

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

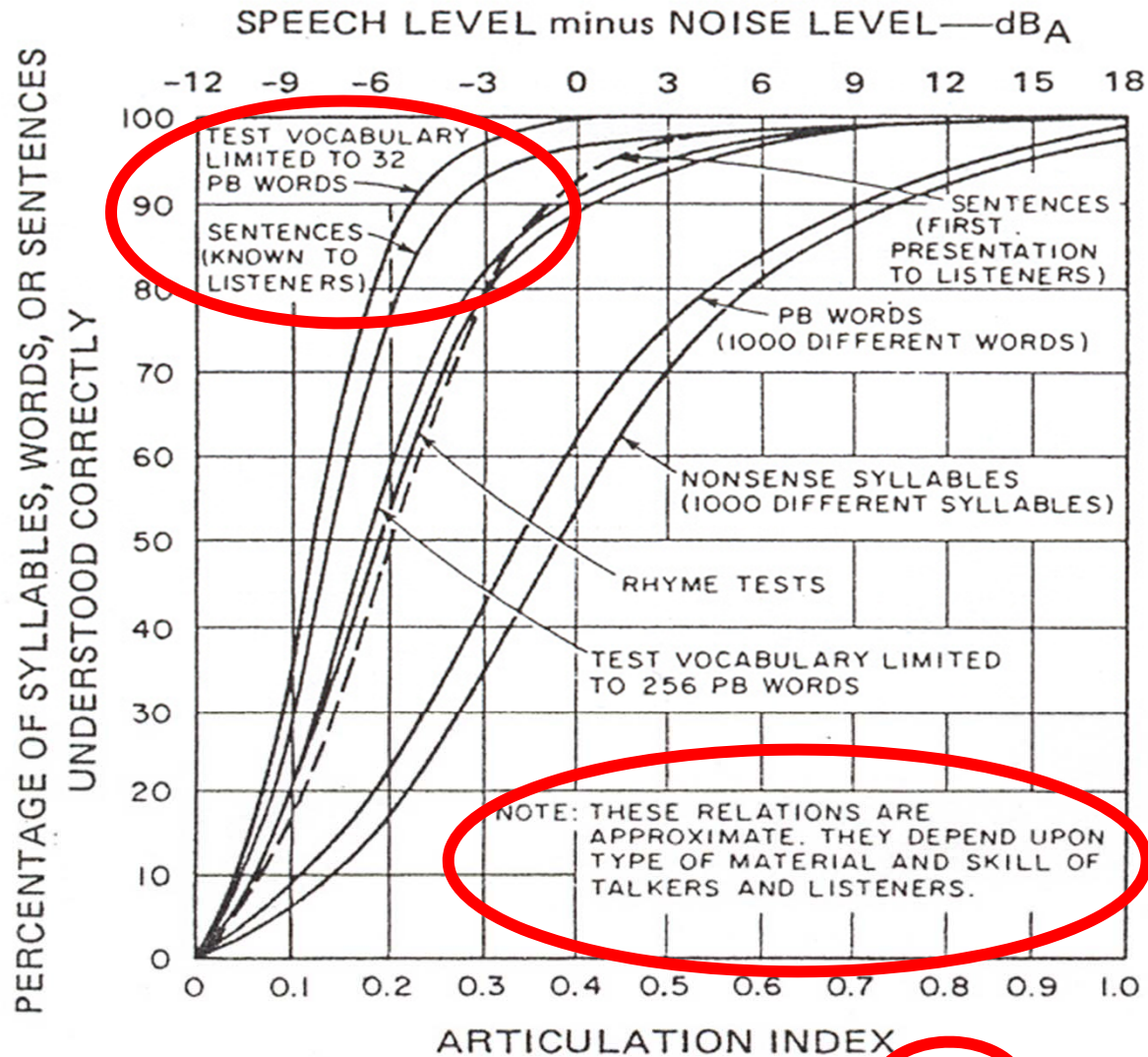


Outline

1. **More than one way to recognize a word**
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Speech Intelligibility in Noise

