Vanderbilt Audiology's Journal Club: Noise Reduction, Directional Microphones, and Listening Effort

Presenter: Erin Picou, Ph.D.

Moderator: Gus Mueller, PhD - AudiologyOnline Contributing Editor

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Seems like someone is missing
Be sure to also check out Erin’s article at 20Q

20Q: Listening Effort - We Know It’s a Problem But How Do You Measure It?
Erin Margaret Picou, AuD, PhD

Noise reduction, directional microphones, and listening effort
Erin Picou, Ph.D.

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Terms / Definition to put us all on same page

- **Cognition** – mental processes; the activities of thinking, understanding, learning, and remembering
- **Listening effort** – cognitive resources necessary for speech understanding
- Cognitive resources are finite…
  - ….like a bowl of Cheetos®

Measuring Cognition

- **Attention**
  - The train sang a song.
  - The girl brushed her teeth.
  - The house had nine bedrooms.

- **Cognitive speed**
  - DUCK
  - WORS

- **Cognitive capacity**
Measuring Listening Effort

- Subjective reports
  - Standardized questionnaires
  - Patient reports
- Physiologic measures
  - Pupil dilation
  - Skin conductance
- Recall tasks
  - Paired associates
  - Free recall
- Reaction time measures
  - Response time
  - Dual task

Why Study Listening Effort?

Data from Picou, Ricketts & Hornsby (2013) *Ear Hear*, 34, e52-64
Today’s Focus

- Hearing aid benefit
  - (Desjardins & Doherty 2013)
- Digital noise reduction
  - For adults (Desjardins & Doherty 2014)
  - For children (Gustafson et al 2014)
- Directional microphones
  - Effort and fatigue (Hornsby 2013)
  - Effort and driving (Wu et al 2014)

Age-related changes in listening effort for various types of masker noises

Jamie L. Desjardins & Karen A. Doherty
Department of Communication Sciences and Disorders
Syracuse University, Syracuse NY

*Ear and Hearing, 34(3), 261 – 272 (2013)*
What they asked . . .

- What are the effects of age and hearing loss on listening effort in noise?
- What is the relationship between cognitive capacity and listening effort in noise?

A little background from the article . . .

- When audibility is accounted for, working memory capacity and processing speed are the most important predictors of speech recognition in older adults (Vaughn et al, 2006)
- Regarding listeners with normal hearing,
  - younger adults exert less effort than older adults (Gosselin & Gagné, 2010)
- Regarding older listeners,
  - Listeners with normal hearing exert less effort than those with hearing loss (Tun et al 2009)
Why it matters.

- Increase our understanding of the separate and combined effects of age and hearing loss on listening effort
- Work towards defining specific factors that contribute to patient reports of difficulties understanding speech
- Help guide our expectations counseling

What they did.

- Participants were 15 YNH (18 – 25yo); 15 ONH (55 – 77yo); 15 OHI (59 -76yo) with mild to moderate SNHL and hearing aid experience
- Cognitive battery
  - Selective attention, working memory capacity, processing speed
- Dual task paradigm
  - Primary task: Sentence recognition with RSPIN sentences
  - Secondary task: Digital Visual Pursuit Rotor Tracking

- Conditions:
  - Speech-shaped noise
  - Six talker babble
  - Two talkers
What they found . . .

Older exert more effort than younger

No effect of hearing loss

More Effort

Less Effort

More capacity, less effort

Faster processing, less effort

Fig. 6. Mean listening effort scores collapsed across context for the 15 YNH triangles, 15 OHI circles, and the 16 OIH squares participants for the three background-masker conditions. Error bars represent ± SE from the mean. OIH, older hearing-impaired; OHI, older normal-hearing; SIX, six-talker SSN, speech-shaped noise; TOE, time on target; TT, two-talker; YNH, young normal-hearing.

What they found . . .

Table 4. Pearson correlations (r) and p values of the variables in the analysis (N = 48)

<table>
<thead>
<tr>
<th>Cognitive Function</th>
<th>Reading Span Test (r)</th>
<th>DSST (r)</th>
<th>Stroop Test (r)</th>
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</thead>
<tbody>
<tr>
<td>Listening Effort</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSN</td>
<td>-0.304</td>
<td>0.020</td>
<td>0.032</td>
</tr>
<tr>
<td>SIX</td>
<td>0.031</td>
<td>0.379</td>
<td>-0.072</td>
</tr>
<tr>
<td>TT</td>
<td>-0.253</td>
<td>0.045</td>
<td>-0.202</td>
</tr>
</tbody>
</table>

Correlation is significant at the 0.01 level.
* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.10 level.
SIX, six-talker; SSN, speech-shaped noise; TT, two-talker.
Why is this important?...

