Brain plasticity: Implications for Rehabilitation

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We’ve come a long way in 10 years
HEADLINE: 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 by hearing aids
  - Those with lower cognitive function
    - do less well with such complex devices

- Questions:
  - Why does cognition matter?
  - Should audiologists measure cognition?
  - How would we measure it?
  - What would we do with the results?
And there’s a long (and winding) road ahead…

Everything old is new again….

http://www.youtube.com/watch?v=d7fy2Ls0zbA
Outline

1. More than one way to recognize a word
2. Cognitive aging, compensation, training
3. Implications for aural rehabilitation
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1. More than one way to recognize a word
2. Cognitive aging, compensation, training
3. Implications for aural rehabilitation
Speech Intelligibility in Noise

Kryter 1994 – based on ANSI 1969

Small set
Sentences
Familiarity

Listener
Talker
Type of noise
Task demands

NOTE: THESE RELATIONS ARE APPROXIMATE. THEY DEPEND UPON TYPE OF MATERIAL AND SKILL OF TALKERS AND LISTENERS.
Speech Perception in Noise Test
(Pichora-Fuller, Schneider, Daneman, JASA, 1995)

- 8 lists of 50 sentences
  - Half low-context
    
    *John did not talk about the feast.*
  - Half high-context
    
    *The wedding banquet was a feast.*

- Repeat last word of sentence
  - (Sometimes also recall)

- Vary S:N
  - + 15 dB S:N in quiet home
  - - 2 dB S:N in subway/aircraft

- Old need 3 dB better S:N
  - Auditory temporal processing

- Context helps
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 or repair errors
    - knowledge used to fill in gaps, constrain alternatives, correct errors (slower)
As Processing Effort Increases

Extreme demand: Accuracy drops

But if accuracy is remains high, increased processing effort (cognitive load is manifested by

- Reduced working memory span
- Slower speed
Working memory

- System responsible for the **PROCESSING** and temporary **STORAGE** of information
  - during the performance of all complex cognitive tasks, including comprehension
  - assumed to have a **limited capacity** that must be shared between processing and storage

(Baddeley, 1976)
Effect of Simulated Auditory Aging on Working Memory Span

Graphs showing the effect of signal-to-noise ratio on mean percent correct scores and number of words recalled.
Measuring Working Memory: Why and How…

Fred
Fred in Quiet
Fred in Noise
Fred in More Noise

Mary

Off-line
WM = 5
WM = 7

On-line
WM = 5
WM = 3
WM = 1

If task demand does not exceed capacity, would recognition accuracy be reduced?
If task demand does exceed capacity, would recognition accuracy be reduced?
If WM measured on-line, would it correlate with performance (accuracy, speed, effort)?

Adapted from Pichora-Fuller, 2006 Phonak Conference
## Word Span with NU6s (quiet)

*(Smith, Pichora-Fuller, Alexander, Wilson, & Anderson, in prep)*

<table>
<thead>
<tr>
<th>Word</th>
<th>Recognition</th>
<th>Judgment</th>
<th>Recall</th>
</tr>
</thead>
<tbody>
<tr>
<td>RICE</td>
<td>✔</td>
<td>✔</td>
<td>Rice, ☑</td>
</tr>
<tr>
<td>FIST</td>
<td>X, Fish</td>
<td>✔</td>
<td>Fish, ☑</td>
</tr>
<tr>
<td>RISK</td>
<td>✔</td>
<td>✔</td>
<td>Risk, ☑</td>
</tr>
<tr>
<td>GRACE</td>
<td>✔</td>
<td>✔</td>
<td>Grace, ☑</td>
</tr>
<tr>
<td>BAR</td>
<td>X, Car</td>
<td>X</td>
<td>Card, X</td>
</tr>
<tr>
<td>SHOVE</td>
<td>✔</td>
<td>X</td>
<td>Shove, ☑</td>
</tr>
<tr>
<td>WHAT</td>
<td>✔</td>
<td>✔</td>
<td>What, ☑</td>
</tr>
<tr>
<td>MOON</td>
<td>✔</td>
<td>✔</td>
<td>Moon, ☑</td>
</tr>
<tr>
<td>CALF</td>
<td>✔</td>
<td>✔</td>
<td>Rice, ☑</td>
</tr>
<tr>
<td>THAT</td>
<td>✔</td>
<td>✔</td>
<td>That, ☑</td>
</tr>
</tbody>
</table>
OHL
Split group based on median span
≥3.67 HIGH
≤3.33 LOW

Adding task demand affects LOW span group at smaller set size
## Correlations for OHL

<table>
<thead>
<tr>
<th>Auditory Measures</th>
<th>Recognition</th>
<th>Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTA or HFPTA</td>
<td>r = .70-.77 (p &lt; .001)</td>
<td>ns</td>
</tr>
<tr>
<td>WIN 50% Point</td>
<td>r = -.82 (p &lt; .001)</td>
<td>ns</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Memory Measures</th>
<th>Recognition</th>
<th>Span</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Span-Forward</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Digit Span-Backward</td>
<td>ns</td>
<td>r = .28 (p = .03)</td>
</tr>
<tr>
<td>Digit Span-Sequencing</td>
<td>ns</td>
<td>r = .34 (p = .009)</td>
</tr>
<tr>
<td>Auditory Free Recall</td>
<td>r = .31 (p = .007)</td>
<td>r = .35 (p = .007)</td>
</tr>
<tr>
<td>Visual Free Recall</td>
<td>ns</td>
<td>r = .42 (p = .001)</td>
</tr>
<tr>
<td>MoCA (total)</td>
<td>ns</td>
<td>r = .37 (p = .004)</td>
</tr>
</tbody>
</table>
Outline