Small set
Sentences
Familiarity



Listener
Talker

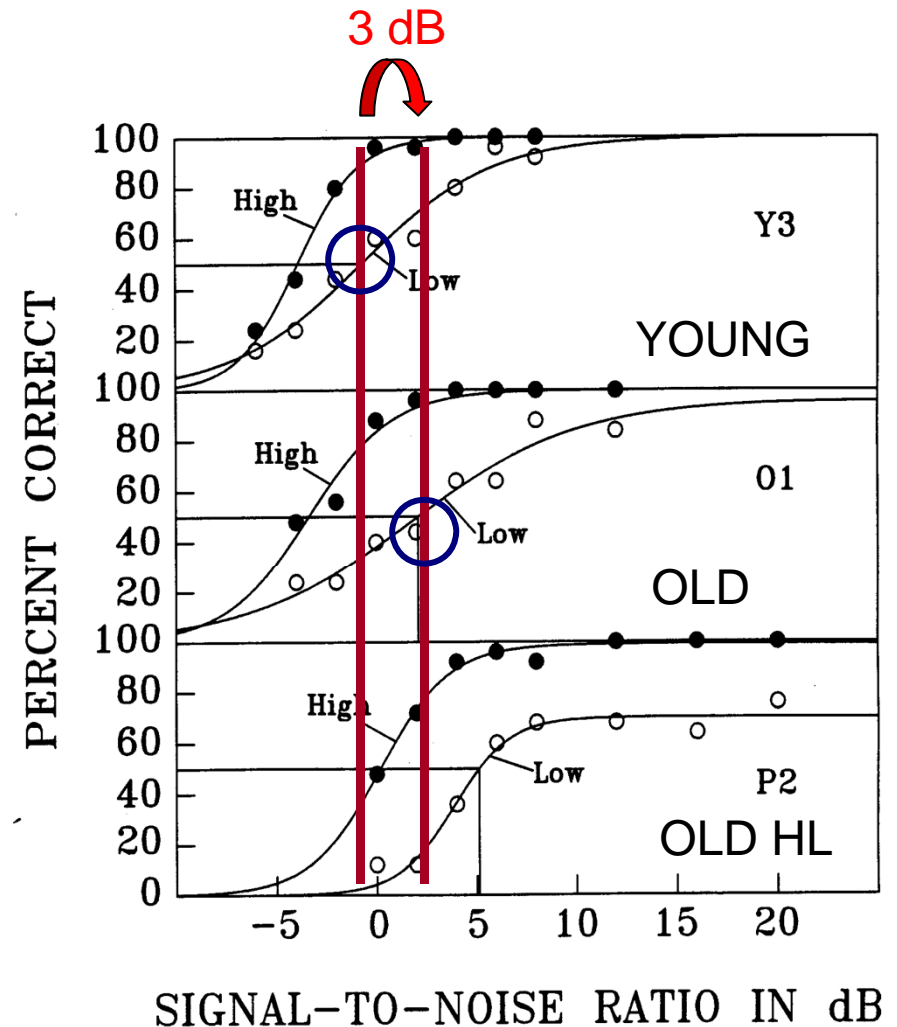
Type of noise
Task demands

Kryter 1994 – based on ANS, 1969

Speech Perception in Noise Test

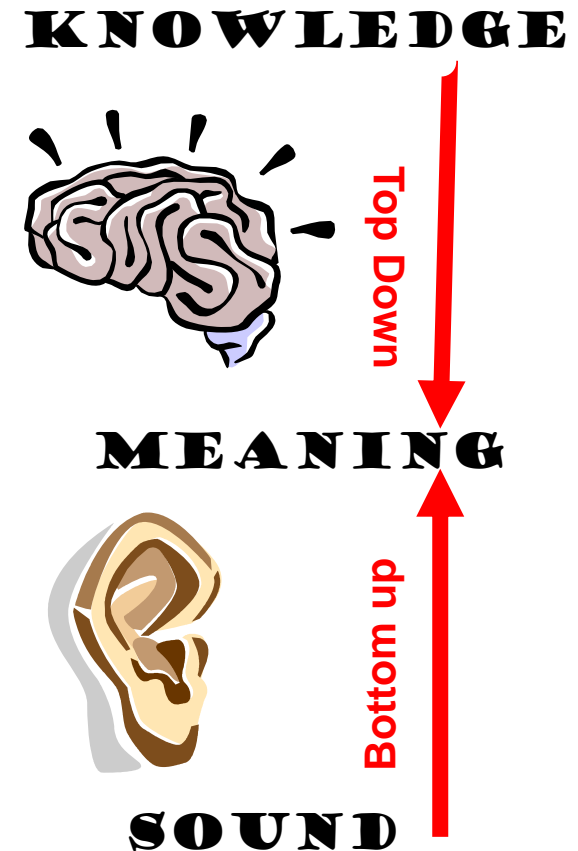
(Pichora-Fuller, Schneider, Daneman, JASA, 1995)