- Results suggest hearing aids can compensate for effects of hearing loss on listening effort
- Listeners with more capacity and faster processing speed may exhibit less listening effort

Does it really matter clinically?

- Probably – these results suggest that compensating for hearing loss with hearing aids allows patients to exert similar effort as their peers with normal hearing
- Patients with less capacity or who have slower processing speed may be more tired and work harder to understand speech in noise
The effect of hearing aid noise reduction on listening effort in hearing-impaired adults

Jamie L. Desjardins & Karen A. Doherty
Department of Communication Sciences and Disorders
Syracuse University, Syracuse NY

*Ear and Hearing, 35(6), 600 – 610 (2014)*

What they asked . . .

- What are the effects of digital noise reduction on listening effort?
A little background from the article . . .

- Hearing aids without advanced features can improve listening effort (Downs 1982; Picou et al 2013)
- Digital noise reduction does not affect speech recognition, but can improve ratings of comfort
- Digital noise reduction has been shown to improve listening effort for adults with normal hearing (Sarampolis et al 2009)

Why it matters . . .

- If listening effort is improved by noise reduction, it may lead to less fatigue, more time on task, and a variety of other potential benefits.
What they did . . .

- Participants were 12 OHI (50 – 74 yo) with mild to moderate SNHL and hearing aid experience
- Hearing aid settings: 1) features disabled and 2) DNR enabled
- Dual task paradigm
  - Primary task: Sentence recognition with RSPIN sentences
  - Secondary task: Digital Visual Pursuit Rotor Tracking
- Conditions
  - Moderate SNR (~76%)
  - Difficult SNR (~50%)
- Cognitive test battery:
  - Working memory
  - Processing speed

What they found . . .

Word Recognition
No effect of noise reduction
Task difficulty
What they found . . .

Listening Effort

- NR helps (difficult)
- No effect NR (moderate)

Why is this important?...

- More evidence that listening effort is different from speech recognition
- An additional potential benefit of digital noise reduction
- Clinically, if patients are in difficult listening situations, they may experience less effort, even if speech recognition performance isn’t better
Listening effort and perceived clarity for normal-hearing children with the use of digital noise reduction

Samantha Gustafson\textsuperscript{a,c}, Ryan McCreery\textsuperscript{b}, Brenda Hoover\textsuperscript{b}, Judy G. Kopun\textsuperscript{b}, & Pat Stelmachowicz\textsuperscript{b}

\textsuperscript{a}Arizona State University, Phoenix AZ
\textsuperscript{b}Boys Town National Research Hospital, Omaha NE
\textsuperscript{c}Vanderbilt University, Nashville TN

*Ear and Hearing, 35(2), 183 – 194* (2014)

\textbf{What they asked . . .}

- Does digital noise reduction affect listening effort and ratings of clarity for children with normal hearing?
A little background from the article . . .

- DNR has little effect on speech understanding for children (Stelmachowicz et al. 2010)
- In adults, DNR has been shown to improve listening effort (Sarampolis et al 2009; Desjardins & Doherty 2014)
- In adults, DNR has been shown to improve ratings of sound quality (Ricketts & Hornsby 2005)

Why it matters. . .

- Although DNR may not affect speech recognition, if it can improve listening effort (and thus reduce cognitive load), it could have significant implications
- Implications may be even more important for children, because they are still developing
What they did . . .

- Participants were 24 children (7 – 12 yo) with normal hearing
- Stimuli were recorded through hearing aids: DNR off / DNR on
- Speech recognition task with CVC nonwords
  - Phoneme recognition
  - Verbal response time (VRT)
  - Ratings of sound clarity

- Conditions
  - Moderate SNR (+5 dB)
  - Difficult SNR (0 dB)

What they found . . .

Better recognition

Worse recognition
What they found . . .

More clarity

Overall better clarity with DNR on

Less clarity

What they found . . .

More effort

Overall less effort with DNR on

Less effort
Why is this important?...

- Another indication that digital noise reduction can have significant benefits, regardless of effects on speech recognition... this time for children.

- Clinically, we don’t know yet how these results generalize to listeners with hearing loss.

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The Effects of Hearing Aid Use on Listening Effort and Mental Fatigue Associated with Sustained Speech Processing Demands

Benjamin W.Y. Hornsby
Vanderbilt University, Nashville TN

*Ear and Hearing, 34(5), 523 – 534 (2013)*
What he asked . . .

- How does hearing aid use affect listening effort and mental fatigue?
- How does advanced signal processing (directional microphones / digital noise reduction) affect listening effort and mental fatigue?

A little background from the article . . .

- Hearing aids improve listening effort (Downs 1982; Picou et al 2013)
- DNR can improve listening effort (Desjardins & Doherty 2014)
- Listeners with hearing loss are at increased risk of stress, tension, and fatigue due to listening at work (Hétu et al 1988; Kramer et al 2006)
Why it matters. . .

