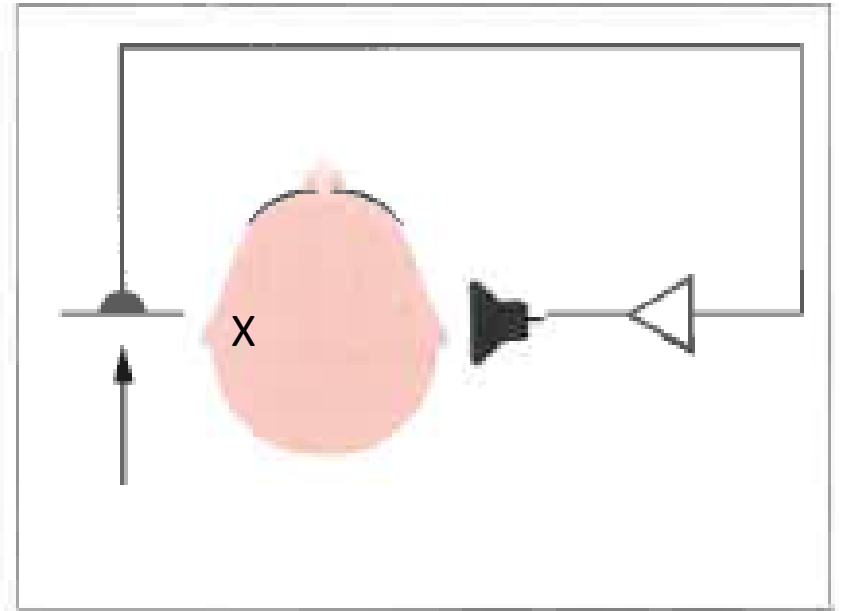
- problems with sound localization
- problem with speech intelligibility in noisy conditions
- difficulty to understand people located at the deaf side
- academic difficulties for children

# SSD rehabilitation: available devices

- Bone stimulation on the deaf side:
  - percutaneous: BAHA, PONTO
  - transcutaneous: BAHA Attract, Sophono, Bonebridge, Adhea, more to come...
- CROS, BICROS with conventional HA
- Cochlear implant (+ incapacitating tinnitus)



BICROS



CROS

# Rerouting SSD with BAHA

[Prosthetic rehabilitation of unilateral anacusis. Study with stereoaudiometry].

Vaneecloo FM, Hanson JN, Laroche C, Vincent C, Dehaussy J.

Ann Otolaryngol Chir Cervicofac. 2000 Dec;117(6):410-417

[The monaural pseudo-stereophonic hearing aid (BAHA) in unilateral total deafness: a study of 29 patients].

Vaneecloo FM, Ruzza I, Hanson JN, Gérard T, Dehaussy J, Cory M, Arrouet C, Vincent C.

Rev Laryngol Otol Rhinol (Bord). 2001;122(5):343-50

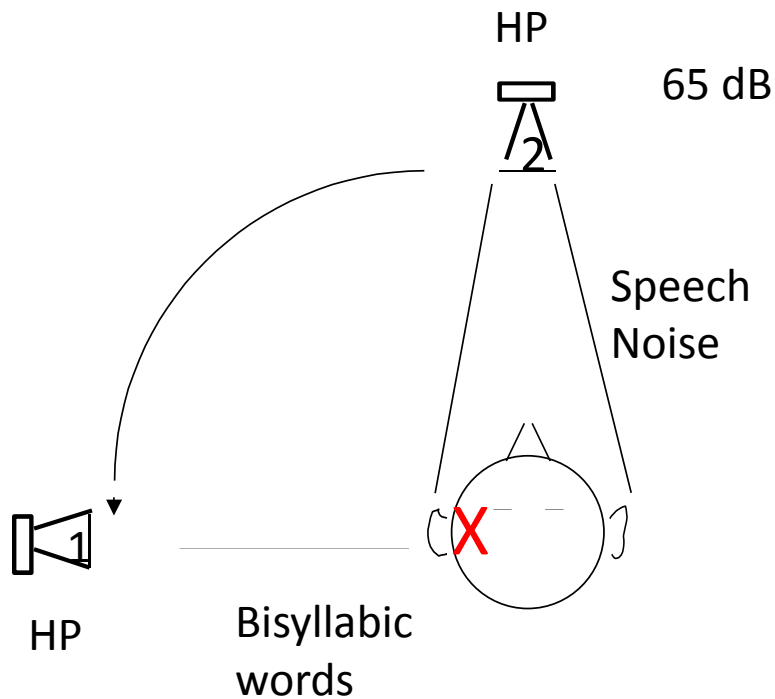
- Hearing in noise benefit
- Localization benefit
  
