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Ph.D.

National Center for Rehabilitative Auditory Research,
Portland OR
Mission

“to benefit veterans by alleviating the communicative, economic and social problems resulting from auditory system dysfunction”
Investigators
Audiologists
Research Assistants
Engineers
Biostatisticians
Administrative

NCRAR
Components

- Research
- Education & Outreach
- Mentoring
- Collaborate
RESEARCH

- Prevention of Hearing Loss, and Hearing Conservation
- Diagnosis and Assessment
- Rehabilitation Strategies, Devices and Techniques
Future Research Directions

- Rehabilitation of blast-related and noise-induced auditory injuries
- Rehabilitation strategies based on neural plasticity of the central auditory system
- Rehabilitation of dual-sensory impairment
- Telehealth and web-based audiological services and programs

All are translational hearing research initiatives
NCRAR Collaborating Sites

VA Research Centers
COE for Aging Veterans with Vision Loss, MS COE West, HSR&D Polytrauma and Blast Injury QUERIs Palo Alto & Minneapolis, COE on Restoration of Function in Spinal Cord Injury & MS

VA Medical Centers

Portland VAMC
Audiology and Speech Pathology, Otolaryngology, Education, Neurology, Internal Medicine, Psychology, Oncology, HSR&D Division

OHSU
OHRC, Dept. Med., Public Health & Preventative Medicine, SOSE, Behav. Neuroscience, Neurology, Advanced Imaging Research Center, School of Nursing, Oncology, Otolaryngology

Universities
Maryland, South Florida, Western Oregon, Pittsburgh, Wisconsin, Emory, Indiana, Connecticut, Southern Illinois, Oregon, Washington, Regensburg Germany

Institutes & Agencies
Components

MENTORING

- ‘The next generation of auditory scientists’ (post-doctoral fellows, career development candidates, career scientists, visiting scientists)
- VA clinicians who have a desire to participate in conducting research
- *Au.D. students*
Au.D. students

• 4th year externships: a research-based clinical experience

• NIH-sponsored summer research internship experiences: four students/year over the next 5 years
Components

EDUCATION

- Professionals
- Students
- Veterans
- Community
Education

- Professional seminar series
- Community Lecture Series
- Brochures for download
- Web-based Programs (tinnitus training for clinicians)
- Multimedia Hearing Loss Prevention Program
- Training Programs/workshops
• **NCRAR Biennial Conferences:**
  Hearing Therapies for the Future
  September 27\textsuperscript{th} & 28\textsuperscript{th} 2007

• **Pre-conference workshop:**
  “Best practices in hearing loss prevention” Theresa Schultz Ph.D., Kyle Dennis Ph.D. & David Chandler Ph.D.

www.ncrar.research.va.gov/Education/Conf2007/Index.asp
Some of My Research

- Performance-Perceptual Test as a Counseling Tool
- Localization and aging auditory system
- Hearing Loss Prevention program

Worked on these with Anna Forsline, Samantha Lewis and Susan Griest
Why measure hearing aid outcome?

• Justify costs to insurers and government

• Validate clinical decisions

• Demonstrate effectiveness of intervention to patients and their families.

• To help improve service we provide

• To create benchmarks against which to compare our clinical results.

• To establish a database for evidence-based practice and clinical practice guidelines
Hearing Aid Outcome Measures

Two types are commonly used:

- Questionnaires to assess ‘subjective’ outcome
- Measures of speech understanding (in quiet and in noise) to assess performance-based outcome.
What Are We Measuring?

**FACT:**

Questionnaire responses do not always reflect measured performance

*i.e. there is often a disconnect between reported benefit and measured benefit*
Some people report low satisfaction BUT testing shows considerable benefit

Others report high satisfaction BUT testing shows little or no benefit

WHY?
At least 2 reasons:

1. Performance testing is conducted in the clinic, questionnaires reflect ‘real world’ listening.

Is it surprising then?