- 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)





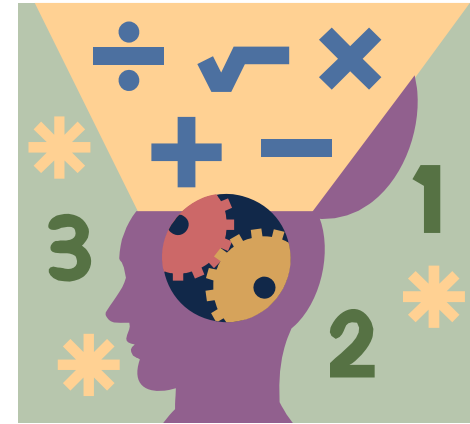
As Processing Effort Increases

Extreme demand: Accuracy drops

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

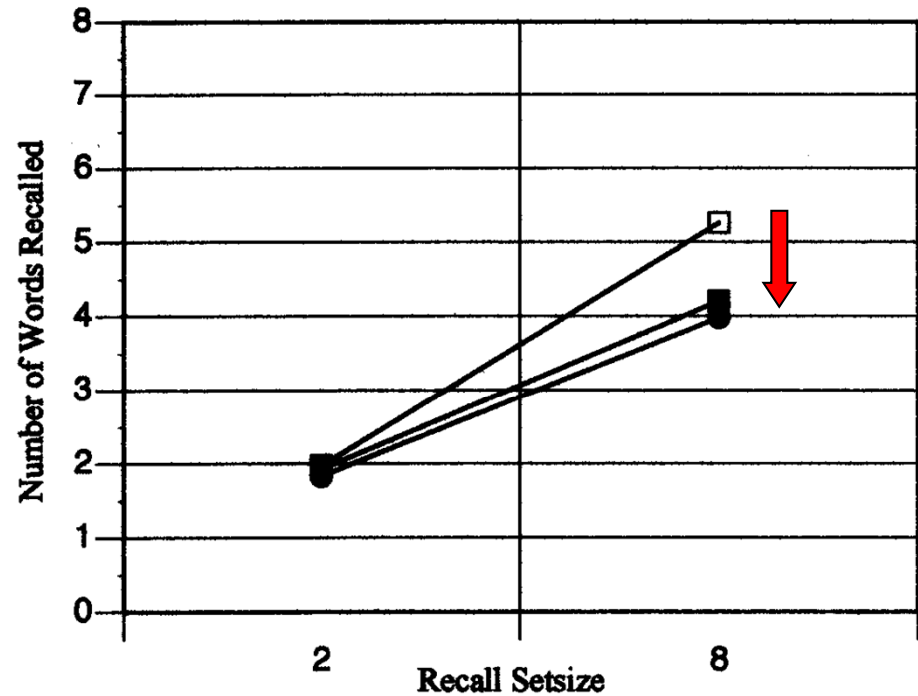
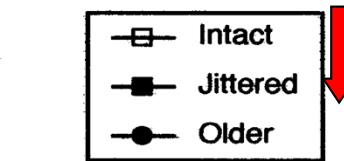
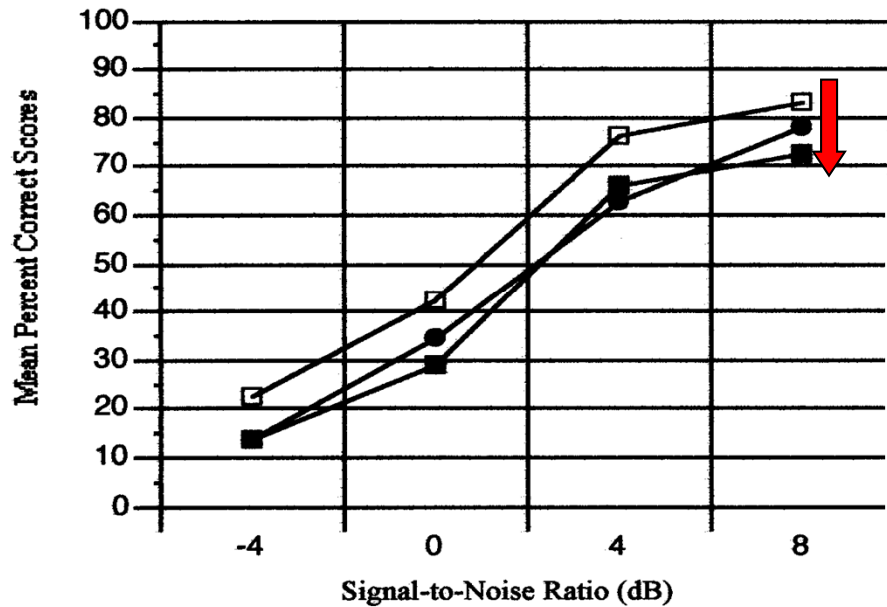
- Reduced working memory span
- Slower speed

