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, Technical University of Denmark
James M. Harte, Interacoustics Research Unit
Torsten Dau, 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)
The need for SUPRA-threshold evaluation

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:

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

- Kujawa and Liberman (2009),
- Lin et al. (2011),
- Furman et al. (2013)

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

- Lobarinas 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.

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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
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)

B

(1 kHz @ 87 Hz)
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)
**Results:** A representative HI subject (N=7)

C

D

(2 kHz @ 93 Hz)

(4 kHz @ 98 Hz)

**NH**

**HI**
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

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 \mu V]
Intermediate summary

Assessment of Stimulus Response (ASSR) magnitude vs. Stimulus level [dB SPL].

- ASSR magnitude [dB re 1 μV]
- Stimulus level [dB SPL]

The graph shows a linear relationship between the stimulus level and the ASSR magnitude.
Intermediate summary

- Chart showing the relationship between ASSR magnitude [dB re 1 μV] and stimulus level [dB SPL].
- The graph displays a trend line indicating an increase in ASSR magnitude as the stimulus level increases.
Intermediate summary
Intermediate summary
Intermediate summary

![Graph showing ASSR magnitude vs. Stimulus level](image)
Intermediate summary
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]
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)
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

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, -5, 0, 5, 10

Graphs showing the relationship between discharge rate (sp/sec) and stimulus level (dB SPL) on the left, and ASSR magnitude [dB re 1 μV] and stimulus level (dB SPL) on the right.
Potential explanation
Potential explanation

- **Discharge rate (sp/sec)**
- **Stimulus level (dB SPL)**
- **ASSR magnitude [dB re 1 μV]**

**Graphs:**
- High-SR vs. Stimulus level (dB SPL)
- ASSR magnitude vs. Stimulus level (dB SPL)

**Potential explanation:**

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

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

Potential explanation
Potential explanation
Potential explanation

Bharadwaj et al. (2014)
Pilot results: Individual NH subjects
Subject: APG

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

Subject: KGS

ASSR magnitude [dB re 1 \(\mu\)V]

Stimulus level [dB SPL]

ASSR m = 100%
ASSR m = 85%
ASSR m = 50%
ASSR m = 25%
Linear Ref.
Subject: IGC

Pilot results: Individual NH subjects

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]

ASSR m = 100%
ASSR m = 85%
ASSR m = 50%
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Linear Ref.
Subject: IGC

Pilot results: Individual NH subjects

ASSR magnitude [dB re 1 \(\mu\)V]

Stimulus level [dB SPL]

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
Next steps
Next steps
Next steps

Low exposure NH
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!