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ARA Webinar Series, in partnership with AudiologyOnline

- Building relationships: Patient-centered care and psychosocial engagement in audiology appointments
  Caitlin Grenness, PhD & Katie Ekberg, PhD

- Listening effort and spatial awareness in cochlear implant users
  Ann Perreau, PhD

- Music training for adult cochlear implant users
  Kate Gfeller, PhD

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Beyond the Audiogram: Subjective Assessments of Spatial Hearing and Listening Effort, presented in partnership with ARA

Ann Perreau, Ph.D., CCC-A
Assistant Professor, Communication Sciences and Disorders, Augustana College
Purpose of today’s talk

• Define spatial hearing and identify ways to measure subjective spatial hearing ability

• Describe outcomes of self-reported spatial hearing ability for individuals with hearing loss and normal hearing.

• Define what listening effort is and describe how listening effort is measured and assessed.

Subjective assessment of spatial hearing ability
Background – sound localization

• Holistic approaches to intervention are recommended (Boothroyd, 2007) and should assess everyday function including speech perception and localization
• Sound localization is difficult for individuals with hearing loss, and is often overlooked
• Localization provides a sense of spatial orientation (spatial hearing)

Background – sound localization

• Adequate localization is necessary for social interactions
  – Group conversations: locate talker as conversation quickly switches from one person to the next
  – Likely plays a larger role in speech communication than is realized (Byrne & Noble, 1998)
Background – binaural hearing

- Likewise, binaural hearing produces many advantages (Zurek, 1993)
  - Improves the overall loudness of a sound (binaural summation)
  - Aids in segregating different speech and noise sources (binaural squelch)
  - Helps determine the location of a sound source (sound localization)

- Using binaural cues, hearing in difficult listening situations is enhanced

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Questionnaires assessing spatial hearing

1. Speech, Spatial, and Qualities of Hearing Scale (SSQ; Gatehouse & Noble, 2004)

2. Spatial Hearing Questionnaire (SHQ; Tyler et al., 2009)
The SSQ
(Gatehouse & Noble, 2004)

- 49-item questionnaire with three subscales
  - Speech perception
  - Spatial hearing of direction, distance, and movement
  - Other: segregation of sounds, identification, clarity, effort
- Uses 10-point scale
- Has good test-retest reliability ($r = .83$, Singh & Pichora-Fuller, 2010)

Appendix 1. A sample item from the SSQ Questionnaire

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at all</th>
<th>Prefectly</th>
<th>Filled if not applicable</th>
</tr>
</thead>
</table>
| Listen to a TV show | 0 | 10 | | 0

Assessing binaural hearing using the SSQ
(Noble, 2010; Noble & Gatehouse, 2006)

- Binaural hearing (two aids) provides more benefit over monaural hearing when the task is more difficult
Comparing CI users abilities on the SSQ (Noble, 2010; Noble et al., 2008)

- Self-rated hearing abilities decrease in more challenging tasks
- Bilateral CI group has highest ratings for spatial hearing domain and quality domain

SSQ overview

- Questionnaire is sensitive to performance differences among different groups, including cochlear implant and hearing aid users, and between patients with asymmetrical and symmetrical hearing loss
  (Beijen et al., 2007; Gatehouse & Noble, 2004; Noble, 2010; Noble & Gatehouse 2006; Noble et al., 2008)
- 5-item and 12-item screening versions now available (Demeester et al., 2012; Noble et al., 2013)
Introducing the SHQ
(Tyler et al., 2009)

- 24-item questionnaire with 8 subscales
  - Compare stimuli of different frequency content (male’s vs. female’s voices)
- Represents situations where binaural hearing abilities would potentially be emphasized
- Total score calculated from average of all 24 items

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Item Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Speech in noise</td>
<td>A man talking to you is standing in front of you. There is a loud fan directly behind him. How well can you understand him?</td>
</tr>
<tr>
<td>22. Localization</td>
<td>You hear a car off in the distance, but you cannot see it. How accurately can you tell where it is coming from?</td>
</tr>
</tbody>
</table>