Which should we take notice of?
2. Different tools are used to measure each. i.e. Questionnaires vs. Performance tests

Difficult to directly compare these two types of measure
We came up with a test that enables a direct comparison of these.
Performance-Perceptual Test (PPT)

Tests two conditions:

- **Performance** = Actual ability to understand speech in noise (HINT)
- **Perceptual** = Perceived ability to understand speech in noise

**USING THE SAME TEST PROCEDURES**

so results from the two are directly comparable
**Performance**
Subjects repeat back HINT sentences presented in noise

Noise level is fixed
Speech level is altered depending upon response:
- Made quieter when sentence is repeated correctly (S/N more adverse)
- Made louder when repeated wrongly (S/N less adverse)

**Perceptual**
Subjects say whether they can understand sentences presented in noise

Noise level is fixed
Speech level is altered depending upon response:
- Made quieter when subjects say they can understand the sentence (S/N more adverse)
- Made louder when subjects say they cannot understand the sentence (S/N less adverse)
The difference between these is a direct measure of the degree to which subjects (in)correctly assess their ability to hear:

\[ \text{Performance SRTN} - \text{Perceptual SRTN} = \text{Performance Perceptual Discrepancy (PPDIS)} \]

\[ 5 \text{ dB S/N} \text{ Performance SRTN} \quad \text{minus} \quad 5 \text{ dB S/N} \text{ Perceptual SRTN} = 0 \text{ dB} \]

\[ \rightarrow \text{Subject accurately estimates hearing ability} \]
**Negative PPDIS**

\[
\begin{align*}
5 \text{ dB S/N} & \quad \text{minus} \quad 10 \text{ dB S/N} \\
\text{Performance SRTN} & \quad \text{Perceptual SRTN}
\end{align*}
\]

\[= -5 \text{ dB} \quad \text{PPDIS} \]

→ **Subject underestimates hearing ability**

**Positive PPDIS**

\[
\begin{align*}
5 \text{ dB S/N} & \quad \text{minus} \quad 0 \text{ dB S/N} \\
\text{Performance SRTN} & \quad \text{Perceptual SRTN}
\end{align*}
\]

\[= +5 \text{ dB} \quad \text{PPDIS} \]

→ **Subject overestimates hearing ability**
Test-retest Reliability

Data from a number of studies

Performance SRTN range: \( r = 0.924 \) to \( 0.988 \)

Perceptual SRTN range: \( r = 0.934 \) to \( 0.989 \)

PPDIS range: \( r = 0.810 \) to \( 0.880 \)
Some studies
PPT & OAD

Used the PPT to examine individuals with ‘Obscure Auditory Dysfunction (OAD)’

Individuals who complain of difficulties hearing speech in noise and yet have ‘clinically normal’ hearing
PPT & OAD

Purpose: What is the underlying basis of OAD?

- Tested 50 subjects with OAD & 50 controls, (pairs matched on age, thresholds, noise exposure history)

- Large test battery including PPT, frequency resolution, personality questionnaires, dichotic listening test, gap detection
PPT & OAD

Used stepwise logistic regression to determine which combination of variables best differentiated OADs from matched controls.
### Results

PPDIS explained 33.1% total variance

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>% variance explained</th>
<th>β-value</th>
<th>P&lt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPDIS</td>
<td>33.1</td>
<td>-0.59</td>
<td>0.006</td>
</tr>
<tr>
<td>Performance SRTN</td>
<td>27.0</td>
<td>0.41</td>
<td>0.007</td>
</tr>
<tr>
<td>Dichotic listening test</td>
<td>12.7</td>
<td>-0.29</td>
<td>0.003</td>
</tr>
<tr>
<td>2kHz masked threshold</td>
<td>9.5</td>
<td>-0.38</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82.3</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
PPT & OAD

Next obtained a classification matrix via discriminant function analysis (DFA) to determine whether individuals were correctly or incorrectly identified using this equation.
### Results

