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)
Rerouting SSD with BAHA

[Prosthetic rehabilitation of unilateral anakusis. Study with stereoaudiometry].
Vaneecloo FM, Hanson JN, Laroche C, Vincent C, Dehaussy J.

[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 ≠ 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
Hearing in noise benefit with BAHA & SSD

• Summation effect ≈ 6 dB

• Better speech intelligibility in noise ≈ 25 %

• Better hearing from the deaf side
Subject seated at 1.5 m from the loudspeakers

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

<table>
<thead>
<tr>
<th>Binaural localization cue</th>
<th>Localization accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 1000 Hz</td>
</tr>
<tr>
<td>ITD</td>
<td>Good</td>
</tr>
<tr>
<td>ILD</td>
<td>Impossible</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Monaural localization cue</th>
<th>Localization accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 7000 Hz</td>
</tr>
<tr>
<td>HRTF</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

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

Mean RMS Error (°)

Non Aided      Aided initial      Aided longterm
Evolution of localization performances

![Graph showing the evolution of localization performances. The x-axis represents time points: Non Aided, Aided initial, and Aided longterm. The y-axis represents the Mean RMS Error in degrees. The graph includes box plots for each time point, with non-parametric tests indicating significant differences.]

- Non Aided
- Aided initial
- Aided longterm

*** Significant difference
Evolution of localization

Duration of use

Before BAHA
BAHA: initial result
BAHA: last result

RMS chance level: 81°
Evolution of localization performances

Mean RMS Error improvement (°)

Time of use (year)

Mean Improvement over time 4.11° (0-6.6) per year

$\text{r}^2=0.54$
Bern Benefit in Single-Sided Deafness Questionnaire (BBSS)

Sound localization task (car horn)

much more pleasant without the aid

much more pleasant with the aid
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
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