Cognition and Hearing Loss

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Hearing impairment: Pure tone audiogram

Hearing involves more than tone detection
Speech Reception Threshold in noise as function of Pure Tone Threshold
Components of speech perception

- Pure tone threshold
- Suprathreshold: spectral & temporal resolution
- Binaural hearing: interaction of both ears

Peripheral hearing – (Central) Auditory – Bottom up

Brain - Cognitive – Linguistic – non-auditory – Top down
New field of science...

Cognitive Hearing Science

Linköping, Sweden (Rönnberg, Rudner, Lunner, Lyxell)
Toronto, Canada (Pichora-Fuller)
Bloomington, USA (Humes, Pisoni)
Boston, USA (Wingfield, Tun)
Amsterdam, Netherlands (Zekveld, Koelewijn, Kramer)
Ease of Language/Speech Understanding (ELU; ESU)

Rönnberg et al., 2008
Speech comprehension is a complex process...  
......it involves cognitive processes and capacity!
cognitive correlates of speech intelligibility
Speed of processing

- Manipulation of speech rate:
  - 172 words/min: NORMAL
  - 215 words/min: MEDIUM
  - 285 words/min: FAST

- Speed ↑ Intelligibility ↓
- This effect is larger in older listeners: processing of speech is slower in older than in younger listeners

Younger (17-21 yr)  
Older (64-78 yr)

**Normal speech rate.** Young: -6 dBSNR, Old: -2 dBSNR

**Medium speech rate.** Young: -4.5 dBSNR, Old: -1 dBSNR

**Fast speech rate.** Young: -3 dBSNR, Old: +1 dBSNR
Cognitive functions....

- Working Memory
- Inhibition
- Linguistic Closure
- Linguistic Content
- Hands on....
Use of context

A bicycle has two ...........

The color of my coat was ........

A large number of people were ........

With age

Wingfield, J Am Ac Audiol, 1996
Linguistic context and hearing loss

Benichov et al., Ear Hear, 2012
Inhibition

Green
Inhibition...

... important when someone needs to ignore a disturbing sound source, such as an interfering speaker in the background.
With optimal levels of intelligibility (100%)

RECALL OF THE PERCEIVED SPEECH

In stationary noise

In 4-talker babble

Ng et al. Int J Audiol, 2013
Objective test for listening effort
Cognitive load as measured with pupil dilation

Pupil dilation is recorded during the tests
Cognitive load as measured with pupil dilation

Koelewijn et al. Ear Hear 2012
Working memory

Reading Span Test

De horses were running √
His friend told a story √
The dog was selling boots X
The neighborhood walked miles X
Working memory strongly correlated to age

with age

Akeroyd, IJA, 2008, Besser et al., TiA, 2013
Working memory and hearing loss

Correlation between Working Memory and Speech Intelligibility in hearing impaired listeners

Correlation: $r = -0.61$

Lunner, 2003; Foo et al. 2007; Rudner et al., 2008
Reading Span & Speech Perception in noise

- Consistent pattern of correlation (R ranges from 0.35 – 0.60)
  - across different studies
  - across various speech in noise tests (different masker types)

Akeroyd, IJA, 2008, Besser et al., TiA, 2013
Reading Span test

Suitable or feasible for clinical practice?
Linguistic Closure
Text Reception Threshold test

...disentangle modality-specific auditory processes from more global cognitive functioning......

(McFarland and Cacace, 1995; Watson et al., 1996; Pichora-Fuller et al., 2005; Humes et al., 2007)
Speech-Reception-Threshold in noise *

- List of short everyday Dutch sentences
- Masking noise
- Adaptive procedure
- SRT: threshold at which 50% correctly reproduced

* (Plomp & Mimpen, 1979)
Visual analogue of the SRT test:
Text Reception Threshold (TRT) test

Zekveld et al., JSLHR 2007
The Hebrew word for good is "tov".
The Hebrew word for 'good' is 'tov'.
Visual analogue

TRT score: percentage unmasked text needed to read 50% of the sentences correctly
N = 34 adults, normally hearing, (corrected to) normal vision

Age: 19 – 78 years (M=34, sd 18.4),

\[ R = 0.54 \]
\[ (p < 0.01) \]
Hearing impaired, N=21

Stepwise multiple regression analysis
(To predict the outcome on the Speech-in-Noise test)

