Evaluation of peripheral compression and auditory nerve fiber intensity coding using Auditory Steady-State Responses (ASSR)

Encina Llamas, Gerard; Epp, Bastian; M. Harte, James; Dau, Torsten

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Gerard Encina Llamas
Bastian Epp,
James M. Harte,
Torsten Dau,
Technical University of Denmark,
Interacoustics Research Unit,
Technical University of Denmark

27th of August, 2015
International Symposium on Auditory and Audiological Research (ISAAR), Nyborg (Denmark)
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The need for SUPRA-threshold evaluation
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Humans in clinics:

5-10% of patients self-report hearing difficulties while showing normal audiograms

Saunders and Haggard (1989, 1992); Kumar et al. (2007); Hind et al. (2011)
Humans in clinics:

- 5-10% of patients self-report hearing difficulties while showing normal audiograms

Saunders and Haggard (1989, 1992); Kumar et al. (2007); Hind et al. (2011)

Physiological studies in animals:

Normal behavioral thresholds with 80% loss of IHCs

Lobarinas et al. (2013)
The need for SUPRA-threshold evaluation

Humans in clinics:

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Physiological studies in animals:

Normal behavioral thresholds with 80% loss of IHCs

Lobarinas et al. (2013)

Auditory nerve fibers (ANF) deafferentation is not reflected as permanent threshold elevation

Kujawa and Liberman (2009), Lin et al. (2011), Furman et al. (2013)
Compression: Animal data
Compression: Animal data

Ruggero et al. (1997)
Compression: Animal data

Ruggero et al. (1997)
Compression: Auditory Steady-State Responses
Compression: Auditory Steady-State Responses

- The healthy cochlea shows a compressive growth as a function of stimulation level.

Ruggero et al. (1997)
Compression: Auditory Steady-State Responses

- The **healthy cochlea** shows a **compressive growth** as a function of stimulation level.

- ASSR reflect **envelope** coding.

\[
A \cdot \sin(2\pi f_c t) \cdot \left[ \frac{1 + m \cdot \sin(2\pi f_m t)}{2} \right]
\]

1 kHz @ 80 Hz

\[m = 85\%\]
Compression: Auditory Steady-State Responses

- The **healthy cochlea** shows a **compressive growth** as a function of stimulation level.
- ASSR reflect **envelope** coding.

\[ A \cdot \sin(2\pi f_c t) \cdot \left[ \frac{1 + m \cdot \sin(2\pi f_m t)}{2} \right] \]

1 kHz @ 80 Hz

\[ m = 85\% \]
Compression: Auditory Steady-State Responses

- The healthy cochlea shows a compressive growth as a function of stimulation level.
- ASSR reflect envelope coding.
- Compression affects to the envelope, hence it should affect to ASSR.

Rønne, F.M. (2012)
Research question
Is it possible to estimate **peripheral compression** using **ASSR**?
Results: A representative NH subject (N=13)
Results: A representative NH subject \((N=13)\)
Results: A representative NH subject (N=13)
Results: A representative HI subject (N=7)
Results: A representative HI subject \( (N=7) \)
Results: A representative HI subject (N=7)

A
(0.5 kHz @ 81 Hz)

B
(1 kHz @ 87 Hz)

C
(2 kHz @ 93 Hz)

D
(4 kHz @ 98 Hz)
Results: A representative HI subject (N=7)

A. (0.5 kHz @ 81 Hz)

B. (1 kHz @ 87 Hz)

C. (2 kHz @ 93 Hz)

D. (4 kHz @ 98 Hz)
Results: A representative HI subject (N=7)

A

(0.5 kHz @ 81 Hz)

ASSR magnitude [dB re 1 uV] vs Stimulus level [dB SPL]

B

(1 kHz @ 87 Hz)

ASSR magnitude [dB re 1 uV] vs Stimulus level [dB SPL]

C

(2 kHz @ 93 Hz)

ASSR magnitude [dB re 1 uV] vs Stimulus level [dB SPL]

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(4 kHz @ 98 Hz)

ASSR magnitude [dB re 1 uV] vs Stimulus level [dB SPL]
Results: A representative HI subject (N=7)
Results: A representative HI subject \((N=7)\)
Results: A representative HI subject  \((N=7)\)

- **A** (0.5 kHz @ 81 Hz)
- **B** (1 kHz @ 87 Hz)
- **C** (2 kHz @ 93 Hz)
- **D** (4 kHz @ 98 Hz)
Intermediate summary
**Intermediate summary**

A graph showing the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 μV). The x-axis represents the stimulus level in dB SPL, ranging from 15 to 95. The y-axis represents the ASSR magnitude in dB re 1 μV, ranging from -50 to -5.
Intermediate summary

![Graph showing ASSR magnitude vs. stimulus level]
**Intermediate summary**

![Graph showing ASSR magnitude vs. stimulus level](image)

- **Stimulus level [dB SPL]**: 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95
- **ASSR magnitude [dB re 1 \( \mu \text{V} \)]**: -50, -40, -30, -20, -10, -5, -0
Intermediate summary
Intermediate summary

