How vision matters for young cochlear implant users: Auditory cortex contributes to photo processing

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Introduction

• Vision and hearing are two most important communication styles.

• Closed cross-modal correlation has been proved.
Introduction

- In normal subjects, auditory cortex involves in photo processing.

Introduction

- In deaf adults
  - visual take-over of auditory cortex.
  - The reversal of visual take-over was related to the auditory ability.

Prelingual deaf children

- Get no or little sound stimuli
- Depend on vision for communication.
- Fast developing brain.

Q:

1. Does the vision matter on the auditory cortex in prelingual deaf children?

2. How does the vision matter on auditory cortex in children post CI? is it related to the auditory outcomes?
Methods

• Subjects
  – 24 Prelingual deaf children, age from 3-6 years.
  – 10 normal controls, age from 4-6 years
  – 176 children with CI within 12M
    • ages were from 3-6 years
    • All CIs were on the right ears
    • average hearing levels were below 30dB HL for the frequency of 500—4000Hz.
  • The vision of the subjects were normal or corrected to normal.
Methods

Subjects: 10 postlingual deafs, 10 normals

Proverbio et al., 2011
LORETA Source analysis

BA41 and BA42

Brain function network
### Category of Auditory Performance (CAP scores)

<table>
<thead>
<tr>
<th>score</th>
<th>Category of Auditory Performance score</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Use of telephone—known speaker</td>
</tr>
<tr>
<td>7</td>
<td>Understands conversation, no lipreading</td>
</tr>
<tr>
<td>6</td>
<td>Understand common phrases, no lipreading</td>
</tr>
<tr>
<td>5</td>
<td>Discrimination of speech sounds</td>
</tr>
<tr>
<td>4</td>
<td>Identification of environmental sounds</td>
</tr>
<tr>
<td>3</td>
<td>Response to speech sounds (e.g., go)</td>
</tr>
<tr>
<td>2</td>
<td>Awareness of environmental sounds</td>
</tr>
<tr>
<td>1</td>
<td>No awareness of environmental sounds</td>
</tr>
</tbody>
</table>

CAP $\geq 5$ good performers  
CAP $< 5$ poor performers
Results

In deaf children:

• Enhanced N1 Amp for both ‘sound’ and ‘nonsound’ photo
• Enhanced N2 Amp for ‘sound’ photo
Source analysis——N1

- Deaf children
- controls

Deaf children:
- BA 37 for ‘sound’ photo
- BA 18 for ‘nonsound’ photo

And ‘sound’ photo > ‘nonsound photo’

Controls:
- BA 37 for ‘sound’ photo
- BA 18 for ‘nonsound’ photo

Stronger activation of **BA41 and BA42** were found in deaf children
Source analysis— N2

- Both deaf children and controls on BA37 for either ‘sound’ photo or ‘nonsound’ photo
- Deaf children had stronger response

Stronger responses were found in BA42 in deaf children than controls
<table>
<thead>
<tr>
<th></th>
<th>Latency</th>
<th></th>
<th>amplitude</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>P</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td>age</td>
<td>2.47 (3,19) *</td>
<td>0.093</td>
<td>7.76 (3,19)</td>
<td>0.001</td>
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<tr>
<td>Stimuli type</td>
<td>5.14 (1,19)</td>
<td>0.061</td>
<td>10.71 (1,19)</td>
<td>0.004</td>
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<td>electrodes</td>
<td>4.33 (1,19)</td>
<td>0.051</td>
<td>0.17 (1,19)</td>
<td>0.685</td>
</tr>
<tr>
<td>Age*stimuli type</td>
<td>4.56 (3,19)</td>
<td>0.092</td>
<td>0.38 (3,19)</td>
<td>0.766</td>
</tr>
<tr>
<td>Age*electrodes</td>
<td>2.38 (3,19)</td>
<td>0.077</td>
<td>0.46 (3,19)</td>
<td>0.713</td>
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<tr>
<td>Stimuli type* electrodes</td>
<td>0.51 (1,19)</td>
<td>0.482</td>
<td>0.43 (1,19)</td>
<td>0.520</td>
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<tr>
<td>Age<em>stimuli type</em> electrodes</td>
<td>3.08 (3,19)</td>
<td>0.081</td>
<td>0.786 (3,19)</td>
<td>0.516</td>
</tr>
<tr>
<td></td>
<td>Latency</td>
<td>amplitude</td>
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<td></td>
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<tr>
<td></td>
<td>F</td>
<td>P</td>
<td>F</td>
<td>P</td>
</tr>
<tr>
<td><strong>age</strong></td>
<td>2.81 (3,19) *</td>
<td>0.067</td>
<td>7.76 (1,19)</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Stimuli type</strong></td>
<td>3.40 (1,19)</td>
<td>0.081</td>
<td>46.48 (1,19)</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>electrodes</strong></td>
<td>0.16 (1,19)</td>
<td>0.690</td>
<td>0.11 (1,19)</td>
<td>0.746</td>
</tr>
<tr>
<td><strong>Age*stimuli type</strong></td>
<td>0.21 (3,19)</td>
<td>0.892</td>
<td>0.25 (1,19)</td>
<td>0.863</td>
</tr>
<tr>
<td><strong>Age*electrodes</strong></td>
<td>0.32 (3,19)</td>
<td>0.812</td>
<td>4.72 (1,19)</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Stimuli type*electrodes</strong></td>
<td>0.21 (1,19)</td>
<td>0.655</td>
<td>26.59 (1,19)</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Age<em>stimuli type</em>electrodes</strong></td>
<td>0.63 (3,19)</td>
<td>0.605</td>
<td>0.94 (1,19)</td>
<td>0.443</td>
</tr>
</tbody>
</table>

FC3, 'sound'; FC3, 'nonsound'; FC4, 'sound'; FC4, 'nonsound';
N1 Lat (ms); N1 Amp (uV)
Summaries for Q1

- Auditory cortex contributes to photo processing, especially in deaf children and to ‘sound’ photo.