More false negatives than false positives i.e. under-predicted OAD status

<table>
<thead>
<tr>
<th>Actual group</th>
<th>Predicted group</th>
<th>OAD</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>OAD</td>
<td>80%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>10%</td>
<td>90%</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

The PPT, in particular the PPDIS variable, provides information over and above that provided by performance measures and questionnaire measures – at least for the OAD population.
PPT and Unaided Handicap

Subjects

• 33 normal hearing, 74 symmetrical SNHL
• 24 binaurally aided

Tests (subset)

• PPT unaided
• HHIE or HHIA
Results

- Performance & Perceptual SRTNs are significantly correlated with thresholds ($r=0.89$ for both)
- PPDIS is not ($r=0.04$)
- No PPT variable is correlated with age when thresholds are accounted for.
PPT and Unaided Handicap

Multiple regression analysis used to predict HHIE/A scores from age, 4F-PTA, Performance SRTN and PPDIS
## PPT and Unaided Handicap

<table>
<thead>
<tr>
<th>Variable</th>
<th>% Variance Explained</th>
<th>β-value</th>
<th>% Variance Explained</th>
<th>β-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPDIS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRTN</td>
<td>0.755</td>
<td>-0.370</td>
<td>13.8</td>
<td>0.715</td>
</tr>
<tr>
<td>Age</td>
<td>8.3</td>
<td>-0.347</td>
<td>10.8</td>
<td>-0.372</td>
</tr>
<tr>
<td>Total</td>
<td>41.2</td>
<td></td>
<td>39.3</td>
<td></td>
</tr>
</tbody>
</table>

- More handicap = underestimation
- More handicap = being younger
- More handicap = poorer SRTN

All subjects: 39.3%
HI subjects only: 41.2%
PPT and Unaided Handicap

• Handicap greater for underestimation of hearing (-ve $\beta$-value)

• Handicap greater for poorer performance (+ve $\beta$-value)

• Handicap greater for younger aged individuals (-ve $\beta$-value)

• Mis-perception explains almost as much variance as actual performance for HI subjects

Saunders et al, 2004
PPT and Aided Listening

- 94 subjects with symmetrical SNHL
- Binaural HA users
- Tests: PPT, HHIE
PPT and Aided Listening

Multiple regression analysis to predict HHIE/A scores showed the same as for unaided listening:

Greater handicap is associated with:

- Underestimation of hearing ability
- Poorer performance
- Being younger
HHIE/A

- Fewer than expected reported difficulties
- Expected reported difficulties
- More than expected reported difficulties

P < 0.002

Saunders & Forsline 2006
PPDIS – what determines it?

Not really investigated this but most likely is a ‘trait’ rather than a ‘state’

Evidence

Comparison of unaided and aided PPDIS values shows no difference (t=0.3, p=0.75)
PPDIS counseling has proven useful with OAD subjects:

- 37/50 subjects responded to a survey regarding their visits. Of these 33% found their visit useful or very useful.
- None received any ‘treatment’ but counseling
- Counseling is now part of a packet used in the UK
PPT as a Counseling Tool

Study in progress evaluating the PPT as a hearing aid counseling tool.

Two groups of 40 dissatisfied HA users

PPT, HHIE/A, APHAB, IOI-HA

Group 1 receive PPT-based counseling

Group 2 receive non-PPT counseling

Outcome is compared
All subjects in Experimental Group 1: PPT-based counseling

- Subjects that underestimated their hearing ability
  - Counseling Content A

- Subjects that accurately assessed their hearing ability
  - Counseling Content B

- Subjects that overestimated their hearing ability
  - Counseling Content C
• **Underestimation:**
  PPDIS < 33rd percentile of normative data

• **Accurate:**
  PPDIS between 33rd & 66th percentile of normative data

• **Overestimation:**
  PPDIS > 66th percentile of normative data
PPT counseling consists of:

- Provision of information
- Suggested Explanations
- Subject Exposition
- Discussion
- Suggested Solutions
<table>
<thead>
<tr>
<th></th>
<th>Provision of information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Underestimate</strong></td>
<td></td>
</tr>
<tr>
<td>Content A</td>
<td>This test shows you hear better than you think you do.</td>
</tr>
<tr>
<td><strong>Accurate</strong></td>
<td></td>
</tr>
<tr>
<td>Content B</td>
<td>You accurately assess your hearing ability.</td>
</tr>
<tr>
<td><strong>Overestimate</strong></td>
<td></td>
</tr>
<tr>
<td>Content C</td>
<td>This test shows you overestimate how well you can hear.</td>
</tr>
<tr>
<td>Underestimate (Content A)</td>
<td>Accurate (Content B)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>High expectations, cautious, reluctant to take risks, lack of confidence, not want to fail</td>
<td></td>
</tr>
</tbody>
</table>
## Subject Exposition

<table>
<thead>
<tr>
<th>Underestimate (Content A)</th>
<th>Accurate (Content B)</th>
<th>Overestimate (Content C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response to above, other explanations?</td>
<td>Response to above, comments?</td>
<td>Response to above, other explanations?</td>
</tr>
<tr>
<td>Discussion/Implications</td>
<td>Underestimate (Content A)</td>
<td>Accurate (Content B)</td>
</tr>
<tr>
<td>--------------------------</td>
<td>--------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Fearful of social interaction, withdrawal, dependency.</td>
<td>Accepting of hearing loss and of the limitations it imposes.</td>
<td>Frustrate others, appear unintelligent or arrogant, misunderstandings or wrong information</td>
</tr>
<tr>
<td>Solutions</td>
<td>Underestimate (Content A)</td>
<td>Accurate (Content B)</td>
</tr>
<tr>
<td>---------------------------</td>
<td>---------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Try guessing, take risks assume you heard correctly, rephrase to clarify to boost confidence, communication strategies</td>
<td>NA. Discuss communication strategies</td>
<td>Ask for clarification, admit to difficulties to self, communication strategies</td>
</tr>
</tbody>
</table>
All subjects in Experimental Group 2

Explanation of audiometric data
Discussion of the relationship between the audiogram and speech understanding ability
Rationale for measuring the Performance SRTN
Concept of S/N
Description of HINT normative data
Comparison of subject’s Performance SRTN with HINT normative data
Discussion of communication strategies
Follow-up at 2 weeks and 10 weeks post-counseling to determine:

Has PPDIS changed?

and more importantly whether

Have reported handicap, disability and HA satisfaction changed?
Results

• Data from 44 subjects:
  23 in Group 1,
  21 in Group 2

Mean age 65.4, range 48-75 years
Interesting that:

- 10 accurate
- 2 overestimators
- 32 underestimators

All dissatisfied HA users – something to do with underestimation perhaps?
Group mean PPT values from Visit 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th>Group 2</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unaided Performance SRTN</td>
<td>-0.46</td>
<td>0.46</td>
<td>0.46</td>
<td>0.50</td>
</tr>
<tr>
<td>Aided Performance SRTN</td>
<td>-3.1</td>
<td>3.1</td>
<td>0.30</td>
<td>0.089</td>
</tr>
<tr>
<td>Unaided PPDIS</td>
<td>-3.7</td>
<td>3.7</td>
<td>0.97</td>
<td>0.330</td>
</tr>
<tr>
<td>Aided PPDIS</td>
<td>-3.2</td>
<td>-3.4</td>
<td>0.025</td>
<td>0.876</td>
</tr>
<tr>
<td>Aided benefit</td>
<td>2.7</td>
<td>1.8</td>
<td>1.43</td>
<td>0.239</td>
</tr>
</tbody>
</table>