- Proper selection of candidates

# Tests for binaural hearing

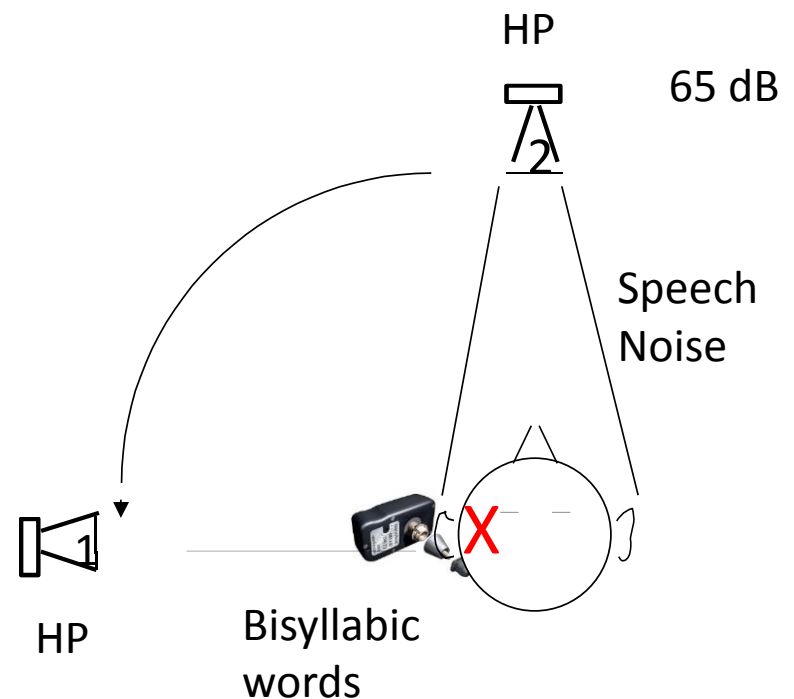
- Discrepancies between questionnaires and audiological tests
  - problem of adequate audiological tests
- clinical test  $\neq$  test performed for a clinical study
- Need to test 2 conditions:
  - Localization of sound
  - Hearing in noise
- Testing at home for 1 month



# Hirsh's test: Head Shadow Effect

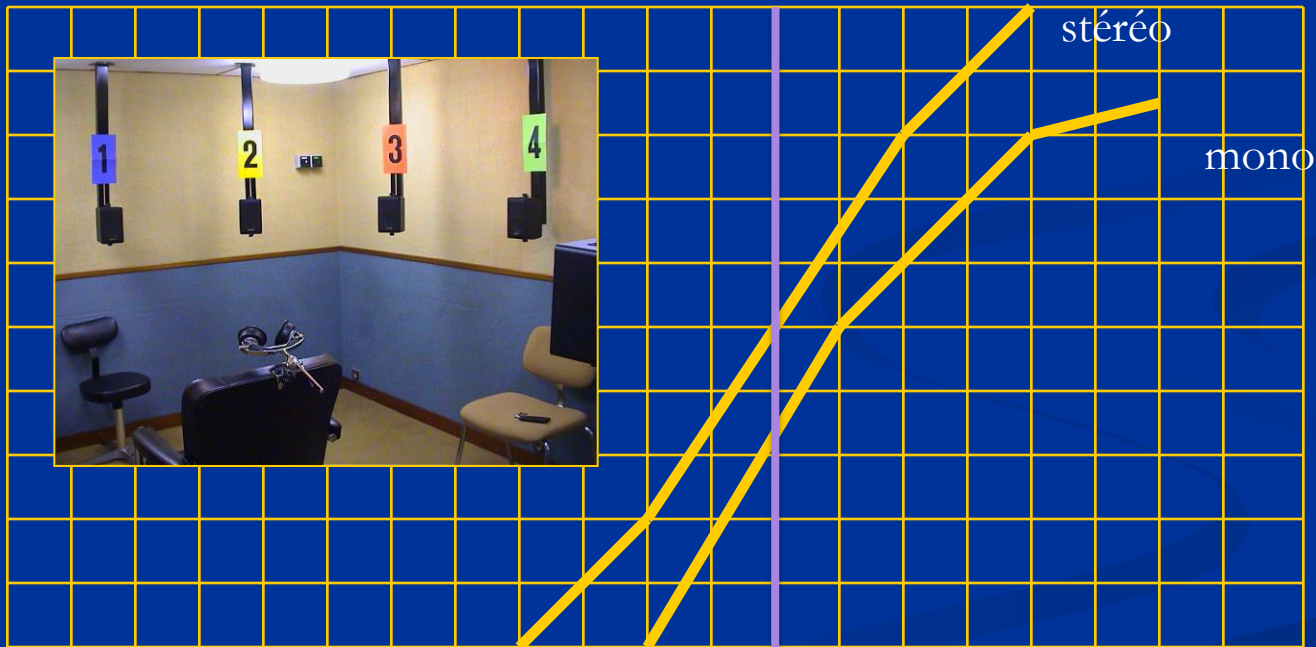
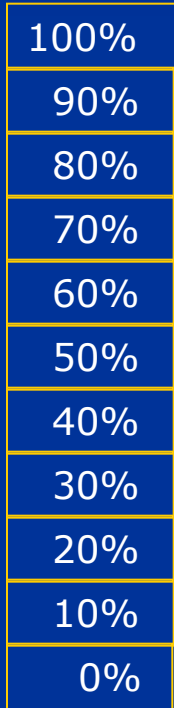
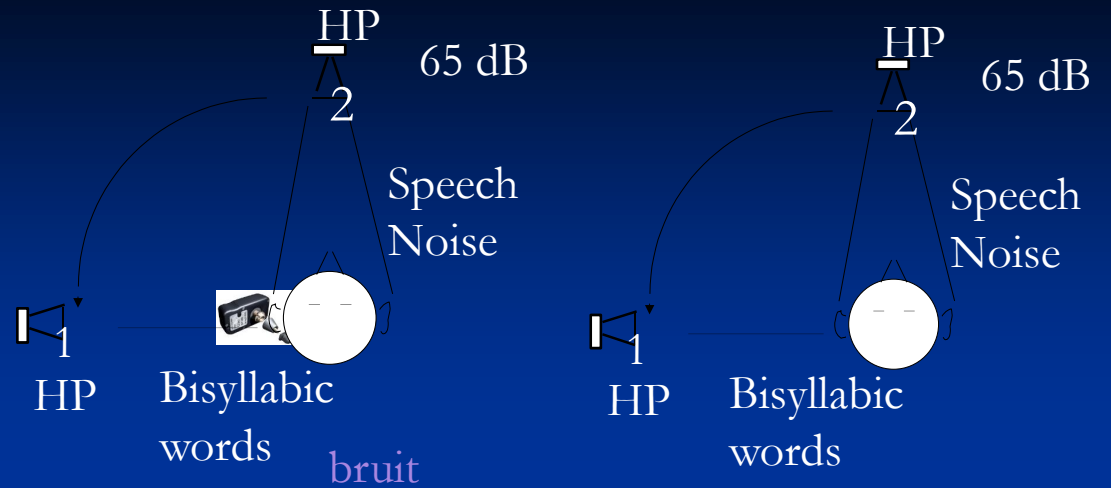