![Graph showing the relationship between stimulus level [dB SPL] and ASSR magnitude [dB re 1 μV]. The graph includes a dotted line and several data points, indicating a general trend of increasing ASSR magnitude with increasing stimulus level.](image-url)
Intermediate summary

A graph showing the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 μV). The x-axis represents the stimulus level in dB SPL, ranging from 15 to 95. The y-axis represents the ASSR magnitude in dB re 1 μV, ranging from -50 to -10. The graph includes data points and a trend line indicating the increasing magnitude of ASSR with stimulus level.
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 \u03bcV]
Intermediate summary

Stimulus level [dB SPL]

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

ASSR magnitude [dB re 1 μV]

-50 -40 -30 -20 -10
Contribution of SR fibers to deafferentation
Contribution of SR fibers to deafferentation

Liberman (1978)
Yates (1990)
Contribution of SR fibers to deafferentation

Liberman (1978)
Yates (1990)
Contribution of SR fibers to deafferentation

Liberman (1978)
Yates (1990)

SPONTANEOUS RATE (SR) FIBERS

Discharge rate (sp/sec)
0 50 100 150 200 250
0 20 40 60 80 100
Stimulus level (dB SPL)
High-SR
Medium-SR
Low-SR
Contribution of SR fibers to deafferentation

Furman et al. (2013) showed that ANF “deafferentation” due to noise over-exposure is more selective to medium- and low-SR fibers.
Potential explanation
Potential explanation
Potential explanation

<table>
<thead>
<tr>
<th>Stimulus level [dB SPL]</th>
<th>ASSR magnitude [dB re 1 μV]</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>-50</td>
</tr>
<tr>
<td>30</td>
<td>-40</td>
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<tr>
<td>35</td>
<td>-30</td>
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<td>90</td>
<td>80</td>
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<tr>
<td>95</td>
<td>90</td>
</tr>
</tbody>
</table>

Full modulation (m = 100%)

Discharge rate (sp/sec)

Stimulus level (dB SPL)

Potential explanation
Potential explanation

- Stimulus level [dB SPL]: 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95
- ASSR magnitude [dB re 1 μV]: -50, -40, -30, -20, -10

- Full modulation (m = 100%)
- Shallow modulation (m = 25%)

Potential explanation

Graphs showing discharge rate (sp/sec) and ASSR magnitude as a function of stimulus level (dB SPL) and modulation.
Potential explanation
Potential explanation
Potential explanation
Potential explanation

Discharge rate (sp/sec)

Stimulus level (dB SPL)

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]

-50
-40
-30
-20
-10

Full modulation (m = 100%)
Shallow modulation (m = 25%)
Shallow modulation - Deafferentation

Potential explanation
Potential explanation
Potential explanation

- **Stimulus level [dB SPL]**
  - 25
  - 30
  - 35
  - 40
  - 45
  - 50
  - 55
  - 60
  - 65
  - 70
  - 75
  - 80
  - 85
  - 90
  - 95

- **ASSR magnitude [dB re 1 μV]**
  - -50
  - -40
  - -30
  - -20
  - -10

- Full modulation (m = 100%)
- Shallow modulation (m = 25%)
- Shallow modulation - Deafferentation

*Potential explanation by Bharadwaj et al. (2014)*
Pilot results: Individual NH subjects
Pilot results: Individual NH subjects

Subject: APG

ASSR magnitude [dB re 1 μV]

ASSR m = 100%
ASSR m = 85%
ASSR m = 50%
ASSR m = 25%
Linear Ref.

Stimulus level [dB SPL]

Subject: APG

ASSR m = 100%
ASSR m = 85%
ASSR m = 50%
ASSR m = 25%
Linear Ref.

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
Pilot results: Individual NH subjects

Subject: KGS

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]

ASSR m = 100%
ASSR m = 85%
ASSR m = 50%
ASSR m = 25%
Linear Ref.

Pilot results: Individual NH subjects
Pilot results: Individual NH subjects

Subject: IGC

ASSR magnitude [dB re 1 μV] vs. Stimulus level [dB SPL]

- ASSR m = 100%
- ASSR m = 85%
- ASSR m = 50%
- ASSR m = 25%

Linear Ref.
Pilot results: Individual NH subjects

Subject: IGC

- ASSR m = 100%
- ASSR m = 85%
- ASSR m = 50%
- ASSR m = 25%
- Linear Ref.

Bharadwaj et al. (2015)
Pilot results: Individual NH subjects
Pilot results: Individual NH subjects

Subject: APG

Subject: KGS

Subject: IGC

ASSR magnitude [dB re 1μV]

Stimulus level [dB SPL]
Next steps
Next steps
Next steps

Low exposure NH
Next steps

Low exposure NH

High exposure NH

High exposure mild HI
Next steps

Low exposure NH

High exposure NH

High exposure mild HI
• ASSR are already used in the clinics to estimate thresholds objectively

• **ASSR growth functions** are suggested to be used as a tool to assess compression (and loss of compression) at different frequencies simultaneously

• We hypothesize that ASSR growth functions at higher stimulation levels using shallow modulations reflect the integrity of ANFs
Thank you!

Mange tak!

Moltes gràcies!