Working memory



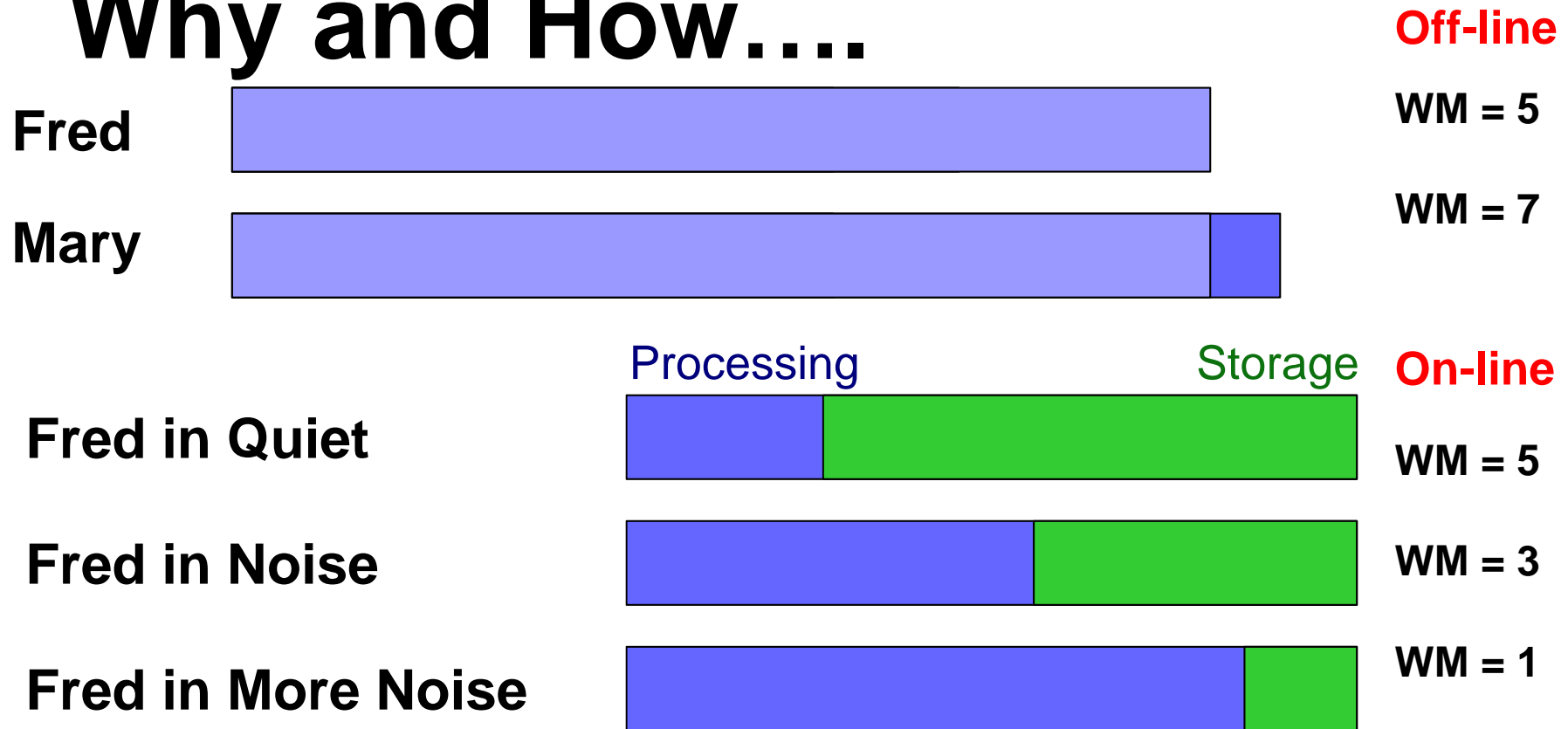
- System responsible for the **PROCESSING** and temporary **STORAGE** of information
 - during the performance of all complex cognitive tasks, including comprehension
 - assumed to have a **limited capacity that must be shared between processing and storage**
(Baddeley, 1976)

Effect of Simulated Auditory Aging on Working Memory Span



Perception ~ Memory

Measuring Working Memory: Why and How....