No group differences at baseline on PPT variables
Repeated measures ANOVAs comparing Visits 1 & 2 Performance SRTNs

**Significant finding:**
- main effect of aiding

**Non-significant findings:**

**main effect:**
- retest

**interactions:**
- Group x aiding
- Group x retest
- Group x aiding x retest
Repeated measures ANOVAs comparing Visits 1 & 2 PPDIS

Significant finding:
main effect of aiding

Non-significant findings:
main effect:
  • retest
interactions:
  • Group x aiding,
  • Group x retest
  • Group x aiding x retest
Conclusion so far:

• Counseling does not change PPDIS value ‘significantly’ when examined in the manner
Examined subjects in terms of whether they changed PPDIS status i.e. whether they over-, accurately or under-estimated their hearing ability
<table>
<thead>
<tr>
<th></th>
<th>Visit 1</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Underestimator</td>
<td>Accurate</td>
<td>Overestimator</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>7</td>
<td>8</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accurate</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Overestimator</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Group 2</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accurate</td>
<td>1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Overestimator</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
The groups do not differ significantly but almost
chi-square = 0.091
Questionnaire data

• To date, the questionnaire responses show no group differences

• Data from a final interview are more interesting
### Final Interview

Has your ability to hear with your hearing aids changed?

<table>
<thead>
<tr>
<th></th>
<th>Better</th>
<th>Same</th>
<th>Worse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>8</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>Group 2</td>
<td>6</td>
<td>15</td>
<td>0</td>
</tr>
</tbody>
</table>
Have you had your hearing aids reprogrammed since beginning the study?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>Group 2</td>
<td>6</td>
<td>15</td>
</tr>
</tbody>
</table>
As a result of being in this study do you feel differently about your hearing?

Group 1
I realize I ‘fake’ a lot
Am more willing to rely on HAs
Questionnaires made me think about my hearing
Your +ve feedback was helpful
Now I realise I need HAs
I am willing to try/wear my HAs
I can explain the difficulties I have better to my family
I am more aware of what I miss
I feel vindicated to know I do have a problem

Group 2
I am more aware of my difficulties
I accept and understand my HL better
I know there is hope
I pay more attention to what is said
I have more confidence now
I ask for help from people
I understand I have a hearing loss and now have lower expectations

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Group 2</td>
<td>11</td>
<td>10</td>
</tr>
</tbody>
</table>
Do you feel differently about your hearing aids as a result of being in this study?

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Group 1</td>
<td>13</td>
<td>10</td>
</tr>
</tbody>
</table>

Group 1
Before study I thought HAs didn’t help, now I know they do
I have more respect for my HAs
I realize they help me a lot
I now realize I’ll never hear normally again
I wear them more
I’m pleased to have them now
Intellectually I realize their value
I am more aware of what they do for me

Group 2
I have an FM system now and so I wear them more
Now I leave them in after work, this helps at home
I feel friendlier towards them
I am more relaxed with them in
I know they help
I am more accepting of the HAs
Have you been wearing your hearing aids more since starting this study?

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>Same</th>
<th>Wore fulltime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>9</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Group 2</td>
<td>11</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Seventy-three percent of patients who didn’t already wear their hearing aids all waking hours reported increased use on Visit 2.
Summary

- Almost 3 times as many individuals in Group 1 as Group 2 had a desirable change in PPDIS
- Counseling for Group 2 was also helpful
- Both groups of dissatisfied users benefited
From the final interview many people liked the counseling – even those in group 2. So if nothing else it would seem that education of patients is very helpful.
Summary

- PPT is quick and efficient (10 minutes)
- It provides information additional to that currently measured by audiometric and performance tests
- Potentially has applications as a counseling tool
Applications of the PPT

- to help ‘deniers’ (people who overestimate their hearing ability?) become aware that they do have hearing loss
- to give confidence to individuals that underestimate their hearing ability
- to improve HA satisfaction
Acknowledgements