Monaural

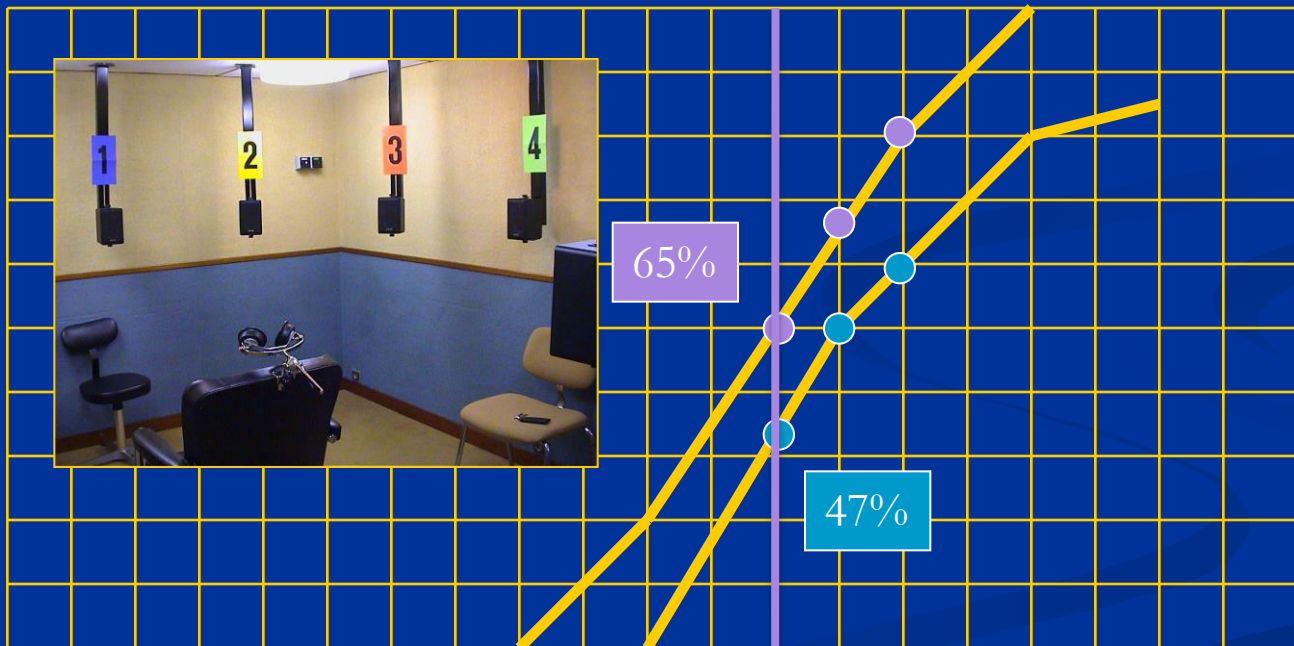
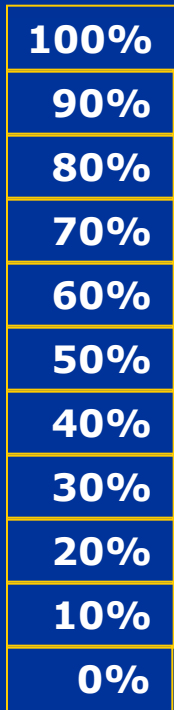
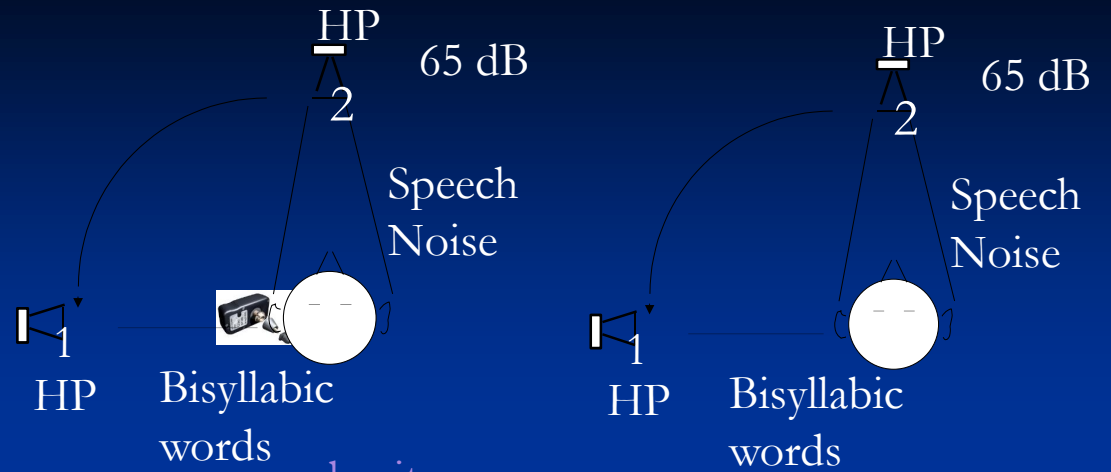