- Visual take-over of auditory cortex happens in the prelingual deaf children
  - Visual evoked enhanced N1,N2 response
  - Stronger response in BA41 and BA42, especially to ‘sound’ photo

- The visual take-over increases as the age increases in children
  - N1 and N2 amplitude increased across the age

Q1. Does the vision matter on the auditory cortex in prelingual deaf children?
Vision matters on auditory cortex post CI and its related to auditory outcomes
N. of cases

Cl periods

N=176

- good performers
- poor performers

1M 3M 6M 12M

0 6 12
32

0 6 12
26 22

38 40
Deaf children

Amplitude (μV)

FC3

N1 N2

FC4

N=24 N=38 N=46 N=48 N=44

Blue line: ‘sound’ photo
Red line: ‘nonsound’ photo

Amplitude (μV)
BA41, BA42 source analysis

- BA41R: sing
- BA41R: read
- BA41L: sing
- BA41L: read
- BA42R: sing
- BA42R: read
- BA42L: sing
- BA42L: read

Graphs showing the distribution of deaf children across different ages (1M, 3M, 6M, 12M).
Functional network analysis

- Good, ‘sound’
- Poor, ‘nonsound’

A/V ratio

deaf  CI1M  CI3M  CI6M  CI12M  controls

‘Sound’
‘nonsound’
### N2 Amp related to the CAP scores

<table>
<thead>
<tr>
<th></th>
<th>Good performers (n=64)</th>
<th>Poor performers (n=112)</th>
<th>p※</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FC3 N1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S (μV)</td>
<td>-13.2(2.2)</td>
<td>-13.9(1.8)</td>
<td>0.72</td>
</tr>
<tr>
<td><strong>NS (μV)</strong></td>
<td>-12.8(1.3)</td>
<td>-11.6(1.6)</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>FC3 N2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S (μV)</td>
<td>-9.6(0.8)</td>
<td>-11.8(1.1)</td>
<td>0.03</td>
</tr>
<tr>
<td><strong>NS(μV)</strong></td>
<td>-7.8(1.0)</td>
<td>-10.8(1.3)</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>FC4 N1</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S (μV)</td>
<td>-13.2(1.3)</td>
<td>-13.8(1.8)</td>
<td>0.28</td>
</tr>
<tr>
<td><strong>NS (μV)</strong></td>
<td>-12.6(1.5)</td>
<td>-13.2(1.6)</td>
<td>0.24</td>
</tr>
<tr>
<td><strong>FC4 N2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S (μV)</td>
<td>-9.7(0.9)</td>
<td>-11.2(0.8)</td>
<td>0.04</td>
</tr>
<tr>
<td><strong>NS(μV)</strong></td>
<td>-7.6(0.7)</td>
<td>10.8(1.2)</td>
<td>0.03</td>
</tr>
</tbody>
</table>

At FC3, N2 Amp had negative relation to CAP scores \( r_{\text{sound}} = -0.754, p<0.05; \)
\( r_{\text{nonsound}} = -0.823, p<0.01 \)

At FC4, N2 Amp also had negative relation to CAP scores.
\( r_{\text{sound}} = -0.354, p<0.05; \)
\( r_{\text{nonsound}} = -0.423, p<0.01 \)
Summaries for Q2

- N1, N2 amplitudes decreased, significantly from 6M for N1, and 12M for N2.
- BA41 and 42 was significant stronger activated by visual stimuli at 6M post CI, especially for ‘sound’ photo. Then the activation decreased.
- Brain function network showed an increase in auditory-visual communication at early stage post CI, then decreased.

• This results further confirm the visual take-over of auditory cortex, and the auditory cortex contributes to the visual processing.
• Reversal of visual take-over starts at about 3-6 month post CI

2. How does the vision matter on auditory cortex in childen post CI? is it related to the auditory outcomes?
Summaries for Q2

- Brain function networks showed a different pattern post CI in good performers comparing to poor performers
- N2 amplitude was negatively related to the CAP scores.

• The impact of vision on the auditory cortex is related to the auditory outcomes in CI children
• N2 amplitude might be a suitable parameter to reflect the vision’s impact on auditory cortex.
Discussions

• Our results confirm the form of vision’s impact on the auditory cortex in prelingual deaf children and with CI, and it’s related to the auditory outcomes post CI

• Further research should take a longer longitudinal follow-up study

• To find out if different study styles (e.g. with vs without sign language) would affect the visual take-over and auditory outcomes.
Thanks for the gathering in Toronto,
Thanks very much for your attention!

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