CORTICAL AUDITORY EVOKED POTENTIAL (CAEP) AND BEHAVIOURAL MEASURES OF AUDITORY FUNCTION IN AN ADULT WITH A SINGLE SIDED DEAFNESS: CASE STUDY

Oscar M. Cañete1-2, Suzanne C. Purdy1-2, Colin Brown3, Michel Neeff3, Peter R. Thorne2-4

1Speech Science, School of Psychology, The University of Auckland
2Centre for Brain Research, The University of Auckland
3Starship Children’s Hospital, Auckland
4Audiology section, School of Population Health, The University of Auckland
Background

- Despite the presence of a normal hearing ear, adults with unilateral hearing loss (UHL) are at risk to experience difficulties recognizing speech in challenging environments, localising sounds and higher levels of disability.

  - (Brookhouser, Worthington, & Kelly, 1991; Lieu, 2004; Lieu, Tye-Murray, Karzon, & Piccirillo, 2010; Oyler & McKay, 2008; McLeod et al, 2008)
Background

• Acoustic Neuroma refers to a benign schwannoma of the eight cranial nerve

• Account for 8% to 10% of all intracranial tumours (Brackman & Arriaga, 2010)

• A single sided deafness (SSD) as a result of surgery (translabyrinthine approach) for the removal of a unilateral acoustic neuroma
Single Sided Deafness (SSD) definition

• Severe to profound unilateral sensorineural hearing loss (normal hearing in the opposite ear),

• poor word recognition scores,

• **unaidable** hearing or inability to tolerate amplified sounds

Audiological Approach

- Contralateral Routing of the Signal (CROS)
- Auditory Osseointegrated Implant System (AOIS)
  - PONTO (Oticon Medical), BAHA (Cochlear)

American Academy of Audiology
The aims of this case study were:

- to compare cortical auditory evoked potentials (CAEPs) and behavioural measures of spatial speech in noise recognition, sound localisation and self-reported perception of hearing performance before and after surgical removal of an acoustic neuroma,

- to monitor changes over time after surgery, and

- to compare results with and without use of a hearing instrument.
Case

- Male, 53 year
- Referred to ENT for sinus surgery
- Progressive hearing loss in right ear and tinnitus about 2yr previous consultation (2014)
- Two vertigo episodes (after ENT consultation)
- Occupation: Self-employed business professional
- Computerized axial tomography and MRI: Acoustic Neuroma right ear (6 cm)
- Treatment: surgery
Methodology

- Auditory skills and brain responses were assessed using:
  - Basic hearing assessment (pure tone audiometry, tymp and AR),
  - Sound localisation,
  - Spatial speech perception in noise,
  - CAEPs in noise and
  - self-ratings of spatial listening (Speech, Spatial and Qualities of Hearing questionnaire, short version) questionnaire

*Measurements took place at two, six and one year after surgery and one month post use of a bone anchored device on a softband and CROS aid*
Sound Localisation

**Stimulus**
- Spondee word “French-fries” spoken by a female native speaker of New Zealand English

**Presentation level**
- 62 dB SPL on average, randomly varied between 54 and 70 dB SPL (roved +/- 8 dB).
Spatial Speech Perception in Noise

- Conditions tested:
  - Monaural Direct (MD): signal to good ear/noise to bad ear (+/- 45)
  - Monaural Indirect (MI): signal to bad ear/noise to good ear
  - Speech/noise in front (S0N0)

- Speech Material: CNC words (%) / BKB sentences (dB SNR)
Speech, Spatial and Qualities of Hearing Scale (SSQ) (Gatehouse & Noble, 2004)

• This questionnaire is designed to measure self-reported auditory disability across a wide variety of domains, reflecting the reality of hearing in the everyday world.

• Original version 49 questions

• SSQ12 short version (Noble et al, 2013), baseline & benefit
### CAEP protocol

<table>
<thead>
<tr>
<th><strong>Stimulus</strong></th>
<th><strong>Recording</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimuli: <em>speech syllables</em> (/di, gi, ti/)</td>
<td>Electrode montage: Cz, Fz, C3, C4, F3, F4, M1 and M2</td>
</tr>
<tr>
<td>Intensity level:</td>
<td>Number of averages: 150</td>
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<tr>
<td>• Speech: 65 dB SPL</td>
<td>Artefact rejection: ± 50 µV</td>
</tr>
<tr>
<td>• Multi-talker babble noise: 60 dB SPL</td>
<td>Time window: -100 ms pre-stimulus to 600 ms post stimulus</td>
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<td>Duration: 246 ms</td>
<td>Filter setting: 1-100 Hz Online, 30 Hz low pass post-hoc filter</td>
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<tr>
<td>Onset polarity: single onset polarity</td>
<td></td>
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<tr>
<td>Interstimulus interval (ISI): 942 ms</td>
<td></td>
</tr>
<tr>
<td>Transducers: Speakers</td>
<td>Number of runs: 2</td>
</tr>
</tbody>
</table>

*The speaker setup was the same as spatial speech recognition in noise test* with two conditions assessed (MD and MI conditions) | Subject state: awake, passive attention
Baseline (04-2014)

SNHL mod-sev RE
Tymp “A” bilateral
AR present LE, Absent RE

Post surgery (06-2014)