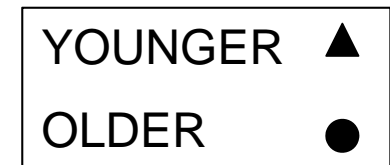
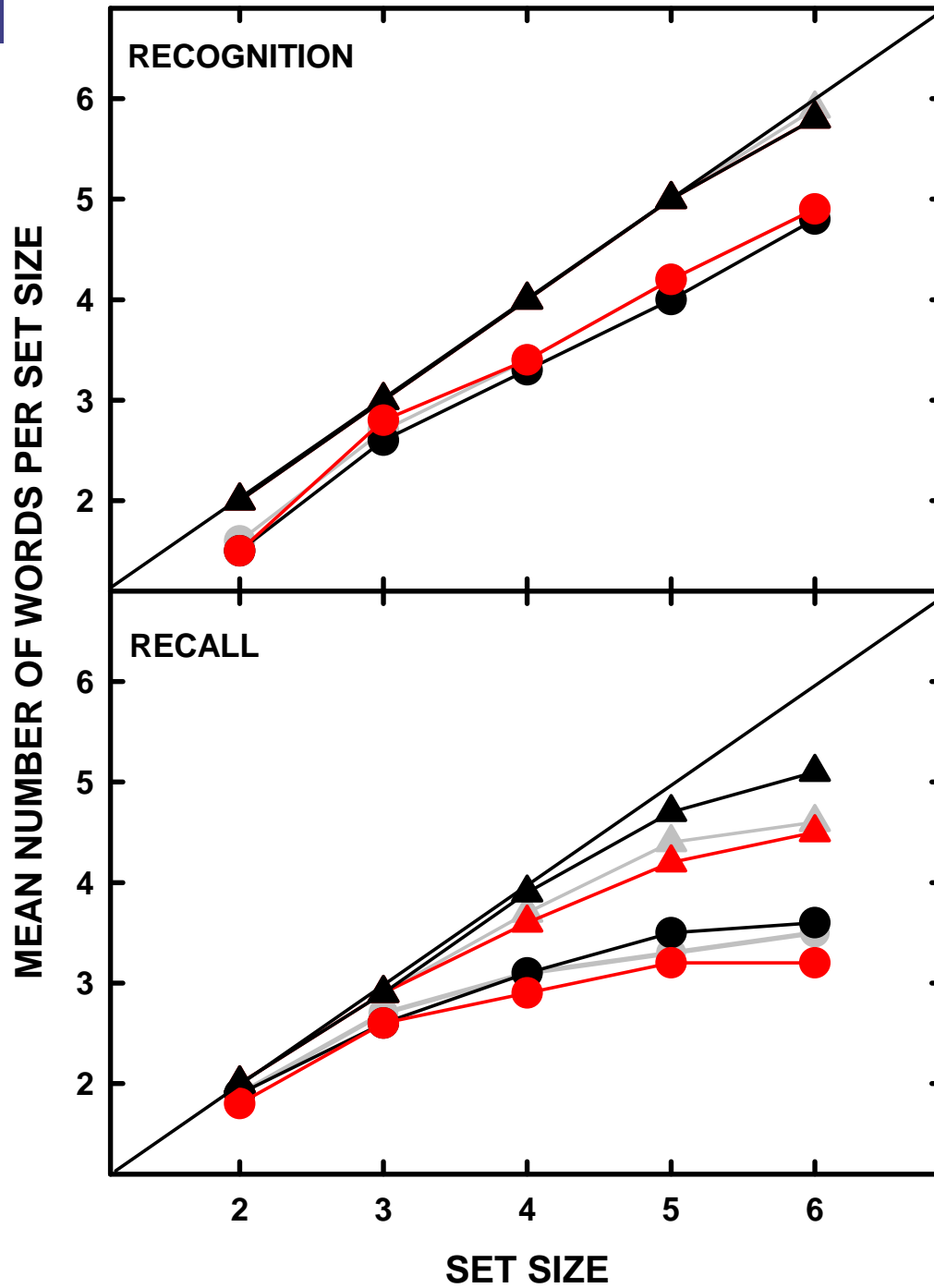
If task **demand does not exceed capacity**, would recognition accuracy be reduced?
 If task **demand does exceed capacity**, would recognition accuracy be reduced?
 If WM measured **on-line**, would it correlate with performance (accuracy, speed, effort)?

