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

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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
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%
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
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)

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
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)

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B. (1 kHz @ 87 Hz)

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Intermediate summary
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]
Intermediate summary

The graph shows the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 μV). The ASSR magnitude decreases as the stimulus level increases. The data points are plotted along a linear trend line, indicating a consistent trend across the measured stimulus levels.
Intermediate summary
Intermediate summary

![Graph showing ASSR magnitude vs. Stimulus level in dB SPL]

- 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
Intermediate summary

The graph illustrates the relationship between stimulus level [dB SPL] and ASSR magnitude [dB re 1 \(\mu V\)]. 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 \(\mu V\), ranging from -50 to -10. The data points show a clear trend, indicating a linear correlation between stimulus level and ASSR magnitude.
Intermediate summary

![Graph showing ASSR magnitude vs. Stimulus level](image)
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 V):
- -50
- -40
- -30
- -20
- -10

Discharge rate (sp/sec):
- 0
- 50
- 100
- 150
- 200
- 250

Stimulus level (dB SPL):
- 0
- 20
- 40
- 60
- 80
- 100
Potential explanation
Potential explanation
Potential explanation
Potential explanation
Potential explanation
Potential explanation

The figure shows the relationship between stimulus level (in dB SPL) and discharge rate (sp/sec) for different levels of modulation. There are three modulation types: High-SR, Medium-SR, and Low-SR.

- **High-SR** shows a steep increase in discharge rate as stimulus level increases.
- **Medium-SR** has a gradual increase.
- **Low-SR** shows a linear increase.

The graph also illustrates the ASSR magnitude (in dB re 1 μV) for different stimulus levels. There are three modulation levels indicated:
- **Full modulation (m = 100%)**
- **Shallow modulation (m = 25%)**
- **Shallow modulation - Deafferentation**

The potential explanation suggests that the observed patterns may be related to the modulation level and the effect of deafferentation on ASSR magnitude.

The diagrams further illustrate the modulation effect on the discharge rate and ASSR magnitude, highlighting the differences across modulation levels.
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]

Stimulus level [dB SPL]

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

Linear Ref.
Pilot results: Individual NH subjects

Subject: KGS

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

-50 -40 -30 -20 -10

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.

Pilot results: Individual NH subjects
Subject: IGC

ASSR magnitude [dB re 1 μV]

Stimulus level [dB SPL]

-50 -40 -30 -20 -10

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.

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] vs. Stimulus level [dB SPL]

ASSR m = 100%
ASSR m = 25%
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!