Profound SNHL RE
Tymp “A” bilateral
AR present LE, Absent RE
Sound Localisation

Aided condition: PONTO Plus (Oticon Medical)
Spatial Speech in Noise Recognition

BKB/A sentences

- SNR (dB)
  - Speech Bad Ear
  - Speech Good Ear
  - Speech/Noise Front

CNC words

- %
  - Speech Bad Ear
  - Speech Good Ear
SSQ12-B

Listening effort
Quality and naturalness
Identification of sound
Segregation
Distance and movement
Localisation
Speech in speech
Multiple speech streams
Speech in noise

Negative: worse (-5)
Zero: unchanged (0)
Positive: Better (5)

no change in self-perception in aided condition  PONTO (4 hrs daily use)
Normal-hearing subjects show predominant activation of the opposite hemisphere to the stimulated ear

Leading to physiological pattern of asynchrony and asymmetry over auditory cortices

Asymmetric pattern relates to contralateral dominance in the auditory pathway (Rosenzweig, 1951, Majkoski et al, 1971)
Functional asymmetry (using monaural stimulation)

- EEG (Khosla et al., 2003; Naatanen and Picton, 1987; Picton et al., 1999; Ponton et al., 2001),

- MEG (Kanno et al., 1996; Pantev et al., 1998; Ross et al., 2005) and

- fMRI methods (Jancke et al., 2002; Langers et al., 2005; Scheffler et al., 1998; Suzuki et al., 2002)

- All show that monaural stimulation results in greater activity over the hemisphere contralateral to the side of stimulation
Left Hemis (C3)  Right Hemis (C4)

Right ear presentation (Grand average)

Normal hearing: 11 adults (aged 18-33 years, < 20 dB HL)

Left Hemis (C3)  Right Hemis (C4)

Left ear presentation (grand average)
N1 Amplitude Contralateral Hemisphere Dominance (%)
N1 amplitude (contra vs ipsi)

A. Central

/di/

/gi/

/ti/

B. Frontal

/pre 2m 6m 12m

/pre 2m 6m 12m

/pre 2m 6m 12m
Effect of age group on the P1–N1 peak-to-peak amplitude obtained over right and left temporal electrode sites.

**P1-N1 Amplitude**


- 11 adults SSD (acoustic neuroma removal)
- Intensity discrimination limens (IDL) better than normative data in the good ear of SSD participants after tumour removal
- Did not measure speech perception in noise in good ear

Mean IDLs (Weber fractions) as a function of frequency (UD, filled symbols and solid line; Controls, open symbols and dashed line). Error bars denote ±1 standard deviation.
• Baseline
  • Reduced hemispheric asymmetry depending on stimuli and electrode location (Li et al, 2006; Morita et al, 2007)
  • Maslin et al, 2013, observed no change in hemispheric asymmetry (preservation of some degree of neural activity leading balancing)

• Abrupt profound unilateral deafness
  • Changes within first 2 months after HL onset for hemispheric asymmetry suggesting functional mechanisms such as unmasking thought disinhibition and/or gain of existing synapses (Maslin et al, 2013; McAlpine et al, 1997 and Wall et al, 2002)

• Longer periods >2 months, suggests structural and/or functional mechanisms.
  • Maslin et al, 2013 found an increase in the amplitude sources in the ipsilateral hemisphere

- 8 adults (20-58 years), steep high frequency hearing loss (> 6 months duration)

- Magnetoencephalographic (MEG) measurements allows non-invasive study of the human cortical functions
  - Auditory evoked magnetic field (AEF); N1m

- Three tone burst stimuli at different frequencies: One “lesion edge” frequency (next to steeply sloping hearing loss), two pre-lesion frequencies (normal hearing region)
Fig. 4 Estimated cortical strength for patient P5, calculated from measurements carried out 11 (session 1), 12 (session 2), 12.5 (session 3) and 13 (session 4) months after lesion onset (hearing loss).

Volker Dietrich, Matthias Nieschalk, Wolfgang Stoll, Ramesh Rajan, Christo Pantev
Cortical reorganization in patients with high frequency cochlear hearing loss
http://dx.doi.org/10.1016/S0378-5955(01)00282-9
What we found so far

• Spatial Speech Recognition performance decrease for the “advantageous” and “disadvantageous” condition and poor sound localisation abilities

• Limited benefits for speech in noise recognition and sound localisation using the bone conduction (softband) hearing device presented limited benefits for this client (Wazen et al, 2005; Niparko et al, 2003; Bosman et al, 2003)

  [although benefits have been reported for speech in noise recognition with short- and long-term of use of bone anchored devices (Lin et al, 2006; Linstrom et al, 2009; Nicolas et al, 2013; Monini et al, 2015)]

• Self-reported SSQ scores differed from NH adults; the quality scale showed the lowest scores, listening effort had the lowest score over time

• Non-monotonic cortical changes over time suggest different auditory plasticity processes are occurring
Take home message

- UHL (SSD) has negative effects on auditory abilities including spatial speech in noise recognition (including speech presented to the good ear) and sound localisation,

- Cortical responses change over time suggesting functional and/or anatomical changes, but these changes are non-monotonic, at least over the first year after deafness,

- People with UHL perceived significant listening difficulties in daily life, especially listening effort

- The use of functional assessments such as the SSQ 12 should be included in the audiological test battery in order to identify the areas in which the person with UHL experiences difficulties in everyday life,

- Audiological approach should be tailored according to the individual’s needs.

- More intense follow up needed for sudden onset of deafness due to dynamic changes in central auditory organisation
Acknowledgment