Implications of Cognitive Factors for Rehabilitation

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Outline

1. Why we should know about cognition
2. Puzzles in hearing rehabilitation
3. Update on cognition and hearing aids
4. Cognition and training
5. Future issues for research and practice

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Speech Understanding in Noise

- Little problem in ideal listening conditions
  - Quiet
  - One talker
  - Familiar person, topic, situation
  - Simple task, focused activity

- Difficulty in challenging listening conditions
  - Noise
  - Multiple talkers
  - Strangers, accents, new topic, novel situation
  - Complex task, many concurrent activities
  - Fast pace
  - Hearing aid

- Avoid by withdrawal from social interaction!

Perspective of an Older Adult who Lives with Hearing Loss

"*When you are hard of hearing you struggle to hear;*
When you struggle to hear you get tired;
When you get tired you get frustrated;
When you get frustrated you get bored;
When you get bored you quit.

-- I didn't quit today."

Cognition & Everyday Function

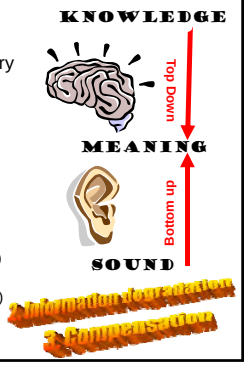
- IJA 2003: International Consensus (Eriksholm, 2001)
  - WHO ICF Concepts (www.who.int/icidh; Schow & Nerbonne, 2006)

    Auditory:
    - **Hearing** – analysis of acoustical signal (impairment)

    Auditory & Cognitive:
    - **Listening** – intention and attention (activity)
    - **Comprehending** – interpretation of meaning (activity)
    - **Communicating** – social interaction (participation)
- The soundbooth vs the real world
  - Professional vs patient views on HL
- "Ease/effort of listening"
  - New goal

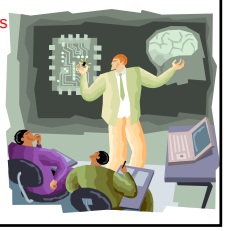
Bottom-Up &Top Down Processing

- As listening becomes effortful
  - Bottom-up processing less efficient
  - Top-down processing more necessary
- Bottom-up (ear to brain)
  - Analysis of acoustic signal
    - Better signal (faster)
    - Poorer signal (slower)
- Top-down (brain to ear)
  - Priming
    - expectations facilitate recognition (faster)
  - Disambiguation
    - knowledge constrain alternatives (slower)
  - Repair
    - Fill in gaps or correct errors (slower)



Cognition & HA Benefit Correlated

- Landmark 2003 studies (Gatehouse et al.; Humes; Lunner)
  - Those with higher cognitive function
    - do better with complex, fast-acting signal processing
  - Those with lower cognitive function
    - do less well to such complex devices
  - Cognition matters in challenging conditions
- Why?
- How measure cognitive status?
  - To predict or guide treatment (HA fitting, training)
  - As a new outcome measure



Good Hearing Health Could Promote Good Cognitive Health

PRESERVE
communication and social interaction
- stave off social isolation
- slow cognitive decline

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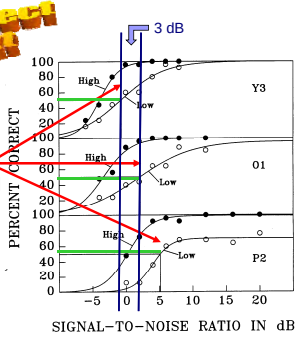
Puzzles about Aided Hearing vs Listening

1. Even if audiograms and fittings are similar, some people understand speech better than others (and some benefit more from hearing aids....)
   - Audibility accounts for a lot, but not all variability
   - What else is important?

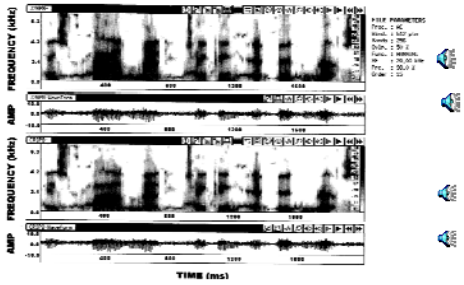
Working Memory

Memory and Listening Effort

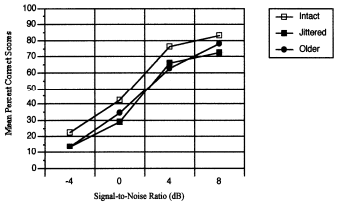
- Effortful listening zone
  - Low-context and high-context curves separated
- Everyone remembers less in this zone than in easy S:N conditions



