Hearing Screening based on Sound Perception in Noise

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School-Age Hearing Screening Rationale
School-Age Hearing Screening in Flanders

3-4 yrs
risk analysis ($\rightarrow$ AUDIO\textsubscript{1+4kHz})

5-6 yrs
 AUDIO\textsubscript{1+4kHz}

10-11 yrs
SPIN-test

14-15 yrs
SPIN-test

10-11 yrs
SPIN-test
School-Age Hearing Screening in Flanders

3-4 yrs
risk analysis (→ AUDIO\(_{1+4kHz}\))

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AUDIO\(_{1+4kHz}\)

10-11 yrs
SPIN-test

14-15 yrs
SPIN-test
Pure Tone Audiometry
Pure Tone Audiometry

Trained Audiologist
Pure Tone Audiometry

Sound Proof Booth (absolute levels)
Pure Tone Audiometry

Full Audiogram

Hearing Thresholds
Screening Context

![Diagram of a person being tested for hearing thresholds.](image)

![Graph showing hearing thresholds for different frequencies.](image)
Screening Context

No Sound Proof Booth → Ambient Noise Levels!
Screening Context

Detection Thresholds
Screening Context

Other screening methods should be considered: **supra-threshold tests**
SPIN-test / Digit Triplet Test

De gehoorstest

Jouw LINKER oor wordt nu getest.

Reeks: 27/27

- Geef telkens drie cijfers in en klik daarna op Ok.
- Indien je niets hebt verstaan, moet je gokken.
- Je kunt een fout corrigeren door op de rode knop te tikken.

<table>
<thead>
<tr>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

→ 0 OK

“245” = 245

“245” = 235

Jansen (2013)
**SPIN-test / Digit Triplet Test**

**Test Outcomes**
- **Speech Reception Threshold (SRT)**: SNR with 50% prob. for correct identification
- **Standard Deviation (SD)**: stability/reliability of measurement

\[
SRT = \frac{\sum_{i=7}^{28} SNR_i}{22} \quad SD = \sqrt{\frac{1}{22} \sum_{i=7}^{28} (SNR_i - SRT)^2}
\]

Jansen (2013)
Advantages

No test-administrator / Low-cost equipment
Advantages

No sound-proof booth (relative levels)
Advantages
Sofie Jansen (2013)

- Test development
  - Normative values

- Test validation
  - Sensitivity & specificity for NIHL = 90%
  - Test-retest reliability = 0.7 dB

- Feasibility in 5E & 1E
Previous Research

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Sam Denys (ongoing)

• Application to SHS: 5E & 3S
  o Normative values & referral criteria

Next talk
Previous Research

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- Test Optimization
  - Digit Scoring Method

Optimizing the Digit Triplet Test for Mobile Devices and the Internet (under review)
Previous Research

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- Feasibility in 1E
  - Influence of cognitive abilities

Manuscript in prep.
Previous Research

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- Development of other tests for SES
  - Digit Triplet Pirates Game (intelligent game)
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  - Digit Triplet Pirates Game (intelligent game)
  - Sound Ear Check
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risk analysis (→ AUDIO\(_{1+4kHz}\))

5-6 yrs
SPIN-test??

10-11 yrs
SPIN-test

14-15 yrs
SPIN-test

3-4 yrs
working memory

5-6 yrs
short-term memory

10-11 yrs
Other confounders

14-15 yrs
attention span

KU LEUVEN
School-Age Hearing Screening in Flanders

Challenges:

- 3-4 yrs: risk analysis (→ AUDIO$_{1+4kHz}$)
- 5-6 yrs: SPIN-test??
- 10-11 yrs: SPIN-test
- 14-15 yrs: SPIN-test

Note: The diagram shows a flowchart indicating different hearing screening tests for different age groups.
School-Age Hearing Screening in Flanders

Challenges:

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risk analysis (→ AUDIO$^\text{1+4kHz}$)

5-6 yrs
SPIN-test??

10-11 yrs
SPIN-test

14-15 yrs
SPIN-test
School-Age Hearing Screening in Flanders

3-4 yrs risk analysis ($\rightarrow$ AUDIO$_{1+4kHz}$)

5-6 yrs SPIN-test??

10-11 yrs SPIN-test

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Challenges:

- Attention span
- Short-term memory
- Other confounders
- Language

KU LEUVEN
School-Age Hearing Screening in Flanders

- **3-4 yrs:** risk analysis (→ AUDIO$_{1+4kHz}$)
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**Challenges:**

- attention span
- short-term memory
- Other confounders
- Language
Intermezzo: Psychometric Functions

\[ \text{Intelligibility} = \frac{100}{100 + e^{4 \cdot \text{slope} \cdot (\text{SRT} - \text{SNR})}} \]

![Graph showing the relationship between SNR and intelligibility score. The graph includes data points for SRT = -9.7 [dB] and S_{50} = 24.9 [%/dB].]
Intermezzo: Psychometric Functions

Intelligibility = \frac{100}{100 + e^{4 \text{slope} \cdot (SRT - SNR)}}
Intermezzo: Psychometric Functions

Intelligibility = \frac{100}{100 + e^{4 \cdot \text{slope} \cdot (\text{SRT} - \text{SNR})}}

![Graph showing the relationship between intelligibility and SNR. The graph includes the SRT value of -9.7 dB, the slope value of 24.9 [%/dB], and the 25% intelligibility threshold. The 1 dB change in SNR is also indicated.]
Intermezzo: Psychometric Functions