Word Span with NU6s (quiet)

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

Word	Recognition	Judgment	Recall
RICE	✓	✓	Rice, ✓
FIST	X, Fish	✓	Fish, ✓
RISK	✓	✓	Risk, ✓
GRACE	✓	✓	Grace, ✓
BAR	X, Car	X	Card, X
SHOVE	✓	X	Shove, ✓
WHAT	✓	✓	What, ✓
MOON	✓	✓	Moon, ✓
CALF	✓	✓	Rice, ✓
THAT	✓	✓	That, ✓



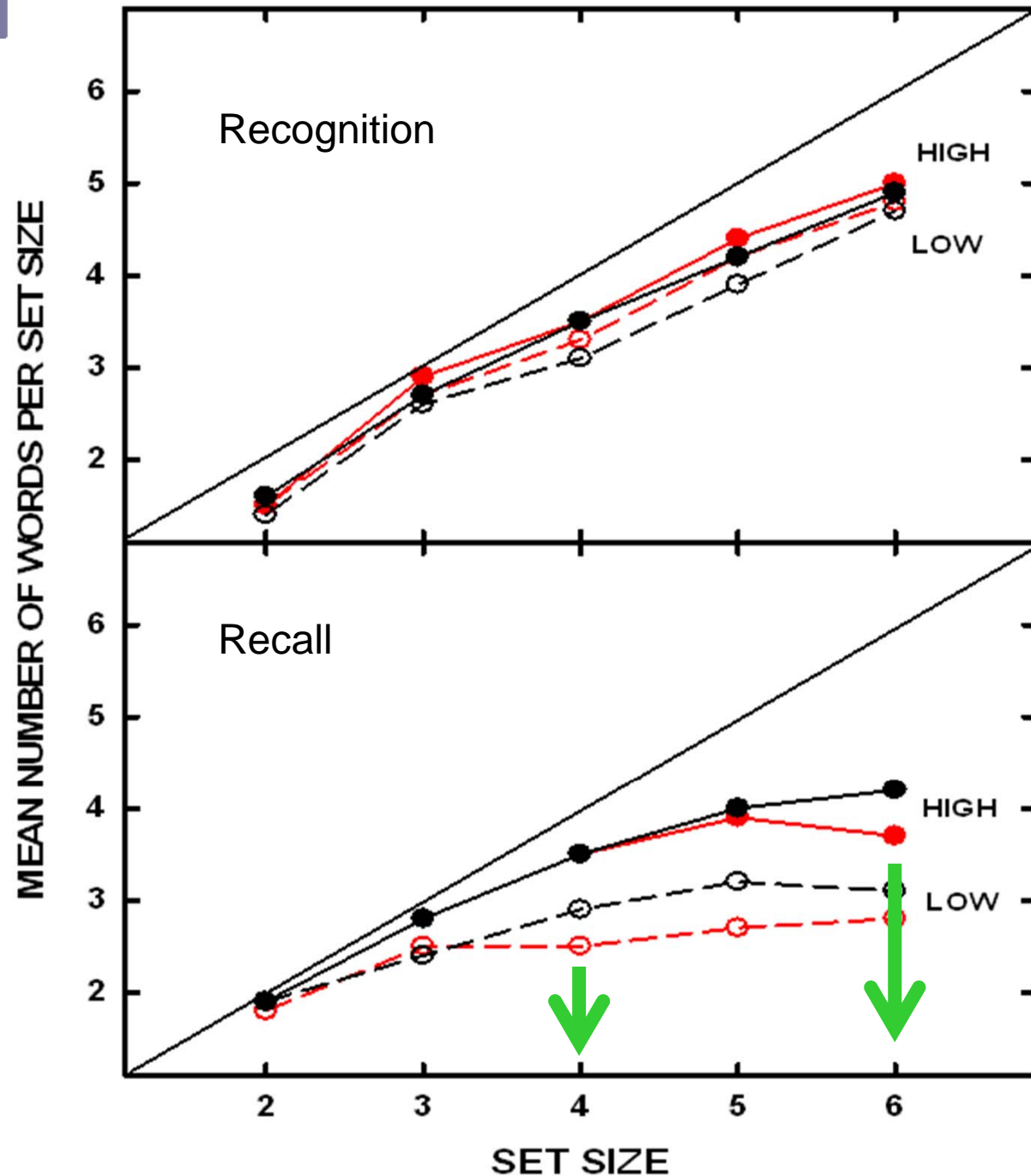




OHL

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

	Recognition	Span
Recognition	-	ns
Span	ns	-

Auditory Measures	Recognition	Span
PTA or HFPTA	$r = .70-.77$ ($p < .001$)	ns