Monaural+BAHA





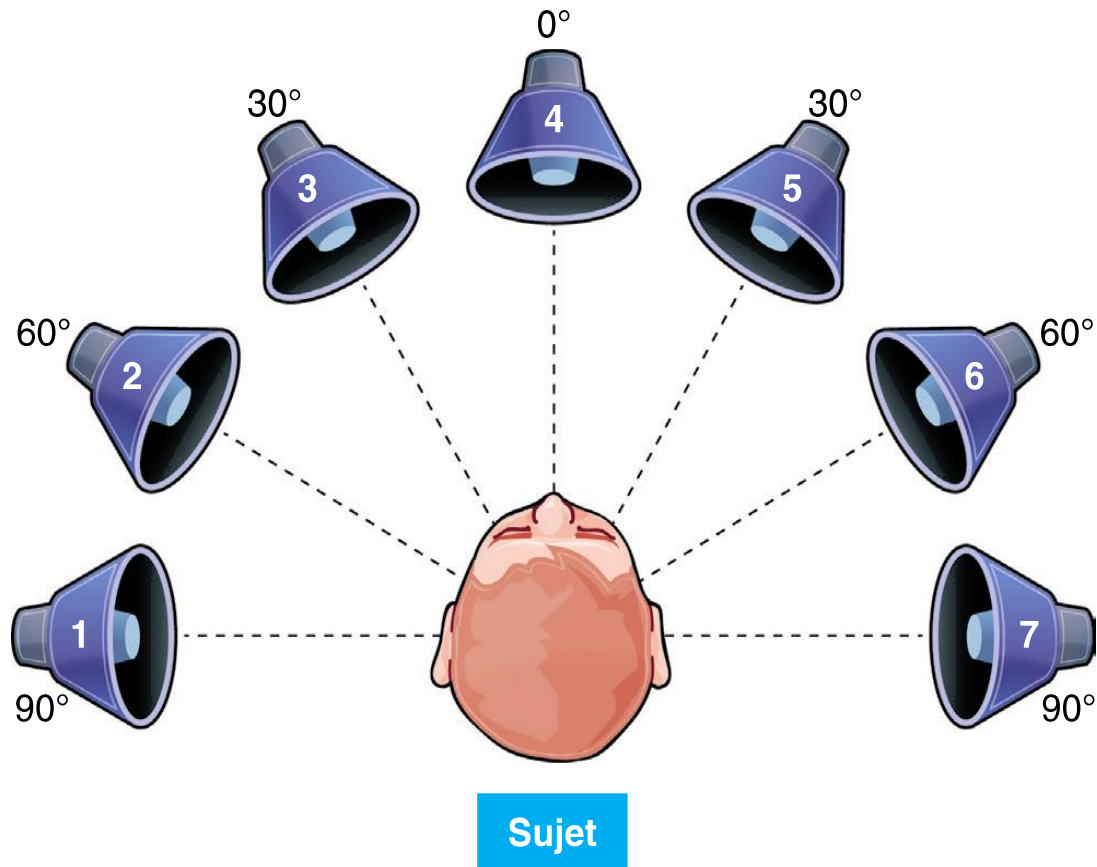
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 dB



5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 dB

# Hearing in noise benefit with BAHA & SSD

- Summation effect  $\approx 6$  dB
- Better speech intelligibility in noise  $\approx 25$  %
- Better hearing from the deaf side



Subject seated at 1.5 m from the loudspeakers

Testing protocol (Risoud et al, Eur Ann Otorhinolaryngol Head Neck Dis. 2018 Aug;135(4):259-264).

Table 1. Accuracy of azimuthal sound source localization by interaural time difference (ITD) and [interaural level difference](#) (ILD) according to frequency.

