Speech-in-Noise Hearing Screening: the new Golden Standard

Drs. S. Denys
Dr. Ir. M. Hofmann
Prof. Dr. A. van Wieringen
Prof. Dr. J. Wouters

Dept. Neurosciences | ExpORL
Hearing Screening Rationale

• Hearing impairment in children has a negative impact on speech- and language development, communication and academic abilities
  o Newborn Hearing Screening (NHS)
  o School-age Hearing Screening (SHS)

• Hearing impairment in adults can lead to psychosocial dysfunctioning (social isolation and depression) and cognitive decline
  o Adult Hearing Screening (AHS)
Hearing Screening Through the Life Span

- **NHS Kind & Gezin**
  - 2-6 wks ASSR

- **SHS Centrum voor LeerlingenBegeleiding**
  - 3-4 yrs risk analysis
  - 5-6 yrs AUD$_{1+4kHz}$
  - 10-11 yrs SPIN
  - 14-15 yrs SPIN

- **AHS online/OHS**
  - 18+ yrs no standard

**Conditions**
- **congenital HL**
  - mild + late onset + progressive HL
- **acquired (noise-induced) HL**
- **age-related/ noise-induced HL**
Hearing Screening Through the Life Span

New standard fully implemented since 2016-2017

NHS
Kind & Gezin

2-6 wks
ASSR

congenital HL
mild + late onset + progressive HL

3-4 yrs
risk analysis

5-6 yrs
AUD_{1+4kHz}

10-11 yrs
SPIN

14-15 yrs
SPIN

SHS
Centrum voor LeerlingenBegeleiding

acquired (noise-induced) HL

AHS
online/OHS

18+ yrs
no standard

age-related/noise-induced HL
Hearing Screening Through the Life Span

- **2-6 wks**
  - ASSR
  - congenital HL

- **3-4 yrs**
  - risk analysis
  - mild + late onset + progressive HL

- **5-6 yrs**
  - AUD_{1+4kHz}
  - acquired (noise-induced) HL

- **10-11 yrs**
  - SPIN

- **14-15 yrs**
  - SPIN

- **18+ yrs**
  - no standard
  - age-related/ noise-induced HL

OHC = Occupational Health Services
Pure Tone Screening Protocols

- Pure tone screening protocols lack accuracy, sensitivity and validity to detect mild sensorineural hearing loss

  - **Accuracy:**
    - detection thresholds ≠ hearing thresholds (often no sound-proof booths)
    - importance of absolute calibration
    - qualified test administrator needed

  - **Sensitivity:**
    - cochlear damage = threshold elevation + distortion
    - “Ik hoor wel, maar versta niet

  - **Validity:**
    - communication ≠ detection of beeps
Speech-in-Noise Hearing Screening [1]

- Speech is presented in background noise at different signal-to-noise ratios (SNR) for identification
  - SNR = level of speech (in dB) relative to level of noise (in dB)

- SNR is varied, depending on the response of the subject (correct or incorrect identification) = adaptive test procedure

- Speech Reception Threshold (SRT) +/- SD is determined
  - SRT = SNR (in dB) with a certain probability of correct identification, e.g. 50%
  - SD = stability of measurement (standard deviation)

- SRT is compared to a pass/fail-criterion
Speech-in-Noise Hearing Screening [2]

SRT = -10.8 dB
SD = 1.2 dB
Digit Triplet Test: the Test

- Digit Triplet Test (DTT) = prototype SPIN-test
  - Automated self-test
  - 27 triplets per ear in speech-shaped noise
    - Triplet = random combination of 3 digits, e.g. 2 4 5
  - Level of speech varies in 2 dB steps
  - Noise level fixed at 65 dB SPL

- Available in > 15 languages*
  - Very comparable!

