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:

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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

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

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
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%
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**.
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)

(1 kHz @ 87 Hz)
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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Intermediate summary
Intermediate summary

Stimulus level [dB SPL]

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

Liberman (1978)
Yates (1990)
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

Potential explanation
Potential explanation

- **Graph 1:**
  - **X-axis:** Stimulus level (dB SPL)
  - **Y-axis:** Discharge rate (sp/sec)
  - **Graph Type:** Line graph
  - **Legend:** High-SR

- **Graph 2:**
  - **X-axis:** Stimulus level [dB SPL]
  - **Y-axis:** ASSR magnitude [dB re 1 μV]
  - **Legend:** Full modulation (m = 100%)

- **Potential Explanation:**
  - The discharge rate increases as the stimulus level increases, reaching a stable plateau.
  - The ASSR magnitude shows a decrease with increasing stimulus level, indicating a modulation effect.
Potential explanation
Potential explanation
Potential explanation
Potential explanation

[Graphs and data plots showing discharge rate, ASSR magnitude, and stimulus level.]
Potential explanation
Potential explanation

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

**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

**Full modulation (m = 100%)**

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

- **Shallow modulation - Deafferentation**

**Discharge rate (sp/sec)**

- 0
- 50
- 100
- 150
- 200
- 250

**Stimulus level (dB SPL)**

- 0
- 20
- 40
- 60
- 80
- 100
Potential explanation

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

Subject: APG

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

ASSR magnitude [dB re 1 µV] vs. Stimulus level [dB SPL]
Pilot results: Individual NH subjects

Subject: KGS

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

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
0
10
20
30
40
50
60
70
80
90
100

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

<table>
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<tr>
<th>Stimulus level [dB SPL]</th>
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**Linear Ref.**

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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!