Spectrograms for Jittered and Intact Sentence in Babble



Word Identification Results

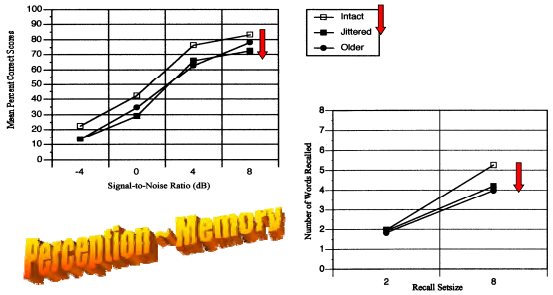


Old = young jittered in LOW-CONTEXT

- Equates for accuracy based on mostly bottom-up processing of signal

Everyday SNR
Living room: +15 dB
Subway: -2 dB

Effect of Simulated Auditory Aging on Working Memory Span



Inter- & Intra-individual Differences

- INTER: Individuals differ in WM capacities

- INTRA: Allocation of capacity resources to processing vs storage varies with task demands

Are Older Adults Special?

- Audibility (audiogram) is primary but not a special aging factor (Humes, 2003, JAAA 2007)

If audibility factor is minimized

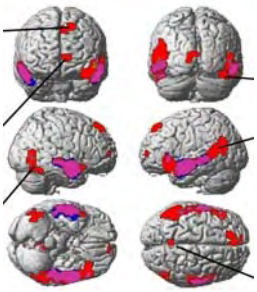
- Age-related auditory temporal processing issues emerge
  - Especially in challenging listening conditions
    - Complex speech (e.g., sentences)
    - Complex backgrounds (e.g., competing talkers)
- Critical age differences when conditions become challenging
  - Older listeners need 2-**3 dB better S:N** than younger listeners
- **Cognitive factors important in challenging conditions!!!**
  - Regardless of age
  - Regardless of audiogram

Cognitive Neuroscience of Aging

- Same performance achieved with different processing
- More widespread activation ~ brain reorganization
  - Young brain activity more lateralized
  - Old brain activity more distributed

- Deterioration or compensation?
- **HAROLD**: Hemispheric asymmetry reduction in older adults (Cabeza, 2002)
- **PASA**: Posterior-anterior shift in aging (Davis, Dennis, Daselaar, Fleck & Cabeza, 2008)

Context, Intelligibility & Brain Activation
(Obleser, Wise, Dresner & Scott, 2006)

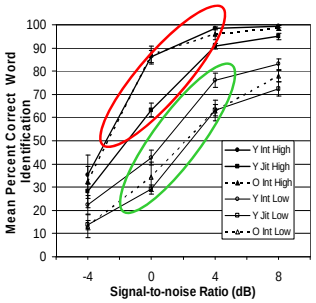


High vs. low predictability at intermediate signal quality for younger adults listening to distorted (noise-vocoded) SPIN sentences

Activation to **HIGH-CONTEXT** > **LOW-CONTEXT** speech

Various areas activated including the **left dorsolateral prefrontal cortex (working memory & semantic processing)**

Use of Context

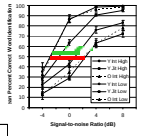


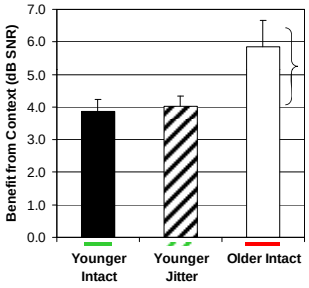
Older = younger jittered in LOW-CONTEXT
- Equates for quality of input for bottom-up processing

Older better than younger jitter in HIGH-CONTEXT
- More expert at top-down processing

Benefit from Context

Older benefit from context more than younger.





2-3 dB SNR

Puzzles about Aided Hearing vs Listening

2. Even if people do well on word recognition, they may complain that it is *effortful* to listen
   - How many ways can one get the word right?
   - How is speed of word access related to accuracy?

Speed of Lexical Processing

e.g., on-line measure of understanding using eye-movement tracking...
Ben-David, Chambers, Daneman, Pichora-Fuller, Reingold, Schneider, submitted JSHLR

Puzzles about Aided Hearing vs Listening

3. Even if clinical speech in noise test results are similar, performance in realistic situations varies
   - How does the task influence performance?
   - How does the background interfere with a foreground?
   - How does knowledge of the environment or signal influence performance?