These studies were funded by VA RR&D grants C2709I & C3951R

Thank you to Anna Forsline my invaluable research audiologist
REFERENCES


Sound Localization and the aging auditory system
Background

Horizontal sound localization and the auditory system

- Interaural time differences (ITD): signals <1.5 kHz
- Interaural level differences (ILD): signals > 2 kHz
- Spectro-temporal pinna cues: > 6.0 kHz & back-front discrimination
Background

Localization in horizontal plane is better for:

- Wide-band signals than narrow-band signals (both ILDs and ITDs are available)
- Low and high frequencies over mid-frequencies
- Re: low vs. high: data are mixed
Impact of hearing loss

- Asymmetric hearing loss is a huge problem
- SNHL has (surprisingly little) impact of localization if the signal is audible
- Localization performance is not easily predicted based on audiogram
- SNHL seems to affect LF localization more than HF localization – audibility provides access to ILD cues not ITD cues?
Background

Impact of Age

Few studies, those that exist show:

• Independent effects of age and HL on sound localization
Study

What are the effects of aging and hearing loss on localization of sound in horizontal plane for signals of different frequency and bandwidth?
Methods

Subjects

• Three groups

  10 young normal hearing listeners (YNH)
  10 Older normal hearing listeners (ONH)
  10 older hearing impaired listeners (OHI)
Repeated measures ANOVA and Tukey post-hoc tests showed all three groups differed significantly.
Participant ages by group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean Age</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>YNH</td>
<td>26.8</td>
<td>4.3</td>
<td>20-35</td>
</tr>
<tr>
<td>ONH</td>
<td>66.3</td>
<td>4.8</td>
<td>60-74</td>
</tr>
<tr>
<td>OHI</td>
<td>69.0</td>
<td>7.2</td>
<td>59-78</td>
</tr>
</tbody>
</table>

Analyses show YNH differs from ONH & OHI but ONH and OHI do not differ.
Test Measures

Audiometric evaluation:
- pure tone thresholds
- Word recognition at 40 dB HL CID W-22 list
- Speech reception threshold CID W-1 list

Speech Perception in Noise
- HINT

Sound Localization measurement
Speech test results, along with ANOVAs for between-group comparisons.

<table>
<thead>
<tr>
<th>Group</th>
<th>SRT (dB HL)</th>
<th>WRS (%)</th>
<th>HINT (S/N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>YNH</td>
<td>9.8 (4.5)</td>
<td>99.2 (1.4)</td>
<td>-78 (1.7)</td>
</tr>
<tr>
<td>ONH</td>
<td>13.8 (4.9)</td>
<td>96.8 (3.2)</td>
<td>-5.7 (2.5)</td>
</tr>
<tr>
<td>OHI</td>
<td>43.3 (9.3)</td>
<td>83.1 (7.1)</td>
<td>-1.3 (2.0)</td>
</tr>
</tbody>
</table>

ANOVA:
- F(2,27) 77.1 p<0.001
- F(2,27) 36.2 p<0.001
- F(2,27) 24.7 p<0.001

OHI scores were significantly poorer than YNH and ONH. YNH & ONH did not differ.
Sound localization

**Signals**
NBN: 0.25-0.5 kHz, 1-2kHz, 3-6kHz  
WBN: Speech-shaped  
500ms duration with 10ms rise-fall times  
70 dB SPL

**Test configuration**
24 speakers, separated by 15º  
3 repetitions per speaker

**Calibration**
Automated process.  
Tolerance of +/- 0.25dB SPL

**Practice run**
White noise
CONTROL ROOM

Digitized signal

6-channel sound card

6-channel amplifier

6-channel sound card

6-channel amplifier

6-channel sound card

6-channel amplifier

6-channel sound card

6-channel amplifier

Video card

SOUND BOOTH

Speaker

1 m

15°

Touch screen
Touch screen

Click Here to Start

You are here

LEFT

FRONT

RIGHT

BACK
Front-Back reversals
Back-Front reversals
Figure 5

YNH mid-frequency noise

ONH mid-frequency noise

OHI mid-frequency noise

Presentation angle

Response angle
YNH high-frequency noise

ONH high-frequency noise

OHI high-frequency noise
Percentage of F-B and B-F reversals by participant group and test stimulus.