- The assumption is that increases in effort over time lead to fatigue, but this hasn’t been validated yet.
- Effects of hearing aid and hearing aid technology on listening effort and fatigue could guide counseling.

What they did . . .

- Participants were 16 adults (47 – 69 yo) with mild to moderate SNHL
- Conditions: 1) unaided, 2) basic (omnidirectional, all features disabled) and 3) advanced (adaptive directional, features enabled)
- 1-2 week acclimatization period between hearing aid conditions
- Recall paradigm:
  - Word recognition and word recall (strings of 8-12 words)
  - Physical response time
- Evaluated over time…
  - Data for 6 sequential 200 word blocks
  - (20 strings of words)
What he found . . .

Better recognition

No effect over time

Worse recognition

Fig. 3. Mean word recognition as a function of listening condition (unaided, aided basic, and aided advanced) and block/time. Error bars = 1 SE. The time from the start of block one to the end of block six is approximately 50 to 60 min. Solid lines show a best fit linear regression. “Mean” data show word recognition, averaged across all blocks, for each listening condition.

What they found . . .

Better recall

No dmic benefit

HA benefit

Worse recall

Fig. 4. Unaided and aided word recall, averaged across serial position, as a function of block/time. Error bars show 1 SE. Solid lines show a best fit linear regression to the average data. “Mean” data show word recall, averaged across all blocks, for each listening condition.
What he found . . .

Why is this important?...

- Sustained effort over time can lead to fatigue
- Hearing aids can reduce listening effort and reduce susceptibility to auditory fatigue
- Effect of directional microphones is still unknown because it wasn’t active
- Clinically, these results suggest reducing effort can reduce fatigue
Measuring Listening Effort: Driving Simulator Versus Simple Dual-Task Paradigm

Yu-Hsiang Wu\textsuperscript{a}, Nazan Aksan\textsuperscript{b}, Matthew Rizzo\textsuperscript{b}, Elizabeth Stangl\textsuperscript{a}, Xuyang Zhang\textsuperscript{a}, & Ruth Bentler\textsuperscript{a}

\textsuperscript{a}Department of Communication Sciences and Disorders, The University of Iowa, Iowa City, IA
\textsuperscript{b}Department of Neurology, The University of Iowa, Iowa City, IA

*Ear and Hearing, 35(6), 623 – 632 (2014)*

What they asked . . .

- Do hearing aids or directional microphones improve listening effort?
- Do laboratory measures give us similar results as more realistic situations?
A little background from the article . . .

- Listening effort can be reduced with hearing aids (Picou et al 2013) and with digital noise reduction (Desjardins & Doherty 2014; Sarampolis et al 2009)
- Effects measured in the laboratory can be hard to translate into realistic listening situations
- Listeners often multi-task in the real world

Why it matters. . .

- Want to be able to translate laboratory effects into clinical practice
- Question of directional benefit for listening effort is still open
What they did . . .

- Participants were 29 adults (56 – 85 yo) with mild to moderate SNHL, hearing aid experience, and driving experience
- Hearing aid settings: 1) unaided, 2) omni, and 3) directional
- Two dual-task paradigms
  - Driving simulator (driving distance)
  - Visual response (response time)

What they found . . .

- Better recognition
- Worse recognition
- Worse driving
- Better driving

Hearing Loss (driving task)
What they found...

**Hearing Loss (dual task)**

**Better recognition**

**Worse recognition**

**More effort**

**Less effort**

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**Normal Hearing (dual task)**

**Better recognition**

**Worse recognition**

**More effort**

**Dmic benefit**

**Less effort**
Why is this important?…

- Driving simulator has good face validity for evaluating hearing aid technologies
- Driving task well-represents laboratory measures
- Results from listeners with normal hearing may not be generalizable to listeners with hearing loss

Does it really matter clinically?

- Clinically, effects of directional technologies on listening effort are still unclear
- Directional microphones may improve listening effort in less challenging situations
Summary of today’s discussion…

- Listening effort is distinct from speech recognition and can be measured in a variety of ways.
- Hearing aids improve listening effort and can allow listeners with hearing loss to perform similarly to their peers with normal hearing (Desjardins & Doherty 2013).
- DNR can improve listening effort for adults (Desjardins & Doherty 2014) and children (Gustafson et al 2014).

Summary of today’s discussion…

- In addition to listening effort, hearing aids can also reduce fatigue (Hornsby 2013).
- Directional microphone technologies have the potential to improve listening effort, but we haven’t seen evidence of it today because:
  - The noise levels chosen probably didn’t activate the advanced features (Hornsby 2013).
  - The listening situations may have been too difficult to reveal a change in effort for listeners with hearing loss (Wu et al 2014).