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>Cum $R^2$</th>
<th>Multiple $R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Temporal Acuity</td>
<td>0.48</td>
<td>0.85</td>
</tr>
<tr>
<td>Step 2</td>
<td>Text-Reception-Test</td>
<td>0.73</td>
<td></td>
</tr>
</tbody>
</table>

George et al., JASA, 2007
Contribution cognition to speech intelligibility

![Graph showing contribution of cognition to speech intelligibility](image)

- **SRT-modulated [dB SNR]**
- **TRT-bars [% text]**

- ▲ = normally hearing
- ▼ = hearing impaired

Auditory vs. non-auditory conditions.
Correlation TRT and Reading Span

- $R = -0.76$ (Koelewyn et al., 2012)
- $R = -0.25$ (Besser et al., 2012)
- TRT related with semantic judgements in Rspan (Mishra et al., 2013)
- No association with spatial working memory (Zekveld et al. 2013)
cognitive correlates
of speech intelligibility
Role of cognition in hearing is evident: it calls for a focus shift

Cognitive functions emphasize importance of hearing strategies:

- Become aware of importance of non-auditory factors!
- Speak slowly, articulate well,
  - in particular when there is background noise
  - or when talking to older individuals
- Provide context!
- Reduce background noise, in particular when it is competing speech!
- .....
Contribution of cognitive functions to hearing aid rehabilitation

Two ways possible:

1. Does cognitive capacity determine effectiveness of HA rehab?
2. Does HA rehabilitation affect cognitive outcomes?
1. Does cognitive capacity determine effectiveness of HA rehabilitation?

- So far, few studies looked at:
  - Time compression
  - Different types of background noise
  - Noise reduction
  - Hearing aid use
  - Hearing aid benefit
A few facts:

Hearing aid use and hearing aid benefit in individuals with lower cognitive abilities (who are less able to exploit their cognitive abilities to compensate for their hearing loss)

A few facts:

Fast versus slow compression

Individuals with **better cognitive abilities:**
best served with **fast** time constants

Individuals with **poorer cognitive abilities:**
best served with **slow** time constants

*Gatehouse et al., 2006; Lunner & Sundewall-Thoren, 2007*
A few facts:

.. ..However, according to Cox & Xu, benefit from long or short release times depends on degree of linguistic context!

Those with low cognitive capacity benefit from long release times only for low context speech. Speech rich in context? Short release times are preferred!

Cox and Xu, 2010
A few facts:

Amplification comes along with distortions

...Distortions caused by frequency compression on noisy speech: greater effect on speech intelligibility in people with low WM than those with high WM capacity...

Arehart et al., Ear Hear 2013
A few facts:

… “Those with high working-memory capacity were better than those with low capacity at identifying and reporting the specific processing effects of the aid….” (through a diary)

Lunner, 2003
2. Does HA rehabilitation affect cognitive outcomes?

- In the acute aided situation?

- In the long term (> 3 months)

Kalluri & Humes, Am J Audiol, 2012
A few facts:

Noise reduction reduces adverse effect of noise on speech recall, only for those with **high WM**

No effect of noise reduction in those with **low WM** (but this group wasn’t affected by noise to begin with)

Ng et al., 2013
A few facts:

Noise reduction (NR) on or off:

- No effect on speech performance
- But…NR reduced reaction times and increased recall of spoken information
- N.B. Study included young NH listeners only!

Sarampalis et al., 2009
2. Does HA rehabilitation affect cognitive outcomes?

- In the long term ( > 3 months)?

Review by Kalluri & Humes & study by Lin et al:

Eight studies available:

- Different cognitive measures, 3 used MMSE
  - 2 +,
- Five used laboratory measures of cognitive function
  - 2 +,

Conclusions:

- Cognition is no longer negligible in audiology!
- It accounts for 20 – 30% of the variance
- Different (cognitive) tests are used throughout studies
- Conflicting evidence or lack of evidence….
- More research is needed before a measure of cognitive functioning can be implemented in clinical practice...
Conclusions contd:
The relation between cognition and hearing aid/benefit isn’t clear yet:

➢ There is an interaction between

- Cognition
- Listening conditions
- Hearing aid characteristics
"It's a special hearing aid. It filters out criticism and amplifies compliments."

THANK YOU!