---

**De gehoor test**

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>Reference-SRT (± 2 SD)</th>
<th>245</th>
</tr>
</thead>
<tbody>
<tr>
<td>VL</td>
<td>7, 8, 9</td>
</tr>
<tr>
<td>FR</td>
<td>4, 5, 6</td>
</tr>
<tr>
<td></td>
<td>1, 2, 3</td>
</tr>
</tbody>
</table>

*EU-project HearCom
Digit Triplet Test: advantages

- **Robust:**
  - Suprathreshold test: no sound proof booth needed
  - Relative levels (SNR): absolute calibration less important
- **Fast:** automated self-test → no test administrator needed
- **Uniform:** 1 threshold per ear
- **Easy:** low load on language and cognitive skills
- **Relevant** to human communication
- **Precise:** measurement error < 1 dB (important for follow-up!)
- **Sensitivity and specificity of 90%** to detect mild SNHL
  - Minimal influence of mild conductive losses (e.g. cold)
- **Portable:** low-tech audio equipment is sufficient (e.g. tablet)
  - Tablet platform with local and central storage of results available
Digit Triplet Test: validation study

- Study sample: 118 noise-exposed workers, 22-59 yrs
- Tests: Digit Triplet Test (2x) + audiometry
- Results:
  - Test reliability = 0.8 dB
  - Strong linear PTA-SRT correlation
  - High sensitivity and specificity (90%) to detect mild SNHL

Pilot projects are running in occupational health companies in Flanders

Jansen, 2013
Digit Triplet Test: application to SHS

- Pilot study in 11/72 CLB
  - N = 3412 5th grade elementary school children (5E, 9-12 years)
  - N = 3617 3rd grade secondary school children (3S, 13-16 years)

- Referral for validation audiometry according to preliminary pass/fail-criteria
  - -7.2 dB (5E)
  - -8.5 dB (3S)

- Study aims:
  - Investigate reliability and feasibility of the test
  - Determine optimal pass/fail-criteria
Digit Triplet Test: application to SHS

-9.8 (±1.8) dB 0.6 dB (ME)
-10.5 (±1.6) dB 0.6 dB (ME)

FP: 15%
FN: 15%
TP: 10%
TN: 60%

FP: 10%
FN: 20%
TP: 20%
TN: 50%

1.1% refer
2.0% refer

Denys et al., to be submitted (Ear & Hearing)
Digit Triplet Test: application to SHS

0.2 dB improvement per year between 9 and 16 years of age

$SRT = -0.16 \times \text{age} - 8.21, \ R^2 = 0.15$
Digit Triplet Test: application to SHS

Stability!
Digit Triplet Test Platform Evolutions

- **DTT\textsubscript{NL}**
  - Via telefoon
  - Limited bandwidth

- **DTT\textsubscript{VL/FR}**
  - Via internet
  - Different transducers

- **DTT\textsubscript{VL/FR}**
  - Via pc-platform
  - Portability +/- precision +/-

- **DTT\textsubscript{VL/FR}**
  - Via tablet-platform
  - Portability ++ precision ++
Digit Triplet Test Platform Requirements

• Portability: tests in schools, medical institutions, companies

• Price: low software/hardware and operating cost

• Flexibility: configurable/modifiable (open source)
  o Language, personal info, cut-offs, number of triplets, ...

• Connectivity: connect to (student) administrations and registration systems
  o Via WIFI or 3G/Hotspot

• Robust: easy to calibrate
Digit Triplet Test Platform: our solution

• Hardware
  o 7” Android Tablet (currently version 4.4)
    • Internal sound card op to 80-90 dB SPL
    • Google Nexus (Asus) or Samsung Galaxy
  o THD39/DD45 in peltor caps
    • Flat frequency response up to 8 kHz
    • 30-40 dB passive attenuation
    • Yearly calibration
  o USB charger
    • One charge for at least one day

• Software
  o Javascript/HTML/CSS on Cordova/Android
  o Works offline, but also cloud-connected
Digit Triplet Test Platform: our solution

• Server
  o Central storage of results
  o Communication with tablets: transfer of
    • Personal information (e.g. Classlist of to test children)
    • Results from tablet (also local storage)
    • Calibration certificates
    • Configuration certificates

• Installation of app on tablet = 10 min (can happen in parallel)
• Calibration of test = 5-10 min
• Currently, we are managing 450 tablets
Customization

![Diagram showing the process]

**Server ExpORL**

- Tablet haalt gegevens op
- Tablet stuurt resultaat op
- Leerling doet de test
- CLB-medewerker selecteert lln
- Klaslijst

---

**Je gegevens**

Gelieve hieronder alle gegevens te controleren.