Attention

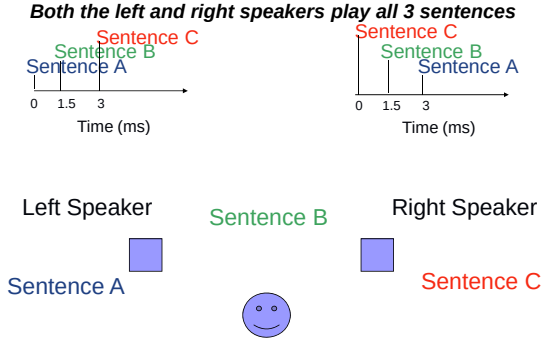
e.g., auditory spatial attention...
Singh, Pichora-Fuller, Schneider, JASA, 2008
Effect of time on attention switching, submitted Attention, Psychophysics & Perception
Task complexity, submitted Psych & Aging
Effect of linear vs non-linear HA compression, ISAAR 2009

Condition 1: Real Separation

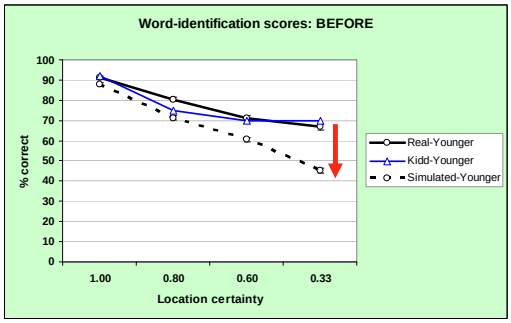
- Callsigns = Charlie, Hopper, Baron, etc.
- Probability of target at the centre location (1.0, 0.33)
- Task: Identify **colour** and **number** with target callsign

Condition 2: Simulated Spatial Separation

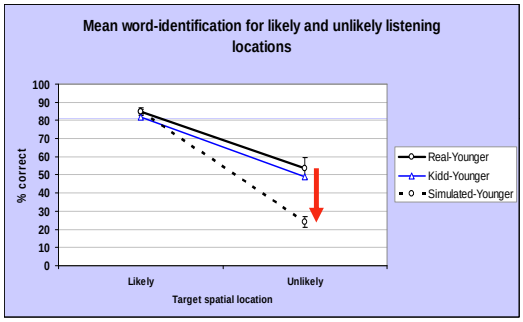
Both the left and right speakers play all 3 sentences



Richer Cues Help When Uncertain



Richer Cues Helps Switch Attention



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Effects of Hearing Aids on Speech

- Signal processing usually helps
  - Renders signal audible
- Signal processing may have little effect
  - Directional microphones, depending on spatial separation of source and noise
- Signal processing can hinder speech perception
  - Fast-acting compression can undermine aspects of speech acoustics
    - Sound quality (Souza, Trends in Amplification, 2004)
    - Words in quiet (Bor, Souza, Wright, JSLHR 2008)
    - Sentences in quiet (Jenstad & Souza, JSLHR 2005)
    - Speech in competing speech (Stone & Moore, JASA 2004)
- Automatic vs manual controls may demand attention depending on listener's goals
- Attention?
  - Spatial cues?
  - Informational masking?
  - Divided attention?

News Breaking Headlines

- General Benefits from HA
  - Davis (IJA, 2003)
    - Population study in UK
    - Those with poorer cognitive function

    (reading working memory – phonological memory, semantic long-term memory)

    show greater overall benefit from HAs

    (aided – unaided score on FAAF 4-alternative word in noise test)

    (worse unaided performance on speech in noise test)

Speech in Noise Baseline

News Breaking Headlines

- General Benefits from HA
  - Humes (Trends in Amplification, 2003)
    - N = 134 older adults over 1 year post fitting
    - Outcomes:
      - Speech recognition
      - HA usage (hours)
      - Subjective benefit and satisfaction
      - All three related to cognitive measure (verbal IQ)
        - Positively with speech recognition and benefit and satisfaction
        - Negatively with HA usage
        - HAs used more by those less able to compensate

HA use greater if less cognitively able

News Breaking Headlines

- Why does cognition relate to HA benefit?
  - Speech in noise performance w/wo HA
  - Ability to evaluate and react to performance of HA

  - Lunner (IJA, 2003)
    - N=72. Higher cognitive function (control for age, HL)
      (reading working memory and verbal information processing speed)
      correlated with speech recognition in noise (w/wo HA) **Speech in Noise**

