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Individual Variability in the Aided Acceptable Noise Level Test

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USF ASSL Research

- Age-related changes in audition – presbycusis (NIH NIA P01; NIH NIDCD F32)
- Voice quality perception and modeling (NIH NIDCD R01)
- Neural-correlates of auditory perception (NIH NIA P01; USF)
- Hearing Enhancement Technology (NSF, Corporate Partners)

Introduction — Background — Methodology — Results — Discussion — Take Home Message
Individual Variability in the Aided Acceptable Noise Level Test
What is HA success?

- Measurable improvement in audibility
- Improved speech understanding in noise
- Full-time/frequent use of HA

Chief complaint in noise
- Clarity
- Comfort

ANL
- Results may predict HA success!

ANL & Hearing Aid Success

Introduction — Background — Methodology — Results — Discussion — Take Home Message

Nabelek et al. (2006): Unaided ANL can predict hearing aid success with 84.8% accuracy

<table>
<thead>
<tr>
<th>ANL Cohort</th>
<th>Range (dB)</th>
<th>Example (MCL-BNL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>&gt;13</td>
<td>60 - 45 = 15</td>
</tr>
<tr>
<td>Mid</td>
<td>Between 7 and 13</td>
<td>60 - 49 = 11</td>
</tr>
<tr>
<td>Low</td>
<td>&lt;7</td>
<td>60 - 53 = 7</td>
</tr>
</tbody>
</table>

- Low ANLs
  - Tolerate more background noise → Full time → “Successful user”
- High ANLs
  - Tolerate less background noise → Part time or non-user → “Unsuccessful user”

ANL Background

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Characteristics of ANL

- ANL measure (ANL = MCL – BNL)
  - Simple, rapid audiological test
  - Predictive of hearing aid use → success (Nabelek et al., 1991; 2006)

- Not related to
  - Speech in noise scores (Nabelek et al., 2004)
  - Wearer gender (Rogers et al., 2003; Nabelek et al., 2006 but not Gordon-Hickey, 2012)
  - Wearer age (Nutt et al., 2007 but not Nabelek et al., 2006)
  - Degree of hearing loss (Plyer et al., 2007)

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Characteristics of ANL

- Not different aided vs. unaided (Nabelek et al., 2004; Mueller et al., 2006)

- Variability/repeatability
  - Stable over time (3 months) (Freyaldenhoven et al., 2006b)
  - Increase with increasing speech presentation level (Franklin et al., 2006; Freyaldenhoven et al., 2007)
  - Individual variability in ANL scores
    - Intra-subject repeatability?
    - Inter-subject variability?
  - Variability across listeners?
  - Variability across studies?
Freyaldenhoven et al. (2006b)

- Intra-session repeatability
  - N = 30 YNH Ss
  - Sound field 0 degrees azimuth
  - Estimated ANL 3 times in a single session using commercial methods
  - Intra-class correlation coefficient (ICC) (Weir, 2005)

\[
ICC = \frac{MS_b - MS_w}{MS_b + (k - 1)MS_w}
\]

- r values ranged from 0.90 to 0.97 (very high) intra-session reliability
- Median intra-session range was 1-2 dB (0 to 6 dB)

Highly repeatable within session

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Freyaldenhoven et al. (2006b)

- Inter-session repeatability (3 weeks later)
  - ICC = 0.81 for LTSSN (excellent)
  - ICC = 0.79 for babble (strong)

Highly repeatable across sessions
ANL Reliability: How do the data stack up?

Gordon-Hickey et al. (2012)
- Inter-examiner reliability
  - Three different testers within a single session
  - ICC with individual testers treated as three test replicates
  - MCL: ICC = 0.81 (excellent)
  - BNL: ICC = 0.94 (excellent)
  - ANL: ICC = 0.83 (excellent)
- ANOVA \( \rightarrow \) no significant difference across examiners

Highly repeatable across examiners

Olsen et al. (2012a,b)
- Coefficient of Repeatability (CR) (Altman & Bland, 1983)
- Intra-session repeatability
- Inter-session repeatability

ANL inter- and intra-session repeatability too low to warrant clinical use
**ANL Reliability:**

**How do the data stack up?**

Inter-subject variability

- All data sets show a wide range of performance across subjects even within a given subject group
- The average range of ANL values across subjects within a subject group is ~ 19 dB!

*Factors underlying variability in ANL performance may underlie variability in HA success!*

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**Research Objectives**

Quantify intra-session repeatability in hearing impaired listeners

Can intra-session repeatability explain inter-subject variability?

Is intra-session repeatability the same for unaided and aided conditions?
Methods

Introduction --- Background --- Methodology --- Results --- Discussion --- Take Home Message

Participants

Target Enrollment
- 30 adults
- 10 per unaided cohort; low, mid, & high ANLs (Nabelek et al. 2006)

Actual Enrollment
- 36 Ss in low, mid, & high ANL cohorts
- Mean age 67 years (27 to 86 years); Symmetrical SNHL
Procedures

- Fixed speech presentation level, varied background noise level
- Unaided ANL
  - 65 dBA speech level
- Aided ANL
  - 65 dBA speech level
  - Starkey X series RIC aids, custom earmolds, NAL-NL2
  - Audioscan Verifit real-ear verification
- 3 ANL repetitions per condition
- Automated testing
  - Custom Matlab GUI
- Audio-visual instructions
  - Screen grab of GUI in Powerpoint
  - Scripted verbal instructions

Automated ANL Procedure: Step 1

1. Please adjust the volume of the background noise to a level that is **too loud** to understand speech.

   - **UP**
   - **DOWN**
   - **CONFIRM**
Automated ANL Procedure: Step 2

Please adjust the volume of the background noise to a level that is soft enough for the speech to be very clear.