- **Voornaam**
- **Achternaam**
- **Geboortedatum**: 20/05/2005
- **Geslacht**: Jongen
- **Leerjaar**: 5

---

**De gehoorstest**

Jouw LINKER oor wordt nu getest.

Reeks: 1/27

- Geef telkens drie cijfers in en klik daarna op OK.
- Indien je niets hebt verstaan, moet je gekken.
- Je kunt een fout corrigeren door op de rode knop te tikken.
Current and Future Research Perspectives [1]

- Digit Triplet Test Across the Life Span
  - Normative values for middle-aged (and older) persons
    - Adjust cut-offs to maximize sensitivity & specificity values
  - Feasibility in younger children (school-entry)
    - Impact of cognitive abilities (e.g. number knowledge, memory)
    - Intelligent game?
    - Sounds-in-noise test?
  - Longitudinal evaluations of hearing, prevalence estimates of childhood hearing
    - Link NHS and SHS database, population level analysis
  - Validation of failed SPIN
    - In children, not always confirmed by audiogram (more sensitive to early signs of NIHL? Auditory processing disorder? Attention?)
DTT in middle-aged persons (40-60 yrs)

<table>
<thead>
<tr>
<th>DTT BB</th>
<th>20-30 yrs</th>
<th>40-60 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>“good”</td>
<td>$\text{SRT} &lt; -10.3 \text{ dB SNR}$</td>
<td>$\text{SRT} &lt; -9.7 \text{ dB SNR}$</td>
</tr>
<tr>
<td>“insufficient”</td>
<td>$-10.3 \text{ dB SNR} \leq \text{SRT} \leq -9.2 \text{ dB SNR}$</td>
<td>$-9.7 \text{ dB SNR} \leq \text{SRT} \leq -8.4 \text{ dB SNR}$</td>
</tr>
<tr>
<td>“poor”</td>
<td>$\text{SRT} &gt; -9.2 \text{ dB SNR}$</td>
<td>$\text{SRT} &gt; -8.4 \text{ dB SNR}$</td>
</tr>
</tbody>
</table>

Application of pass/fail-criterion for young people to middle-aged population causes large drop in specificity.

Sensitivity: 65%
Specificity: 95%
Sensitivity: 92%
Specificity: 92%

Vercammen et al., in prep.
Current and Future Research Perspectives [2]

- Procedural optimization of the test
  - Increasing precision or shortening the procedure

  
  digit scoring with variable step size:
  \[ 4 \left( \frac{n}{3} - 0.76 \right), \ n = \# \text{ correct digits} \]
  (Brand & Kollmeier, 2002)
Current and Future Research Perspectives [2]

- Procedural optimization of the test
  - Other staircase metrics to flag unreliable measurements
  - E.g. Slope > 0 to characterize attention dwells (sustained attention)

\[ r = -0.87, \ p < 0.01 \ (N=11, \ 6-7 \ yrs) \]
Take-Home Message

• Hearing screening throughout the life span is imperative
  o For longitudinal evaluations, validated and precise screening instruments are needed, that are quick and easy to administer, broadly applicable, robust, portable and cheap
  o We offer a DTT tablet platform that fulfills these requirements
  o Its flexibility/configurability and automatic registration of data make the test interesting for use in both occupational and school/youth healthcare
  o The DTT tablet platform is the new standard for hearing screening in CLB

• A lot of research is being conducted on further optimization and validation of the test (in children)
Vragen?

contact: sam.denys@kuleuven.be