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

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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

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Physiological studies in animals:

- Normal behavioral thresholds with 80% loss of IHCs

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

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: 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)
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%

EEG spectrum
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)
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Results: A representative NH subject \((N=13)\)
Results: A representative HI subject (N=7)
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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)

(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

[Graph showing the relationship between stimulus level (dB SPL) on the x-axis and ASSR magnitude (dB re 1 μV) on the y-axis. The graph is linear, indicating a direct correlation between the two variables.]
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]
Intermediate summary

The graph shows the relationship between the stimulus level in dB SPL and the ASSR magnitude in dB re 1 μV. The x-axis represents the stimulus level in dB SPL, while the y-axis represents the ASSR magnitude. The data points indicate a linear relationship between the two variables, with the ASSR magnitude decreasing as the stimulus level increases.
Intermediate summary

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

![Graph showing the relationship betweenASSR magnitude [dB re 1 μV] and Stimulus level [dB SPL]. The graph includes data points and a trend line.](image-url)
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 0 10 20 30 40 50
Intermediate summary

The graph illustrates 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 shows the ASSR magnitude, ranging from -55 dB to -5 dB. The graph includes data points for various stimulus levels, indicating a trend where the ASSR magnitude decreases as the stimulus level increases.
Contribution of SR fibers to deafferentation
Contribution of SR fibers to deafferentation

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

Liberman (1978)
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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**

A graph showing the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 V) for full modulation (m = 100%) and shallow modulation (m = 25%). The graph indicates a higher discharge rate at lower stimulus levels for full modulation compared to shallow modulation.

- **Discharge rate (sp/sec)**
  - X-axis: Stimulus level (dB SPL)
  - Y-axis: Discharge rate (sp/sec)

- **ASSR magnitude (dB re 1 V)**
  - X-axis: Stimulus level [dB SPL]
  - Y-axis: ASSR magnitude [dB re 1 V]

The graph appears to show a trend where higher stimulus levels lead to lower ASSR magnitudes, with full modulation resulting in consistently lower magnitudes compared to shallow modulation.
Potential explanation
Potential explanation
Potential explanation
Potential explanation

The graph on the left shows the discharge rate (sp/sec) at different stimulus levels (dB SPL) for High-SR, Medium-SR, and Low-SR conditions. The graph on the right illustrates the ASSR magnitude (dB re 1 μV) at various stimulus levels (dB SPL). The data points represent Full modulation (m = 100%), Shallow modulation (m = 25%), and Shallow modulation - Deafferentation.
Potential explanation

[Graph showing discharge rate vs stimulus level with curves for High-SR, Medium-SR, and Low-SR]

[Graph showing ASSR magnitude vs stimulus level with markers for Full modulation (m = 100%), Shallow modulation (m = 25%), and Shallow modulation - Deafferentation]

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Potential explanation

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]
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

Subject: IGC

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

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]

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Pilot results: Individual NH subjects

Subject: IGC

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

Subject: APG

ASSR m = 100%
ASSR m = 25%

Subject: KGS

Subject: IGC

ASSR magnitude [dB re 1 μV]

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
Conclusions

- 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!