    - N = 17. Higher vs lower cognitive groups tested –
      higher better reporting processing effects of experimental aid
      …. could impact learning to use HA

Awareness of Processing Differences

News Breaking Headlines

- Effects of HA: Speech Accuracy, Reaction Time, Effort

  - Hällgren, Larsby, Lyxell, & Arlinger (IJA, 2005)
    - N=12 younger and 12 older experienced adult users of bilateral HAs
    - Hagerman sentence test in quiet, speech noise, competing talker w/wo HAs
    - Semantic, lexical, name decision RT tests in quiet and two noises w/wo HAs
    - Report effort

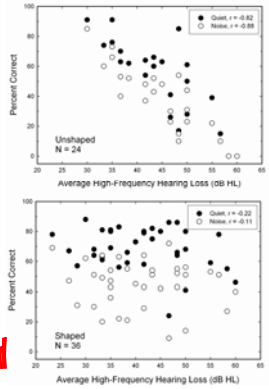
    - HA vs UA:
      - Faster RT in noise measured using fixed SNR of 10 dB (high accuracy)
        - Effort reduced w vs wo HA
        - Effort reduction: speech noise > competing talker

Reaction Time and Effort when Accuracy High

Controlling Audibility
(Humes, JASA 2002, JAAA 2007)

- Audibility is main factor for UNAIDED measures of speech (in noise)

- Aided (or amplified to 4 kHz): other factors account for over half of variance: age, central processing (SNR), and cognitive factors (memory)



Cognition Important when Audibility Good

Speech in Noise and Cognition Review
Ackeroyd (IJA, 2008)

- 20 studies of normal and HI adults
- Individual differences
- HL primary factor, cognition secondary
- Working memory most related

Cognition Important when Audibility Good
Working Memory

News Breaking Headlines

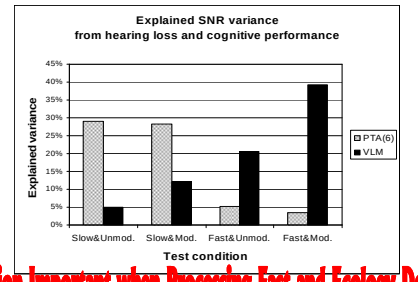
- Compare hearing aid processing algorithms (extension of 2003 study)
  - Gatehouse, Naylor, & Elberling (IJA, 2006)
    - N = 50
    - Cross-over design to compare
      fast-acting WDRC vs
      slow-acting AVC compression fittings
    - Differences in performance
      (satisfaction, reported intelligibility, speech test)
      varied with acoustic ecologies and cognitive capacity
      (visual letter monitoring)

Cognition Important when Processing Fast and Ecology Demanding

Lunner & Sundewall-Thorén, JAAA 2007

N = 32 experienced HA users

Replicates earlier studies (Gatehouse et al. 2003, 2006) with sentence tests



Cognition Important when Processing Fast and Ecology Demanding

News Breaking Headlines

- Outcomes
  - Sarampalis, Kalluri, Edwards, & Hafter (JSHLR, in press)
    - Noise-reduction algorithms in hearing aids
      - Normals: no effect of NR on word recognition, but positive effect on amount remembered and on secondary visual task
  - Sarampalis, Nooraei, Kalluri, & Edwards (AAA, 2009)
    - Directional microphone
      - HI: those with cognitive benefits did better on speech in noise with vs without directional microphone, but some showed neither type of benefit

Benefit from HA Features ~ Cognition

News Breaking Headlines

- Candidature
  - Foo, Rudner, Rőnnberg, Lunner (JAAA, 2007)
    - 32 habitual HA users tested on new compression fitting
    - Two cognitive measures and NEW HA fittings
      (reading working memory span and visual letter monitoring)
      RWMS better than VLM in predicting performance on speech in noise sentence tests
      (Hagerman and HINT sentences)

Cognition Important when HA New

News Breaking Headlines

- Outcomes: Working memory and acclimatization
  - Rudner, Foo, Rőnnberg, Lunner (SJP, 2009)
    - N=32 experienced HA users
      - Half given 9 week experience with one modified compression algorithm
      - Half given 9 week experience with another
    - Initial performance with new algorithm
      - predicted by working memory
    - After experience, performance with learned algorithm
      - not predicted by working memory,
      - but it did predict performance with untrained new algorithm
    - Mismatch hypothesis: Explicit working memory relevant only when the incoming signal is mismatched to expectation (e.g., new vs learned)