Binaural localization cue	Localization accuracy		
	< 1000 Hz	1000–3000 Hz	> 3000 Hz
<b>ITD</b>	Good	Mediocre	Impossible
<b>ILD</b>	Impossible	Mediocre	Good

Table 2. Accuracy of sound source localization in the vertical plane by head-related transfer function (HRTF) according to frequency.

Monaural localization cue	Localization accuracy	
	< 7000 Hz	> 7000 Hz
<b>HRTF</b>	Moderate	Good

# Clinical aspects of patient selection

- No indication based on the tonal audiometry,
  - Clinical test (rod test) and stereaudiometry battery tests,
  - Testing the device @ home for 1 month
  - Patient motivation
- > Major point: duration of sound deprivation.

# First results of our series

- 60 SSD patients with BAHA
- mean age: 53 yo
- mean follow-up: 40 months
  
- questionnaires
- hearing in noise test
- localization test

# GLASGOW HEARING AID BENEFIT PROFILE

- 18.7 % very satisfied,
- 50.7 % satisfied,
- 20 % rather satisfied,
- 5.3 % rather unsatisfied,
- 5.3 % unsatisfied.



# Hearing in noise

- Speech intelligibility: disyllabic word @ 70 dB in a speech noise background @ 65 dB  
+22.8 % (lower SRT: – 6 dB)

## Localization

- Better localization: 25 %
- Localization right/left: 18.3 %
- No benefit in localization: 56.7 %

# Localization with BAHA & SSD

- ~~Interaural time differences (ITD)~~
- ~~Interaural level differences (ILD)~~
- Head-related transfer function (HRTF)

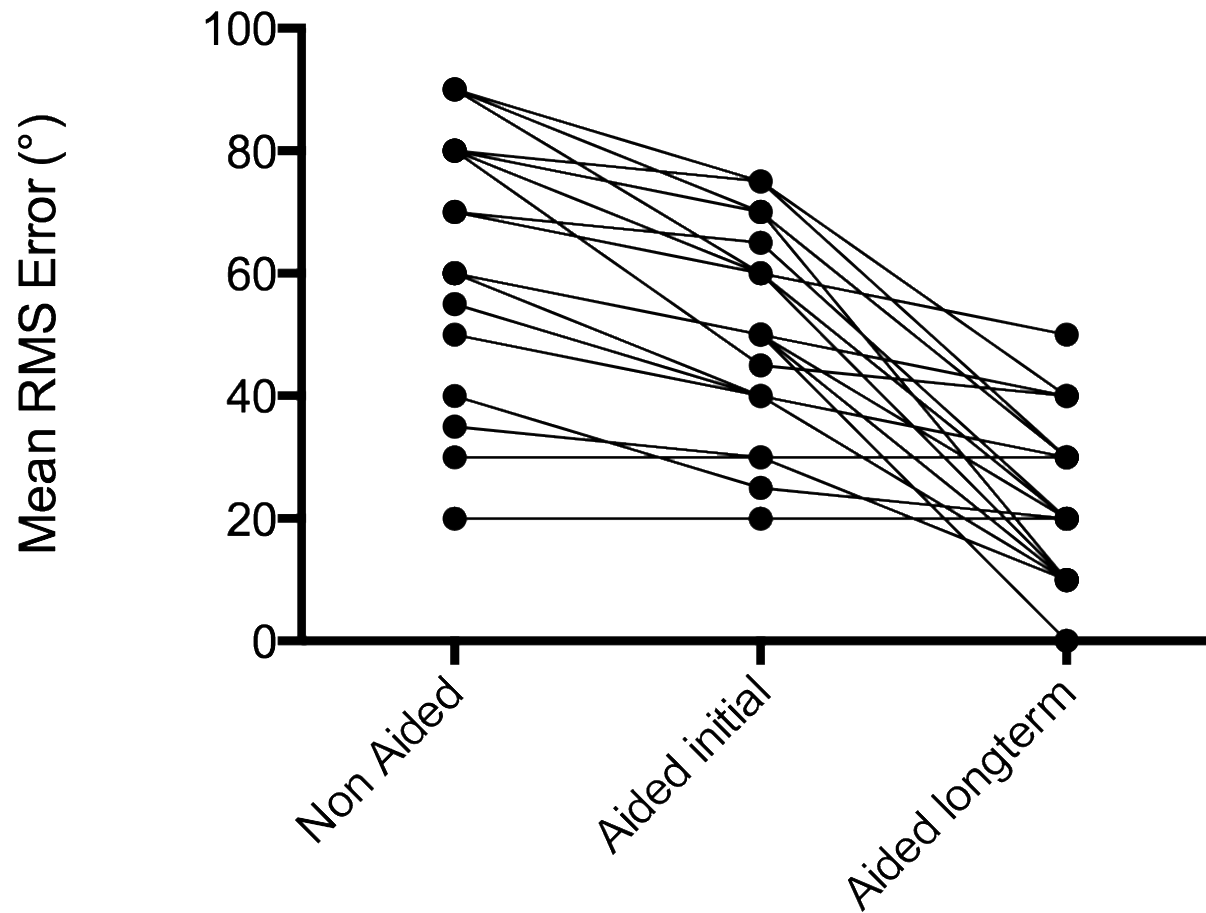
# Aim of the study

- Analyze the evolution of localization skills in the horizontal plane of SSD patients with BAHA
- Comparison of 3 situations:
  - non aided,
  - aided initially,
  - aided at last follow-up