Psychometric evaluation of the SHQ

- Factor analysis shows three factors explain 83% of variance (Tyler et al., 2009)
  - Factor 1: Localization and directionality
  - Factor 2: Speech in noise and music
  - Factor 3: Speech in quiet
- Cronbach’s α is high for those with and without hearing loss (0.93-0.98)
- Good agreement with existing SSQ (Tyler et al, 2009; Zhang et al., 2015)
- Normative data shows it is sensitive to differences between NH and CI groups (Perreau, Spejcher et al., 2014)
Self-assessed abilities of CI users using the SHQ (Perreau, Ou et al., 2014)

• Higher spatial hearing ability reported for bilateral and Hybrid CI users than unilateral CI and bimodal users

Improvement in spatial hearing with CI

• Pre- to post-implant comparison also reveals significant improvements in spatial hearing for all groups
  – Greatest improvement for bilateral CI group
Spatial hearing abilities with short electrode CI

- Bilateral acoustic input (preserved residual hearing) seems necessary to maintain good sound localization abilities.

Comparing asymmetry in hearing loss using SHQ (Potvin et al., 2011)

- The SHQ is sensitive to differences in spatial hearing resulting from asymmetrical hearing loss.
Short version of SHQ is available
(Ou et al., 2016)

• The 12-item version (Chinese) has high reliability

• Good sensitivity to differences in spatial

Overview of the SHQ

• Results indicate that the SHQ is a valid and reliable measure of spatial hearing ability
  – With only 24 items, the SHQ is quick to administer, making it an efficient clinical tool
    • English short 12-item version is in development
  – The questionnaire is available in several languages (Chinese, Ou et al., 2016; Dutch, Potvin et al., 2011; Persian, Delphi et al., 2015)
Spatial hearing training

- Training using spatial separated loudspeakers to improve binaural performance (Tyler et al., 2010)
- Targets sound localization and speech perception in a background of noise
Localization Training
-- Active Exploring

Instructions
Select a loudspeaker to play a sound

Table of Trials

<table>
<thead>
<tr>
<th>Loudspeaker</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trials Expected</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Trials Completed</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Speech in Noise Training

Active Exploring
These programs let you:
1) explore speech in the presence of background noise
2) explore noise from various directions

Guided Learning
These programs test your ability to understand speech in noise:
1) the noise will always be played from either loudspeaker 1 or 8
2) the noise will be played from a randomly picked loudspeaker

Continue  Main Menu
Allows patients to change level of difficulty by moving loudspeakers

Conclusion – spatial hearing

- Self-report outcome measures are helpful in determining binaural benefits in everyday listening situations
  - May represent real-life situations better than objective tests
- The SSQ and SHQ are sensitive to differences in spatial hearing abilities among patients using any type of amplification device
- Both questionnaires are easy to administer in a busy clinic
- Spatial hearing training is available to improve bilateral performance
- Please email rich-tyler@uiowa.edu for copies of SHQ and information on spatial hearing training
Listening effort measured in adults with normal hearing and cochlear implants

Background – listening effort

• Listening vs. hearing
• Assessment of hearing loss should move beyond traditional audiometric testing, and include evaluation of one’s listening effort (McGarrigle et al., 2004)
• Listening takes conscious effort of mental resources when carrying out a listening task (Pichora-Fuller et al., 2016)
Background - listening effort

- Dual-task paradigms are widely used as behavioral measures
  - Research suggests that listening effort is reduced when using hearing aids (Downs, 1982; Hornsby, 2013)
  - As an individual ages, amount of listening effort increases (Bernarding et al., 2013)
  - Across many studies, older adults exerted more listening effort than young adults (Gosselin & Gagne, 2011; Desjardins & Doherty, 2013; Degeest et al., 2015)

Cochlear implants and listening effort

- Cochlear implants (CIs) restore hearing in individuals who have severe-profound deafness
- Adolescent CI users require higher signal-to-noise (SNR) to achieve similar speech perception and listening effort as normal hearing (Hughes & Galvin, 2013)
- More listening effort is exerted as spectral resolution decreases (Pals et al., 2013)
- Bilateral CIs reduce listening effort compared to unilateral CI (Dunn et al., 2010)
Purposes of our study
(Perreau et al., JAAA)

• To determine how listening effort differs among unilateral, bilateral, and Hybrid short electrode users, compared to normal hearing listeners

• To determine how listener traits, such as age, length of cochlear implant use, and working memory capacity, influence one’s listening effort