Cognition Important when HA Processing Changed (not Learned Already)
Ease of Listening Model

Summary: When & Why Cognition Counts

- Speech in noise and subjective benefit (unaided vs aided)
- Hearing aid usage (more use if lower cognition)
- Once control for audibility (good) and accuracy (high but not perfect)
  - Online vs offline measures
    - Reaction Time
    - Dual task performance
    - Effort
- Ecology demanding (modulated noise; competing talkers - distraction, interference)
- Differentiates individuals
  - Awareness of HA processing differences
  - Benefit from various HA features
    - Fast-acting compression (release time < 200 ms)
    - Noise reduction
    - Directional hearing aids
  - Learning
    - Performance with new or changed HA processing
    - Not already learned HA processing

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Possible Cognitive Factors in Aging

Processing ("fluid intelligence") declines:

- Slowing
- Working memory
- Attention

All are reasonable cognitive consequences if sensory (or motor) abilities are reduced

BUT knowledge ("crystallized intelligence") is preserved and context is helpful

Contextual Support & Compensation

Pichora-Fuller, IJA, 2008
Phonak *Hearing Care for Adults,* 2009

- Semantic-Syntactic
- Lexical
- Phonological

Hearing Loss Associated with Dementia

- Gold, Lightfoot & Hnath-Chisolm (1996)
  - 27 of 30 (90%) patients with Alzheimer's had hearing impairment (pure-tone screen & HHIE)
- Uhlmann et al. (1989)
  - Case-control study with 100 pairs
    - Prevalence of hearing loss significantly higher in those with Alzheimer's-type dementia
    - Hearing loss significantly correlated with MMSE
- Lin et al. (2004)
    - Dual sensory loss associated with greatest odds for cognitive decline and for functional decline on five everyday activities over a period of four years

Hearing Loss Can Impair Performance on Any Task Using Auditory Stimuli

- Weinstein & Amsel (1986)
  - N=30 institutionalized elders with senile dementia
  - 10 of 30 reclassified to less severe category of dementia when retested with amplification
  - (83% had hearing loss > 25 dB HL, significantly higher than comparison sample w/o dementia)

"Central Auditory" (Speech in Noise) Problems May *PRECEDE* Dementia

- Longitudinal epidemiological studies
  - Gates et al. (1996)
    - N >700, speech in competing speech test (SSI-ICM) given to those without stroke, dementia, or hearing loss (PTA 40 dB HL)
    - MMSE administered 2, 4, 6 years later
    - Those with low scores on SSI-ICM were 6-12 times more likely to develop clinical dementia
  - Gates et al. (2002, 2008)
    - Similar results for longer follow-up period (3-12years)

Cognitive Benefits of Better Hearing

Arlinger, Lunner, Lyxell, & Pichora-Fuller, SJP, 2009

- Older adults using hearing aids have better emotional and social well-being and greater longevity
  (Appolonio *et al*., 1996; Cacciatore et al., 1999; Naramura *et al*., 1999; Seniors Research Group, 1999)
- Reduced rate of decline in scores on a cognitive screening test over a six-month period following intervention with hearing aids
  (Allen et al., 2003)
- Slower cognitive decline in Alzheimer's cases with better hearing
  (Peters, Potter, & Scholer, 1988; Wahl & Heyl, 2003)
- Hearing aid use reduced problem behaviours judged by caregivers of adults with dementia
  (Palmer et al., 1998)

Mild Cognitive Impairment
(e.g, Troyer & Murphy, 2007)

- Active lifestyle ~ risk of future dementia
  - Cognitive engagement
    - Tasks involving problem-solving, decision-making, learning, remembering new information
  - Social interaction
    - Rich social and active social network
    - Participating in group activities and interactions
  - Physical activity
    - Some activities are done in groups, with music
- Enriched environments
- Complexity: people, ideas, things
- Group interventions
- Communication-related disorders???

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Future Issues for NOW

- How will audiologists use cognitive measures?
  - Candidature and/or outcome measures
- Which measures?
  - Working memory, divided attention, speed
- Realistic conditions
  - Informational masking, spatial displays, tasks
- Customize technology based on cognition
- Brain plasticity and training
  - Acclimatization: frontal lobe helping with context
  - Preserve function and slow cognitive decline

Conclusion

- For both researchers and clinicians
  - Now it is time to move towards an integrated approach to assessing and managing the communication-related needs of older adults so they can maintain social participation
- Auditory-Cognitive Interactions
  - Deleterious effects
  - Supportive effects