<table>
<thead>
<tr>
<th>Participant Group</th>
<th>Front-Back</th>
<th>Speech</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Mid</td>
</tr>
<tr>
<td>YNH</td>
<td>21.4</td>
<td>6.7</td>
</tr>
<tr>
<td>ONH</td>
<td>7.8</td>
<td>3.3</td>
</tr>
<tr>
<td>OHI</td>
<td>13.6</td>
<td>1.2</td>
</tr>
</tbody>
</table>

**Main effect of stimulus**

- **F-B errors**: more for mid than others
- **B-F**: more for LF & HF than mid and speech

No significant effects for comparisons involving group.
Presentation angle

Degrees error

hearing impaired

Test group

older normals

young normals

0 30 60 90 120 150 180 210 240 270 300 330

\[|P-R| = 360^\circ - (285^\circ - 15^\circ) = 90\]

Response angle

|P-R| = 285° - 15° = 270°

Presentation angle
### Mean RMS errors

<table>
<thead>
<tr>
<th>Participant group</th>
<th>Low</th>
<th>Mid</th>
<th>High</th>
<th>Speech</th>
</tr>
</thead>
<tbody>
<tr>
<td>YNH</td>
<td>55.1 (10.2)</td>
<td>50.8 (15.2)</td>
<td>49.0 (20.8)</td>
<td>16.4 (2.9)</td>
</tr>
<tr>
<td>ONH</td>
<td>61.0 (6.5)</td>
<td>66.6 (8.4)</td>
<td></td>
<td>31.3 (9.1)</td>
</tr>
<tr>
<td>OHI</td>
<td>63.6 (8.8)</td>
<td>68.2 (9.2)</td>
<td></td>
<td>51.1 (18.0)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F=(2,29)</th>
<th>P-value</th>
<th>RMS error without F-B and B-F</th>
<th>Main effect of stimulus</th>
<th>Interaction stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>YNH</td>
<td>4.9</td>
<td>0.016</td>
<td>3.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ONH</td>
<td>8.7</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OHI</td>
<td>6.4</td>
<td>0.056</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**RMS error**

**Main effect of stimulus**

**Interaction stimulus**
YNH listeners performed better than ONH and OHI

- For LF & MF signals ONH and OHI did not differ, both performed more poorly than YNH
- For speech-shaped noise all groups differed with YNH best and OHI poorest
- For HF signal there were no group differences
Why?

Not likely due to peripheral HL

• Since thresholds differ in HF but localization in HF does not

• Past studies show mild SNHL has little impact on localization
Why?

Central auditory processing capacity

- Studies have shown older individuals had reduced ability to use ITD cues or needed longer time delays to hear a difference than younger individuals – thus the poorer performance with LF and MF signals
... And then I heard a loud bang and when I turned back he was gone!
What to do?

• HA manufacturers may address: filter to mimic ‘average’ pinna cues

• Use a questionnaire such as the Speech, Spatial and Qualities Scale (SSQ) to monitor changes
Table 5. Pearson correlation r-values for relationships between RMS error values, raw correlations and correlations controlling for days between test and retest at three different levels of signal:

<table>
<thead>
<tr>
<th>Signal</th>
<th>Value</th>
<th>Raw correlation</th>
<th>Partial correlation</th>
<th>Fisher z-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Total RMS error</td>
<td>0.694</td>
<td>0.697</td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td>Total RMS error B</td>
<td>0.757</td>
<td>0.756</td>
<td>0.007</td>
</tr>
<tr>
<td>Mid</td>
<td>Total RMS error</td>
<td>0.841</td>
<td>0.851</td>
<td>0.103</td>
</tr>
<tr>
<td></td>
<td>Total RMS error B</td>
<td>0.786</td>
<td>0.802</td>
<td>0.126</td>
</tr>
<tr>
<td>High</td>
<td>Total RMS error</td>
<td>0.849</td>
<td>0.853</td>
<td>0.042</td>
</tr>
<tr>
<td></td>
<td>Total RMS error B</td>
<td>0.819</td>
<td>0.816</td>
<td>0.026</td>
</tr>
<tr>
<td>Speech</td>
<td>Total RMS error</td>
<td>0.602</td>
<td>0.576</td>
<td>0.116</td>
</tr>
<tr>
<td></td>
<td>Total RMS error B</td>
<td>0.692</td>
<td>0.674</td>
<td>0.115</td>
</tr>
</tbody>
</table>
Figure 3

RT (EDT) at 0.5 kHz

RT (EDT) at 2.0 kHz

RT (EDT) at 4.0 kHz

RT (EDT) at 0.25 kHz

0    30    60    90    120  150  180  210  240  270  300  330
Angle

0.00  0.02  0.04  0.06  0.08  0.10  0.12  0.14  0.16  0.18  0.20
RT (EDT)
PPT and Aided Listening

- 48 individuals with SNHL
- Wore binaurally HAs for 18 months for study.
- Ran PPT once every three months (averaged data used here)
- Completed 4-item HA satisfaction questionnaire
HA satisfaction questionnaire

- How satisfied are you overall with the performance of your HAs?
- To what extent do your HAs fulfill your specific needs?
- Do you think you get as much benefit as others?
- For talking in a group I find my HAs: (very useful to not at all useful)
PPT and Aided Listening

Data were then used to classify subjects into:

- Good vs. poor Performance
- Underestimation versus not underestimating hearing ability

(PPDIS)

Poor SRTN = \( \text{S/N higher than mean } + 2\text{SE} \)

Underestimation = mean PPDIS - 2SE

HA Satisfaction score in top 75% vs. bottom 25%

‘Content’ and ‘Discontent’ users
PPT and Aided Listening

DFA used to examine how well the combination of the PPDIS and the Performance SRTN correctly classified subjects into content and discontent users

i.e. can you use PPT to predict hearing aid satisfaction?
PPT and Aided Listening

Results

<table>
<thead>
<tr>
<th>Predicted group</th>
<th>Actual group</th>
<th>Discontent</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discontent</td>
<td>73%</td>
<td>27%</td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>24%</td>
<td>77%</td>
<td></td>
</tr>
</tbody>
</table>

More false negatives than false positives i.e. over-predicted contentedness

Saunders & Cienkowski, 2002
# Group mean PPT values from Visit 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1</th>
<th>Group 2</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unaided Performance SRTN</td>
<td>-0.46 (2.9)</td>
<td>0.40 (5.3)</td>
<td>F-0.19</td>
<td>P=0.667</td>
</tr>
<tr>
<td>Aided Performance SRTN</td>
<td>-3.1 (2.9)</td>
<td>-1.4 (3.7)</td>
<td>F=3.68</td>
<td>P=0.062</td>
</tr>
<tr>
<td>Unaided PPDIS</td>
<td>-3.7 (2.8)</td>
<td>-4.6 (3.1)</td>
<td>F=0.046</td>
<td>P=0.832</td>
</tr>
<tr>
<td>Aided PPDIS</td>
<td>-3.2 (2.5)</td>
<td>-3.4 (2.5)</td>
<td>F=1.75</td>
<td>P=0.194</td>
</tr>
<tr>
<td>Aided benefit</td>
<td>2.7 (2.3)</td>
<td>1.8 (2.5)</td>
<td>F=3.10</td>
<td>P=0.086</td>
</tr>
</tbody>
</table>