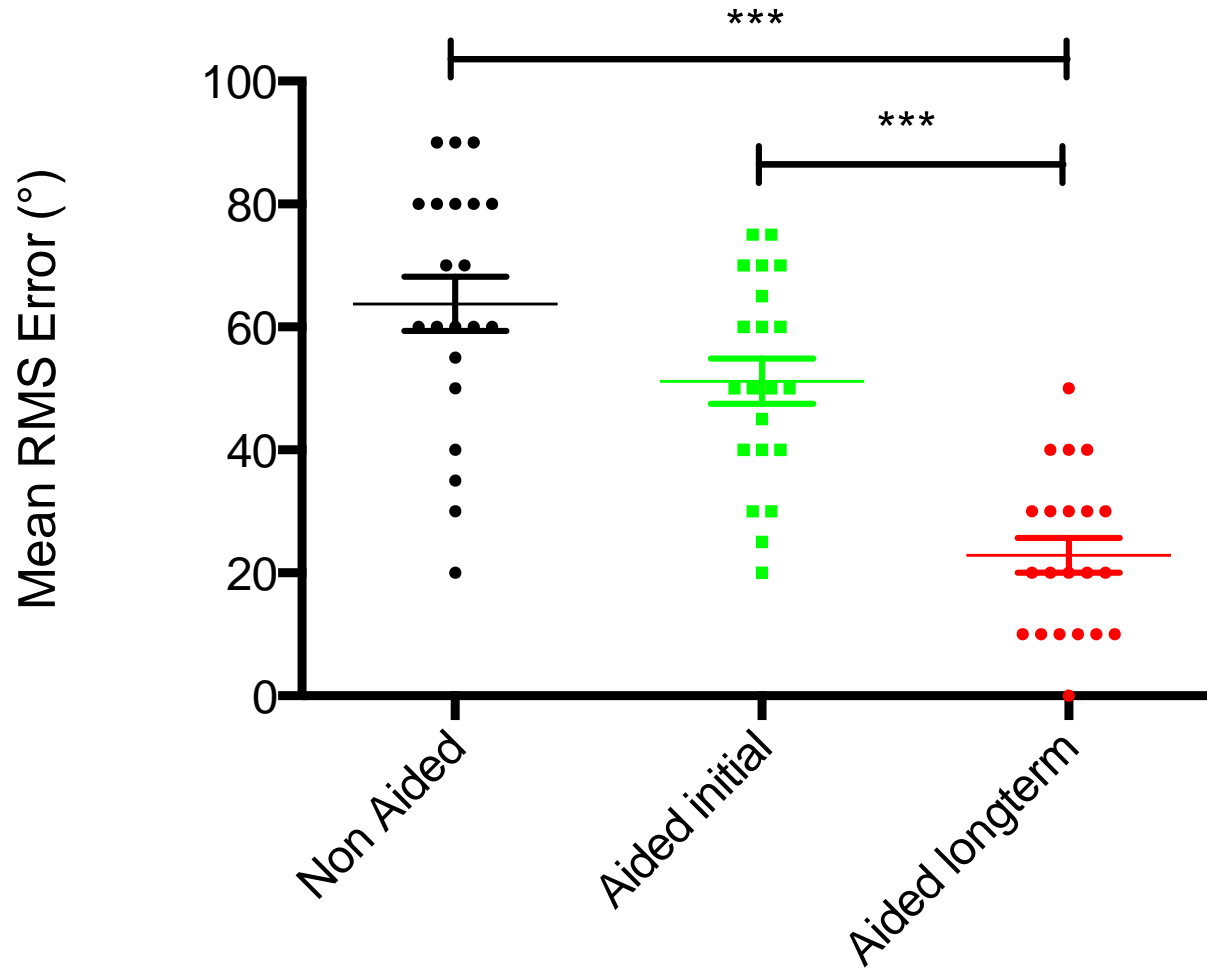
# Our series

- 122 SSD patients rehabilitated with the BAHA device between 2003 and 2012
- 48 patients had normal hearing on the contro-lateral side (PTA < 20 dB, SDS > 90 %)
- 21 patients (mean: 44 yo, median: 50 yo) accepted to come for evaluation
- Mean follow-up time: 6.4 years (median: 8 years)