WIN 50% Point	$r = -.82$ ($p < .001$)	ns

Memory Measures	Recognition	Span
Digit Span-Forward	ns	ns
Digit Span-Backward	ns	$r = .28$ ($p = .03$)
Digit Span-Sequencing	ns	$r = .34$ ($p = .009$)
Auditory Free Recall	$r = .31$ ($p = .007$)	$r = .35$ ($p = .007$)
Visual Free Recall	ns	$r = .42$ ($p = .001$)
MoCA (total)	ns	$r = .37$ ($p = .004$)



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Possible Cognitive Factors in Aging

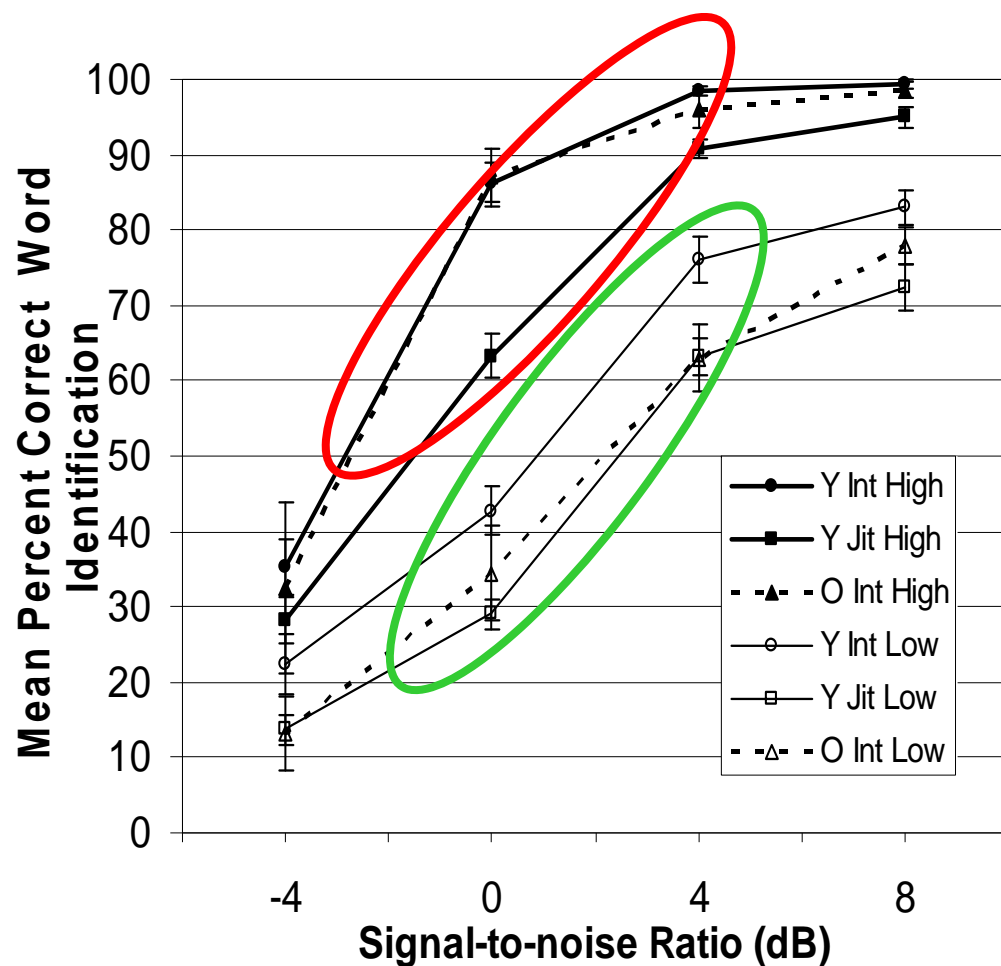
- **Knowledge** is preserved and context is helpful