UP

DOWN

CONFIRM

Automated ANL Procedure: Step 3

Please wait.

UP

DOWN

CONFIRM

Introduction — Background — Methodology — Results — Discussion — Take Home Message
Automated ANL Procedure: Step 4

Please adjust the volume of the background noise to a level that is the maximum level that you would be willing to put up with for a long time while listening to speech.

UP

DOWN

CONFIRM

Automated ANL Procedure: Step 5

Please wait.

UP

DOWN

CONFIRM
Automated ANL Procedure: Step 6

Unaided ANL

- Total of 36 participants enrolled
- Uneven distribution across low, mid, & high ANL cohorts

ANL Distribution
Unaided ANL

- ASSL (shaded) vs. Nabelek et al. (2006; open)

Intra-subject Repeatability

1. Intra-class Correlation Coefficient (ICC)

\[ ICC = \frac{MS_b - MS_w}{MS_b + (k-1)MS_w} \]

- \( MS_w \) = mean square within subjects
- \( MS_b \) = mean square between subjects
- \( k \) = number of replicates (\( k = 3 \))

- Unaided: \( ICC = 0.998 \) (\( SD_w = 1.15 \) dB)
- Aided: \( ICC = 0.997 \) (\( SD_w = 1.52 \) dB)

Highly repeatable within session
Intra-subject Repeatability

- ASSL  ➔ Very high repeatability (ICC = 0.998)
- Freyaldenhoven et al. (2006b)  ➔ High repeatability (ICC = 0.90-0.97)
- Gordon-Hickey et al. (2012)  ➔ High repeatability (ICC = 0.83)
- Olsen et al. (2012a,b)  ➔ Very poor repeatability (CR = 6.8 to 8.8 dB)

Coefficient of repeatability vs. ICC

- Originally introduced by Altman & Bland (1983) to compare two different methods of measurement (e.g., PTA and spondee THD)
- “Value below which the absolute difference between two repeated test results may be expected to lie with a probability of 95%”
- Product of the SDw and 1.96
- It appears that Olsen et al. (2012a,b) used the SDa or inter-subject standard deviation rather than the SDw or intra-subject standard deviation

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Inter-subject Repeatability

- ASSL – Unaided ANL spanned a range of 23 dB between subjects

<table>
<thead>
<tr>
<th>Mean ANL</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.9 dB</td>
<td>19.6 dB</td>
</tr>
<tr>
<td>9.0 dB</td>
<td>18.5 dB</td>
</tr>
<tr>
<td>7.0 dB</td>
<td>18.4 dB</td>
</tr>
</tbody>
</table>

ANL (dB)
Unaided vs. Aided ANL

- \( r = 0.59 \)
- \( r^2 = 0.35 \)
- Unaided < Aided ANL (\( t_{35} = -3.514, p = 0.001 \))
Categorization Based on Aided ANL

- Nabelek et al. (2006) Cohort Criteria

<table>
<thead>
<tr>
<th>ANL Cohort</th>
<th>Aided ANL Range (dB)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>&gt;13.0</td>
<td>12</td>
</tr>
<tr>
<td>Mid</td>
<td>Between 7.1 &amp; 13.0</td>
<td>13</td>
</tr>
<tr>
<td>Low</td>
<td>≤7.0</td>
<td>11</td>
</tr>
</tbody>
</table>

- Speech presentation level
  - MCL: Nabelek et al. (2006) and others (~72 dBA)
  - Fixed at 65 dBA

ANL & Subject Characteristics

- Aided and unaided ANL are not significantly correlated with
  - Age
  - Gender
  - Hearing aid ownership
  - Hearing aid use (full time, part time, minimal)
  - Tinnitus
  - Three-frequency (500, 1000, 2000 Hz) pure tone average for each ear
  - Unaided Words-in-Noise (WIN) test

<table>
<thead>
<tr>
<th>Correlations among Aided ANL values for n = 36 subjects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 dBA VQ2 Off</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>HA Use (p &lt; 0.05)</td>
</tr>
</tbody>
</table>
Summary

- ANL data have very high inter-subject repeatability
  - This may be facilitated by more structured test administration
- ANL data have very high intra-subject variability
- Absolute ANL values differ widely across studies
- ANL depends on input speech level (e.g., Franklin et al. 2006, NH)

References

- Franklin CA, Thelin JW, Nabelek AK, Burchfield SB. The effect of speech presentation level on acceptance of background noise in listeners with normal hearing. J Am Acad Audiol 2006; 17:141-146
- Nabelek AK, Tucker FM, Letowski TR. Tolerance of Background Noises: Relationship with patterns of hearing aid use by elderly persons. JSHD 1991; 34:679-685
References

- Nutt RC, Marietta C, Frisina DR, Eddins DA. Effect of Age on Tolerance of Background Noise as Characterized by Acceptable Noise Level and the Speech-Spatial-Quality Scale. Poster session presented at: Annual Meeting of the Association for Research in Otolaryngology; February, 2007; Denver, Colorado
- Olsen SO, Lantz J, Nielsen LH, Braanstrom KJ. Acceptable noise level (ANL) with Danish and non-semantic speech materials in adult hearing-aid users. Int J Audiol 2012; 51:678-688

Individual Variability in Aided Outcomes

- Individual Differences in Benefit from Directional Microphones
  Jason Galster & Krishna Rodemark

- Individual Variability in Recognition of Frequency Lowered Speech
  Joshua M. Alexander

- Individual Variability in Unaided & Aided Measurement of the Acceptable Noise Level
  David A. Eddins

- Will My Patient Benefit from Audiologic Rehabilitation?
  Harvey Abrams & Theresa Hnath Chisolm

- Individual Differences in Listening Effort With Hearing Aids
  Erin Margaret Picou