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
Human 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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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

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

Ruggero et al. (1997)
Comression: 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.

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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)

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)
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- **A** (0.5 kHz @ 81 Hz)
- **B** (1 kHz @ 87 Hz)
- **C** (2 kHz @ 93 Hz)
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Results: A representative HI subject  \((N=7)\)
Intermediate summary
Intermediate summary

![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, while the y-axis represents the ASSR magnitude in dB re 1 μV, ranging from -50 to -10. The graph shows a linear increase in ASSR magnitude as the stimulus level increases.]
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
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

Stimulus level [dB SPL]
Intermediate summary
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
Intermediate summary

![Graph showing ASSR magnitude vs. Stimulus level](image-url)

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

Stimulus level [dB SPL]
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

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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

- 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

- Graph showing discharge rate (sp/sec) and ASSR magnitude for varying stimulus levels.
- Diagram illustrating full modulation (m = 100%).
Potential explanation
Potential explanation

- **Discharge rate (sp/sec)** vs **Stimulus level (dB SPL)**
- **ASSR magnitude [dB re 1 7V]** vs **Stimulus level [dB SPL]**
- **Full modulation (m = 100%)**
- **Shallow modulation (m = 25%)**

**Potential explanation**

- High-SR

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**Graphs showing discharge rate and ASSR magnitude across different stimulus levels.**
Potential explanation
Potential explanation
Potential explanation

![Graph showing discharge rate vs stimulus level.](image)

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

ASSR magnitude [dB re 1μV]

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

Stimulus level [dB SPL]

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

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] 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 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

**Subject: APG**

- ASSR m = 100%
- ASSR m = 25%

**Subject: KGS**

**Subject: IGC**

ASSR magnitude [dB re 1 μV] vs. 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

Graphs showing data.
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!