Effects of Frequency Compression on Aided Cortical Evoked Potentials of Children with Hearing Loss

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Introduction

• Perception of high-frequency sounds is important for children’s language development.

• High frequency speech sounds are low in intensity -> Difficult for hearing impaired children to achieve comfortable audibility.

• Current conventional hearing aid technology have a limited ability to provide adequate amplification in the high frequencies.

• To overcome this limitation, frequency compression (FC) technology is designed for improving the audibility of high frequency sounds.

![Graph showing frequency compression technology](image)
Introduction

/isɪ/ - /iʃi/

Unprocessed

CT: 4kHz
CR: 2.5:1

CT: 2.5kHz
CR: 1.7:1

CT: 1.5kHz
CR: 4:1
• Recent studies suggest that FC processing can improve high frequency speech recognition and speech production for older children and adults.

• There is insufficient evidence to indicate that FC is beneficial for development of speech and language for young children -> not possible to obtain reliable results from speech perception testing for young children.

• The cortical auditory evoked potentials (CAEP) represent summed neural activity in the auditory cortex in response to sounds.

• Measurements of CAEP have been used previously for evaluation of the effectiveness of hearing aids for infants and young children.

• The validity of this method has been reported, indicating a significant relation between the presence of cortical responses and speech perception scores, or functional measures of hearing ability.
The aim of this study was to use objective measurements of cortical response to speech sounds to evaluate the effect of FC in hearing aids for young children with different degrees of hearing loss.
Methods

Subjects

- N = 36 hearing-impaired children (18 boys, 18 girls)
- Age range: 2.8 to 7.6 years old (4.9 ± 1.4 yr)
- Conventional hearing aids usage experience: 2 to 6.7 yrs (4.1 ± 1.3 yr)
- Bilateral hearing aids users with conventional amplification.
- 4FA (0.5, 1, 2, and 4 kHz) HL in the better ear = 61 ± 17 dB HL
Methods

Procedure

• Phonak Naida V SP/UP behind the ear hearing aids
  - 16 channel hearing aid
  - wide dynamic range compression capabilities

• Hearing aid fitting
  - real ear measurement
  - NAL-NL1 (n = 18)
  - DSL[i/o] (n = 18)

• The FC parameters were selected according to the default settings in the Phonak fitting software and in consultation with experts from Phonak.
Methods

Cortical measurement

HearLab™ System

Free Field Speaker

Movie
Stimuli

Presentation level: 55, 65, or 75 dB SPL via loudspeaker at 0° azimuth
Methods

Recording

• Recording electrodes at vertex, forehead, mastoid.

• A CAEP response was judged to be present if the $p$-value was < 0.05.

• CAEPs were recorded in two conditions:
  - Own hearing aids
  - Naida hearing aids with FC on after 6 weeks
Results

Detection rate of cortical responses for /g/, /t/ and /s/ sounds

**55 dB SPL**

<table>
<thead>
<tr>
<th>Sound</th>
<th>Own aids</th>
<th>FC aids</th>
<th>Percentage of detection %</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>78</td>
<td>81</td>
<td><strong>94</strong></td>
</tr>
<tr>
<td>g</td>
<td>94</td>
<td>94</td>
<td><strong>97</strong></td>
</tr>
<tr>
<td>s</td>
<td>33</td>
<td>75</td>
<td><strong>75</strong></td>
</tr>
</tbody>
</table>

*p < 0.01

**65 dB SPL**

<table>
<thead>
<tr>
<th>Sound</th>
<th>Own aids</th>
<th>FC aids</th>
<th>Percentage of detection %</th>
</tr>
</thead>
<tbody>
<tr>
<td>t</td>
<td>94</td>
<td>100</td>
<td><strong>100</strong></td>
</tr>
<tr>
<td>g</td>
<td>97</td>
<td>97</td>
<td><strong>97</strong></td>
</tr>
<tr>
<td>s</td>
<td>75</td>
<td>97</td>
<td><strong>97</strong></td>
</tr>
</tbody>
</table>

*p < 0.05
Results

Mean detection rates at 55 and 65 dB SPL for two modes of amplification

On average, the mean detection rates of cortical responses for all 3 stimuli sounds were present more often with the FC aids than with the own hearing aids when stimuli were presented at 55 dB SPL.
Results

CAEP detection on /s/ sound stimulus at 55 dB SPL presentation level

<table>
<thead>
<tr>
<th></th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (n=11)</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Group 2 (n=15)</td>
<td>Present</td>
<td>Absent</td>
</tr>
<tr>
<td>Group 3 (n=10)</td>
<td>Absent</td>
<td>Absent</td>
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</table>
Results

Better ear audiogram of group 1 subjects

<table>
<thead>
<tr>
<th></th>
<th>CAEP.FC aids</th>
<th>CAEPOWN aids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 1</strong></td>
<td>Present</td>
<td>Present</td>
</tr>
</tbody>
</table>

