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

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27th of August, 2015
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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:

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

![Graph showing BM velocity vs. Sound Pressure Level](image)

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.

\[
A \cdot \sin(2\pi f_c t) \cdot \left[ \frac{1 + m \cdot \sin(2\pi f_m t)}{2} \right] \quad \text{1 kHz @ 80 Hz}
m = 85\%
\]
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

B

C

D
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)

ASSR magnitude [dB re 1 nV]

Stimulus level [dB SPL]
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)
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]**
- -50
- -40
- -30
- -20
- -10

**Stimulus level [dB SPL]**

**ASSR magnitude [dB re 1 μV]**
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 \mu V]

Stimulus level [dB SPL]
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]

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

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

- ASSR magnitude [dB re 1 μV]
- Stimulus level [dB SPL]
- Data points showing a trend with increasing stimulus level leading to a decrease in ASSR magnitude.
Intermediate summary

![Graph showing the relationship between stimulus level and ASSR magnitude. The x-axis represents stimulus level in dB SPL, ranging from 15 to 95. The y-axis represents ASSR magnitude in dB re 1 μV, ranging from -50 to 0. The graph includes data points and trend lines indicating a linear relationship.]
Intermediate summary

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
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
Potential explanation
Potential explanation

![Graph showing discharge rate (sp/sec) vs stimulus level (dB SPL)](image)

- **High-SR**

![Graph showing ASSR magnitude (dB re 1 μV) vs stimulus level (dB SPL)](image)

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

- **Potential explanation**
Potential explanation
Potential explanation

Discharge rate (sp/sec)

Stimulus level (dB SPL)

ASSR magnitude [dB re 1 mV]

Stimulus level (dB SPL)

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

10

Potential explanation
Potential explanation
Potential explanation

The graphs illustrate the relationship between stimulus level (dB SPL) and discharge rate (sp/sec) for different SR levels: High-SR, Medium-SR, and Low-SR. The discharge rate is shown on the y-axis, while the stimulus level is on the x-axis.

The right graph shows the ASSR magnitude (dB re 1 μV) across different stimulus levels (dB SPL) for Full modulation (m = 100%), Shallow modulation (m = 25%), and Shallow modulation - Deafferentation.

The potential explanation is not explicitly stated in the image but typically involves the interpretation of these graphs in the context of auditory evoked responses and their modulations under different conditions.
Potential explanation

- High-SR
- Medium-SR
- Low-SR

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

ASSR magnitude [dB re 1 μV]

Stimulus level (dB SPL)

Discharge rate (sp/sec)

Stimulus level (dB SPL)
Potential explanation
Pilot results: Individual NH subjects
Subject: APG

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

Subject: KGS

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
Pilot results: Individual NH subjects

Subject: IGC

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV] vs Stimulus level [dB SPL] for Subject: IGC.

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]

Stimulus level [dB SPL]

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

Individual NH subjects

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

Subject: APG

Subject: KGS

Subject: IGC

ASSR magnitude [dB re 1 µV]

Stimulus level [dB SPL]
Next steps
Next steps
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!