1. More than one way to recognize a word
2. **Cognitive aging, compensation, training**
3. Implications for aural rehabilitation
Possible Cognitive Factors in Aging

- **Knowledge** is preserved and context is helpful

**BUT ..... Processing** is less efficient
- Working memory
- Divided attention
- **Speed** of information processing
  - If sensory (or motor) abilities are reduced then cognitive processing demands could increase

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
Increasing Acoustic Distortion of Context Slows Lexical Decision for Later Intact Word


**A Type**

**B Amount**

- Low-pass filtering
- Multi-talker babble
- Time compression

- Less distortion
- More distortion

Average median RT for lexical decision (ms)

<table>
<thead>
<tr>
<th></th>
<th>Congruent</th>
<th>Neutral</th>
<th>Incongruent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**speed**
Facilitation by Congruent Context is Reduced by Signal Distortion but is Greater for Older than Younger Adults
Speed (and Ease) of Listening

- Signal quality affects listening:
  - Faster if signal is intact
  - Slower if signal is distorted or degraded or noisy
  - Could be influenced by hearing aid processing

- Context affects listening:
  - Faster if context is semantically congruent
  - Slower if context is semantically incongruent
  - Could be influenced by AR training
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)
Cognitive Neuroscience of Aging

- Same performance achieved but with different processing (amounts of brain activation and extents of networks)

- More widespread activation ~ brain reorganization
  - Young brain activity more lateralized
  - Old brain activity more distributed

- HAROLD: Hemispheric asymmetry reduction in older adults (Cabeza, 2002)

- PASA: Posterior-anterior shift in aging (Davis, Dennis, Daselaar, Fleck & Cabeza, 2008)

Deterioration or compensation?
Compensation

(Grady, 2012, *Nature Reviews Neuroscience*, 13, 491-505)
Task Demands
(Pichora-Fuller & Jamieson, 2012)

Task 1 depends mostly on auditory capacity (e.g., detecting a sound).

Task 2 depends more on cognitive capacity (comprehending a lecture).

Task 3 depends even more on cognitive capacity (dividing attention during group conversation).

P1 is a person with normal hearing and slightly below average cognitive capacity who has sufficient combined capacities to succeed on all 3 tasks.

P2 is a person with hearing loss and high cognitive capacity who is able to succeed on all 3 tasks by using cognitive capacity (world and linguistic knowledge) to help compensate for deficits in auditory processing.
Cognitive Theories and Training

- **Cognitive Compensation Hypothesis**
  (Li, Krampe, & Bondar, 2005; Li & Lindenberger, 2002)
  - declining sensory (and motor) functions are compensated by higher-level cognitive and attentional processes

- **CRUNCH - Compensation-Related Utilization of Neural Circuits Hypothesis**
  (Reuter-Lorenz & Cappell, 2008)
  - additional brain regions are recruited by older adults when capacity limits are reached in a given task or combined tasks.

- **STAC - Scaffolding Theory of Aging and Cognition**
  (Park & Reuter-Lorenz, 2009)
  - there is the potential to enhance such compensation by training.
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 stimulation and active social network
    - Participating in group activities and interactions
  - **Physical** activity
    - Some activities are done in groups, with music

- **Enriched environments**
- **Group interventions**
- **Communication-related disorders???”
Outline

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Implications for AR

- AR could facilitate brain reorganization
- Approaches based on compensation
  - Use of context
  - Strategies ~ task demands (listening goals)
- Actively engage older adults with HL in re-learning how to listen and understand
  - In realistic environments
    - Talkers
    - Acoustic and social situations
  - Using technologies
  - Multi-modal, sensori-motor
Training

- Time on task
  - Interesting
  - Reinforcing
    - Fun
    - Social support
    - Build self-efficacy

- Complexity
  - Generalization to everyday life

- Health promotion context
  - Stay active, stay healthy
  - Value of communication
Everything Old is New Again

Analytic vs Synthetic Training?
Signal vs Meaning….
Phonemes vs Discourse….
Bottom-up vs Top-down……


http://www.youtube.com/watch?v=Ctev1Yg9XWI
More conferences

- Linkoping, Sweden in June 2013
  2nd International Conference on Cognitive Hearing Science for Communication
  http://www.chscom2013.se/

- Indiana in October 2013
  4th Aging and Speech Communication Conference
  http://www.indiana.edu/~ascpost/program.htm
What Changes in Cognitive Development over the Lifespan?
(Craik & Bialystock, 2008)

- **Representation** (knowledge, habits)
- **Context** (reliance, benefit from supportive environment)
- **Control** (processing effort to guide, organize, monitor behavior)

Younger: --
Older: --