Adaptive: 2-up 1-down

Adaptive: 1-up 1-down

![Graph showing psychometric function](image)

Intelligibility score [%] vs SNR [dB]

SRT = -9.7 [dB]

$S_{50} = 24.9$ [%/dB]
Sound Ear Check (SEC): adaptive sounds-in-noise test

Test Outcomes

- **Sound Reception Threshold (SRT)**: SNR with 50% prob. for correct identification
- **Standard Deviation (SD)**: stability/reliability of measurement

\[
SRT = \frac{\sum_{i=9}^{25} SNR_i}{17} \\
SD = \sqrt{\frac{1}{17} \sum_{i=9}^{25} (SNR_i - SRT)^2}
\]
Test Development: a 3 Step Process

Step 1: selection and preparation of sound & noise material

Spectro-temporal analysis & factor analysis
31 sounds (database UMC Leiden) & 8 words
Test Development: a 3 Step Process

Step 1: selection and preparation of sound & noise material

Selection of sounds that resemble speech
Originally 9 sounds
Test Development: a 3 Step Process

Step 1: selection and preparation of sound & noise material

Generation of broadband sound masker
Test Development: a 3 Step Process

Step 2: perceptual optimization [background]

Reduce spread in item-specific SRTs: item-specific level adjustments

→ Steep slope
Test Development: a 3 Step Process

**Step 2: perceptual optimization [method]**

- **2 optimization waves + validation of level adjustments**
  - **Participants**: N = 10 normal hearing adults per experiment
  - **Materials**:
    - Laptop connected to external soundcard (FireFace UC) & HDA200 headphones
    - Stimuli were monaurally presented via APEX 3.1 software
  - **Analysis**: PI-curves were fitted per sound, averaged across participants

- **Procedure Wave 1**
  - 6 random presentations per sound @ different SNRs
  - SNRs tested: 0, -5, -8, -10, -12, -14, -16, -18 dB SNR (noise @ 65 dB SPL)
  - List at 0 dB SNR was considered as training

- **Procedure Wave 2**
  - Training @ 0 dB SNR: 3 random presentations of each sound + feedback (👍👍)
  - 2x6 presentations per sound @ different SNRs (latin-squared randomized)
  - SNRs tested: -9, -11, -13, -15, -17 dB SNR (noise @ 65 dB SPL)

- **Procedure Validation** = procedure Wave 2
Test Development: a 3 Step Process

Step 2: perceptual optimization [results]

- Item-specific level adjustments were iteratively done
  - After Wave 1 adjustments varied between -1.9 and +1.5 dB
  - After Wave 2 adjustments varied between -0.5 and +0.5 dB

- Final adjustments:

<table>
<thead>
<tr>
<th>Sound</th>
<th>Adj. (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baby</td>
<td>-1.6</td>
</tr>
<tr>
<td>Claxon</td>
<td>-1.8</td>
</tr>
<tr>
<td>Hond</td>
<td>-0.7</td>
</tr>
<tr>
<td>Kat</td>
<td>-2.8</td>
</tr>
<tr>
<td>Piano</td>
<td>-1.2</td>
</tr>
<tr>
<td>Telefoon</td>
<td>-2.5</td>
</tr>
<tr>
<td>Torenklok</td>
<td>-4.3</td>
</tr>
<tr>
<td>Vogel</td>
<td>-11.0</td>
</tr>
</tbody>
</table>

SRT = -13.0 +/- 0.5 dB
Slope = 14.6 +/- 2.5 %/dB
Test Development: a 3 Step Process

Step 3: final evaluation [method]

• Participants:
  - N = 10 normal hearing adults
  - N = 14 normal hearing children (5-6 yrs old)

• Materials:
  - Laptop connected to external soundcard (FireFace UC) & HDA200 headphones
  - Stimuli were monaurally presented via APEX 3.1 software

• Procedure:
  - Pure Tone Audiometry (adults) & PTA$_{1-4kHz}$ (children)
  - SEC Training:
    • 3 random presentations of each sound
    • @ 0 dB SNR (noise fixed @ 65 dB SPL)
    • Feedback (✔️✔️)
  - 2-up 1-down procedure: test-retest

Goal: obtain reference data & quantify test precision
Test Development: a 3 Step Process

**Step 3: final evaluation [results]**

<table>
<thead>
<tr>
<th></th>
<th>Adults (N = 10)</th>
<th>Children (N = 14)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Threshold: SRT (dB SNR)</strong>*</td>
<td>-12.6 +/- 1.0</td>
<td>-8.9 +/- 1.3</td>
</tr>
<tr>
<td><strong>Stability: SD (dB SNR)</strong>*</td>
<td>1.7 +/- 0.2</td>
<td>1.9 +/- 0.5</td>
</tr>
<tr>
<td><strong>Test duration (min:sec)</strong>*</td>
<td>2:07 +/- 0:09</td>
<td>2:58 +/- 0:27</td>
</tr>
<tr>
<td><strong>Precision (dB)</strong></td>
<td>0.6</td>
<td>1.3</td>
</tr>
</tbody>
</table>

*Averaged across test and retest

° 1 ear
SEC Future Research Perspectives

- Test validation:
  - Sensitivity & specificity to detect HL
  - Correlations with Digit Triplet Test

- Pilot results (N = 22 normal hearing & N = 11 hearing impaired adults) are promising
SEC Future Research Perspectives

• EU pilot study (EFAS)
  o Language independancy of SEC
  o Comparison SES methodology with SEC
  o Link NHS result with SEC: prevalence
Thank you!

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