Methods - participants

• Normal Hearing group: 12 participants

• CI groups:
  1. 10 Unilateral CI – 1 implant
  2. 12 Bilateral CIs – 2 implants
  3. 12 Hybrid short electrode CI + bilateral hearing aids

• Recruited from Augustana College and University of Iowa Hospitals and Clinics

• Age:
  • NH group: 54.8 years
  • CI groups: 53.9-65.7 years
Methods – Procedures

- Dual-task paradigm was used (Wu et al., 2014)
  - Primary = sentence recognition in background noise (% correct)
  - Secondary = Stroop test (Reaction time (RT), msec)

- Calculated each subject’s SNR-50 level using Hearing in Noise Test (HINT)

- Administered in six different noise conditions:
  - 0, +2, +4, +6, +8, +10 dB SNR

- Listening effort = (RT on dual task – RT Baseline)/ RT Baseline

Dual-task paradigm - Stroop test

(Stroop, 1992)
Methods – Procedures

• Two subjective measures
  – Three items assessing listening effort (modified SSQ)
    • 1-10 rating scale
  – Spatial Hearing Questionnaire (Tyler et al., 2009)
    • 0-100 rating scale
• Reading Span test
  – Word recall using sets of 3-6 sentences each

<table>
<thead>
<tr>
<th>First</th>
<th>Last</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big</td>
<td>dogs can be dangerous.</td>
</tr>
<tr>
<td>Flowers</td>
<td>grow in the garden.</td>
</tr>
<tr>
<td>She</td>
<td>is eating the cup.</td>
</tr>
</tbody>
</table>

Results – Speech Perception

- Significant improvement in speech perception with more favorable SNR
### Results – Reaction time

- Listening effort was high (.6) for all groups in more difficult situations.
- Change in listening effort across SNR was greatest for normal hearing group.

### Results – Subjective measures

- Significant difference between normal hearing and CI groups for perceived listening effort and on Spatial Hearing Questionnaire.

<table>
<thead>
<tr>
<th>Participant Group</th>
<th>1 - Effort in a Conversation</th>
<th>2 - Concentration While Listening</th>
<th>3 - Effort Compared to Others</th>
<th>SHQ Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Hearing</td>
<td>8.67 (1.56)</td>
<td>8.5 (1.24)</td>
<td>8.75 (1.42)</td>
<td>83.53 (9.88)</td>
</tr>
<tr>
<td>Unilateral CI</td>
<td>5.6 (2.99)</td>
<td>4.6 (3.31)</td>
<td>2.75 (2.99)</td>
<td>49.61 (23.01)</td>
</tr>
<tr>
<td>Bilateral CI</td>
<td>5.83 (2.76)</td>
<td>4.38 (2.95)</td>
<td>3.00 (2.76)</td>
<td>64.82 (21.81)</td>
</tr>
<tr>
<td>Short Electrode CI</td>
<td>5.42 (2.27)</td>
<td>5.58 (2.35)</td>
<td>2.08 (1.73)</td>
<td>58.42 (11.11)</td>
</tr>
</tbody>
</table>
Results – Reading span

- No significant difference in working memory capacity across groups

Results—Listener traits

- Age at onset of HL
- Age at implantation
- Duration of implant use
- *Age
- 1) Reading Span
- 2) Perceived Listening effort
- 3) SHQ
- 4) Dual-task test
Conclusions

- Listening effort was reduced to a greater degree for the normal hearing group compared to CI users
  - No significant difference in listening effort among the CI groups
- Age continues to be a significant factor re: listening effort
- Other variables (duration of CI use and age at onset of HL) were not correlated to listening effort

Future directions and clinical applications

1. Recruit more participants with CIs, especially Hybrid CI and bimodal users (use hearing aid and CI in opposite ears)
2. Aim to determine which CI configuration provides best outcomes for listening effort
3. Improve sensitivity of subjective measures of listening effort → Develop a useful clinical tool of listening effort
Acknowledgments

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- Thank you to Dr. Hua Ou at Illinois State University

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- Thank you to the participants from University of Iowa and Augustana College

• Thank you for your attention!

• Additional questions, comments, email: annperreau@augustana.edu
References-Spatial Hearing


References-Spatial Hearing, cont’d

References—Listening effort

• Gosselin PA, Gagné J. (2010) Use of a dual-task paradigm to measure listening effort. CJSLPA 34:43-51.

References—Listening Effort, cont’d