Audiogram of better ear

- Hearing threshold level (dB HL)
- Frequency (Hz) 250, 500, 1000, 2000, 3000, 4000
- Lines represent different subjects: NL2, NL15, NL17, NL22, NL38, NL40, NL51, NL57, NL58, NL65
Better ear audiogram of group 2 subjects

<table>
<thead>
<tr>
<th>Group 2</th>
<th>CAEP.FC aids</th>
<th>CAEP.Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>Absent</td>
<td></td>
</tr>
</tbody>
</table>

Audiogram of better ear

- NL1
- NL4
- NL6
- NL9
- NL11
- NL18
- NL29
- NL32
- NL34
- NL36
- NL37
- NL39
- NL55
- NL59
- NL62
Results

Better ear audiogram of group 3 subjects

<table>
<thead>
<tr>
<th></th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 3</td>
<td>Absent</td>
<td>Absent</td>
</tr>
</tbody>
</table>

Audiogram of better ear

- Frequency (Hz)
- Hearing threshold level (dB HL)
Check audibility of high frequency /s/ sound by using coupler measurement

- Place a programmed hearing aid onto the RECD coupler, insert the REM probe tube into the coupler’s hole and position the REM headset and the device microphone equidistant from the loudspeaker.
Audibility

Check audibility of high frequency /s/ sound by using coupler measurement

- Play a recorded sustained /s/ stimulus at 55 dB SPL through Media Player
- Read through the coupler response in MedRx software at each 1/3 octave frequency point from 200 to 8000 Hz.
- REAR = Coupler response in SPL + RECD
- Audiometric thresholds is transformed to SPL
Example 1_NL58 from group 1

<table>
<thead>
<tr>
<th></th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>Present</td>
<td>Present</td>
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</tbody>
</table>

Better ear audiogram

![Graph showing hearing loss HL across different frequencies and audiogram](image)
### Audibility

**Example 2_NL 59 from group 2**

<table>
<thead>
<tr>
<th></th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 2</strong></td>
<td>Present</td>
<td>Absent</td>
</tr>
</tbody>
</table>

**Better ear audiogram**

- **Frequency (Hz)**: 250, 500, 1000, 2000, 3000, 4000, 6000, 8000
- **Hearing loss (HL)**: 0, 20, 40, 60, 80, 100, 120, 140

**CAEP_FC aids**

- **Better ear audiogram**
  - **Frequency Hz**: 200, 500, 1000, 2000, 3000, 4000, 6000, 8000
  - **dB SPL**: 20, 40, 60, 80, 100, 120, 140

Legend:
- FC on
- FC off
- HTL
Example 3 _NL 23 from group 3

<table>
<thead>
<tr>
<th>Group 3</th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Absent</td>
<td>Absent</td>
</tr>
</tbody>
</table>

Better ear audiogram

Audibility
Example 3 _NL 69 from group 3

<table>
<thead>
<tr>
<th>Group 3</th>
<th>CAEP_FC aids</th>
<th>CAEP_Own aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>69</td>
<td>Absent</td>
<td>Absent</td>
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</table>

![Better ear audiogram graph](image1)

![Frequency vs dB SPL graph](image2)
Discussion

- As measured by CAEP testing, children fitted with hearing aids according to the NAL or DSL prescription demonstrated good audibility of sounds presented at 65 dB SPL. At 55 dB SPL, detection of /s/ sound may be improved by implementing frequency compression.

- CAEP measures revealed that, on average, audibility at soft input levels was improved with frequency compression hearing aids than with own hearing aids.

- Audiometric configuration has an effect on the effectiveness of FC processing. Children with steeply slope hearing loss did not benefit from the use of FC processing. More varied results were obtained from children with mild to severe sloping loss, with some showing benefits whereas others not.
Discussion

• The absence of cortical responses for some children may be related to inadequate sensation levels of amplified sounds, especially for those with steeply sloping loss.

• Repeated testing may be necessary for children with no detectable cortical responses.

• Assessing audibility of high frequency sounds is useful. When hearing loss prevents access to high frequency sounds through conventional hearing aids or with FC off, it should be considered to activate FC.

• Cortical measurements can be used as an alternative method to evaluate the effectiveness of amplification. This objective testing should be supplemented by subjective evaluations of children’s auditory behavior.
Acknowledgements

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<th>Siemens</th>
<th>The University of Melbourne</th>
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<td>hybrid electronics</td>
<td>Murdoch Childrens Research Institute</td>
<td>MURIGEN</td>
<td>The Shepherd Centre</td>
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<td>The Royal Victorian Eye &amp; Ear Hospital</td>
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<td>The University of Queensland Australia</td>
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<td>Taralye the oral language centre for deaf children getting deaf kids talking</td>
<td>University of Wollongong</td>
<td>VICdeaf</td>
<td>Walter+Eliza Hall Institute of Medical Research</td>
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