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

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
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.

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

\[
m = 85\%
\]
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**

\[m = 85\%\]
**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**.

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**Compression**

**Auditory Steady-State Responses**

- **Frequency (Hz)**
- **Magnitude (dB)**

Rønne, F.M. (2012)
Research question
Is it possible to estimate \textit{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)
Results: A representative HI subject (N=7)
Results: A representative HI subject  \((N=7)\)
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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 \( \mu \)V]
-50 -40 -30 -20 -10 0 10 20 30 40 50

Stimulus level [dB SPL]
Intermediate summary

![Graph showing ASSR magnitude versus stimulus level]

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

![Graph showing ASSR magnitude vs Stimulus level in dB re 1 μV. The graph displays a linear trend with data points and a trend line.](attachment:image.png)
Intermediate summary

The graph shows the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 μV). The x-axis represents the stimulus level in dB SPL, while the y-axis represents the ASSR magnitude in dB re 1 μV. The data points are distributed along a trend line, indicating a positive correlation between stimulus level and ASSR magnitude.
Intermediate summary
Intermediate summary

Stimulus level [dB SPL]

ASSR magnitude [dB re 1 μV]
Intermediate summary

Stimulus level [dB SPL]

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)

SPONTANEOUS RATE (SR) FIBERS

Discharge rate (sp/sec)

Stimulus level (dB SPL)
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 the relationship between stimulus level (dB SPL) and discharge rate (sp/sec).]

- **High-SR**

![Graph showing the relationship between stimulus level (dB SPL) and ASSR magnitude (dB re 1 μV).]

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

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Potential explanation

![Waveforms illustrating high and shallow modulation.]

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

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

Subject: APG

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
Pilot results: Individual NH subjects

**Subject: KGS**

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

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

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
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!