# Evolution of localization performances

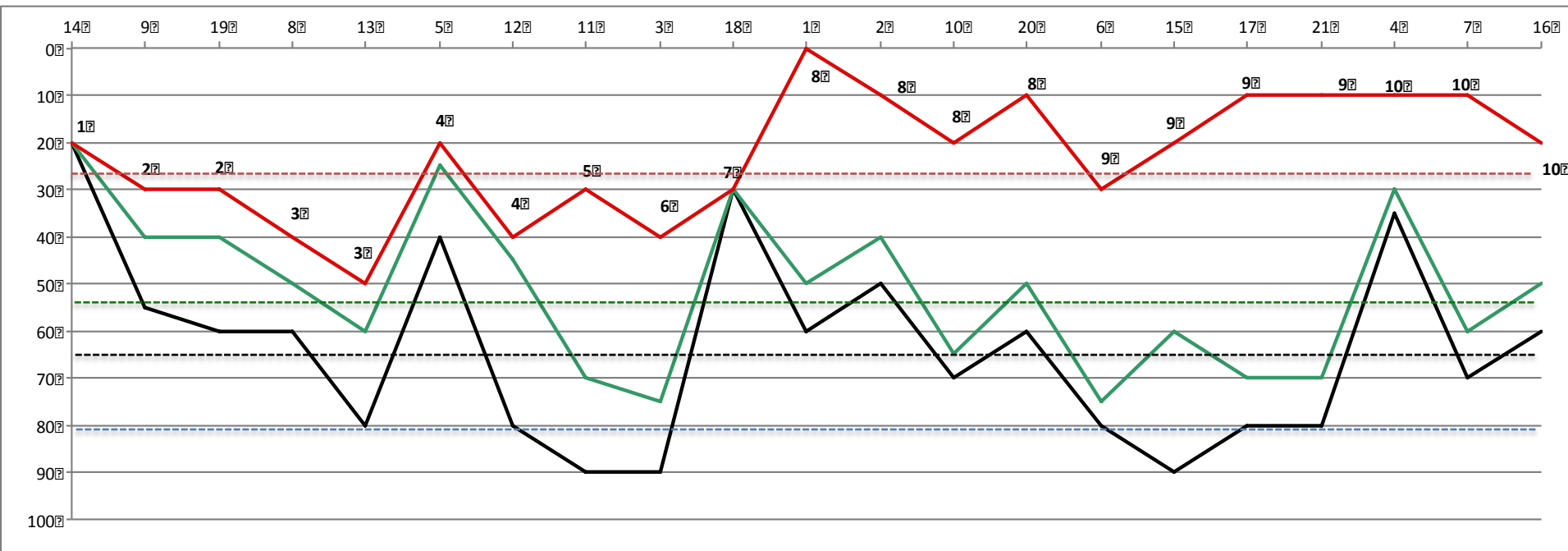


# Evolution of localization performances



# Evolution of localization

Duration of use



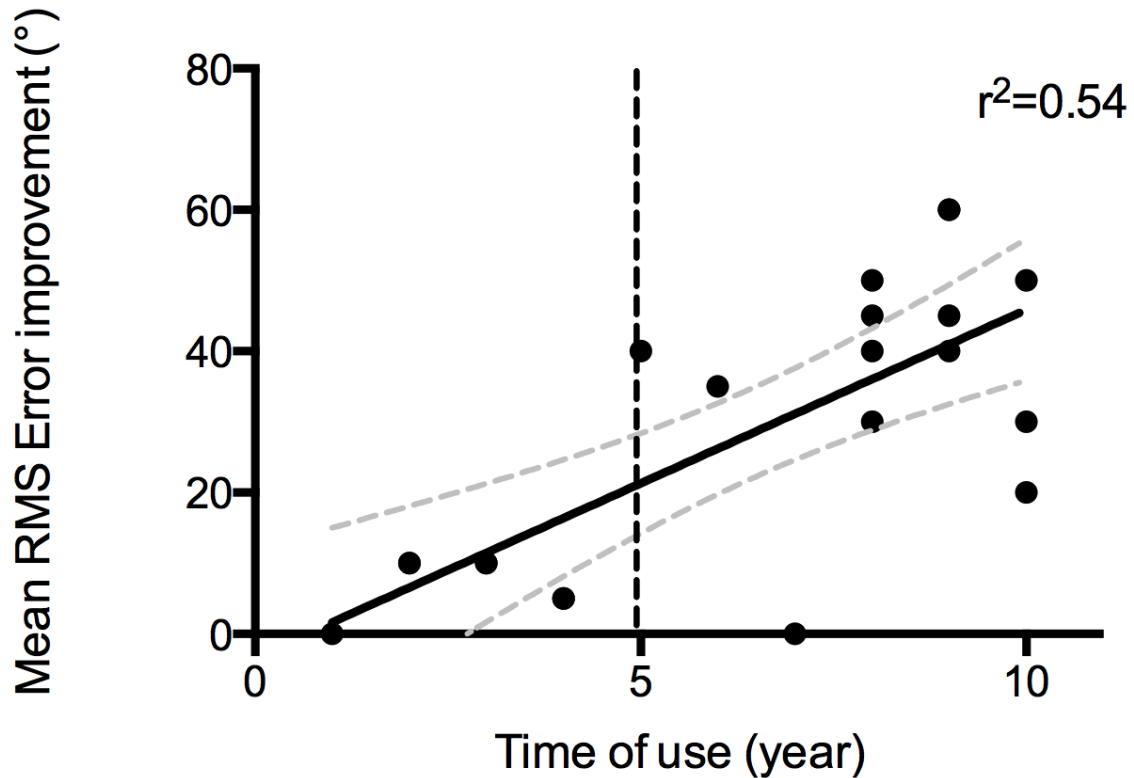
° RMS error

Patient ID #

- Before BAHA
- BAHA: initial result
- BAHA: last result

RMS chance level: 81°

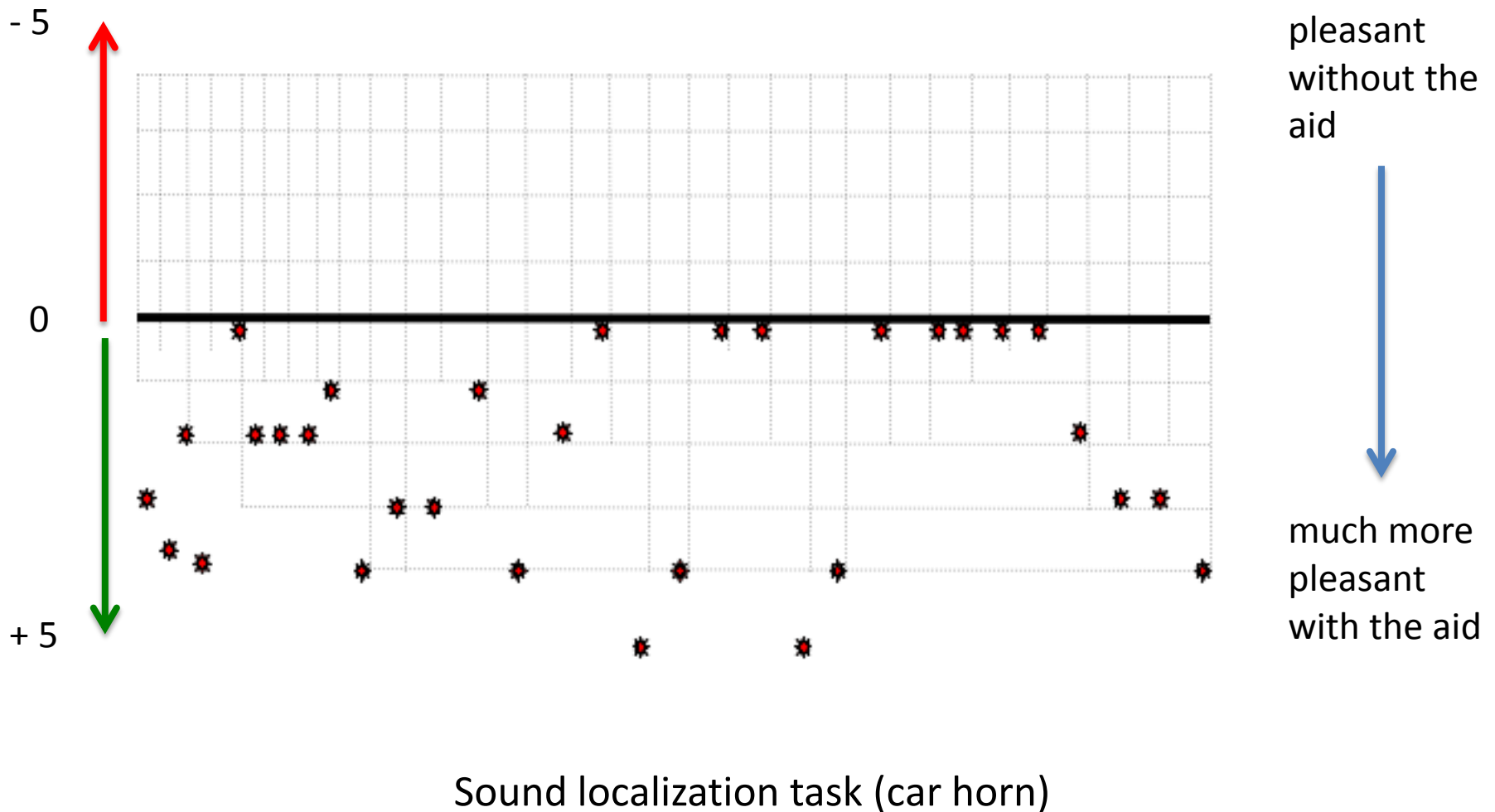
# Evolution of localization performances



Mean Improvement over time  $4,11^\circ(0-6.6)$  per year



# Bern Benefit in Single-Sided Deafness Questionnaire (BBSS)



# Conclusion for localization study

- Evolution of localization for 21 SSD patients with normal hearing and BAHA on deaf side
- Median follow-up was 8 years
- Evolution of RMS localization error:
  - 66° non aided,
  - 53° aided initially,
  - 27° with BAHA at last evaluation.
- Our main hypothesis: the auditory systems relearns to localize via adaptive plasticity with additional azimuth-dependent spectral cues from the BAHA on the deaf side.

# Binaural device with stereophony benefit (Decroix, Dehaussy, 1962)

- 4 criteria:
  - Auditory thresholds as symmetrical as possible especially for the speech frequencies,
  - Respect of the functional independance of both ears,
  - Pick the sound at the ear level,
  - Allow variations of phase, intensity and delay with free head movements.

# SSD rehabilitation

- Bone stimulation on the deaf side:
  - percutaneous: BAHA, PONTO
  - transcutaneous: BAHA Attract, Sophono, Bonebridge, Adhear
- CROS, BICROS with conventional HA
- Cochlear implant (+ incapacitating tinnitus)