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**

(Schneider, B.A., Pichora-Fuller, M.K., & Daneman, M. (2010). The effects of senescent changes in audition and cognition on spoken language comprehension (pp. 167-210). In S. Gordon-Salant, R. D. Frisina, A. Popper, & D. Fay (Eds), *The aging auditory system: Perceptual characterization and neural bases of presbycusis*, Springer Handbook of Auditory Research. Springer: Berlin)

Use of Context



Older = younger jittered
in **LOW-CONTEXT**

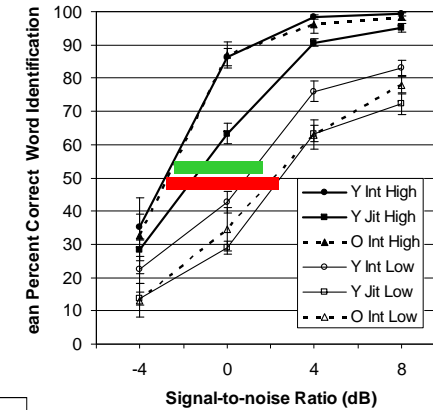
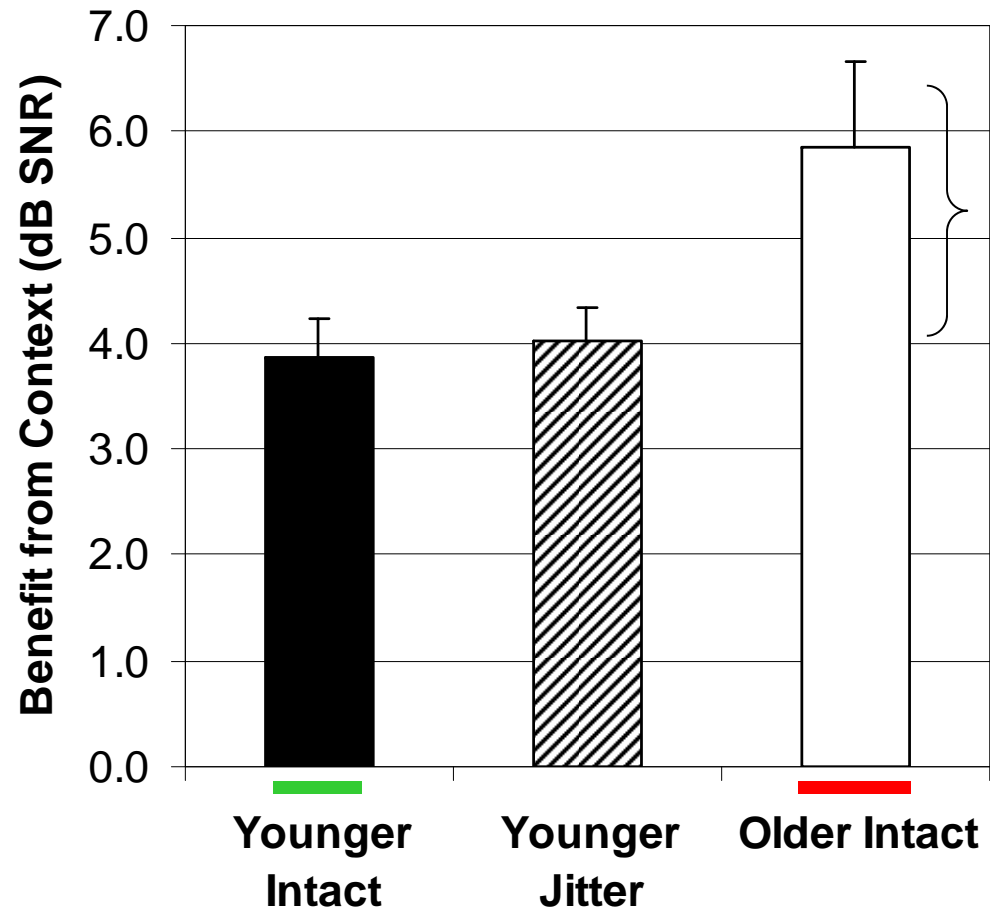
- Equates for quality of input for bottom-up processing

Older better than younger
jitter in **HIGH-CONTEXT**

- More expert at top-down processing

Benefit from Context

Older benefit from context more than younger.

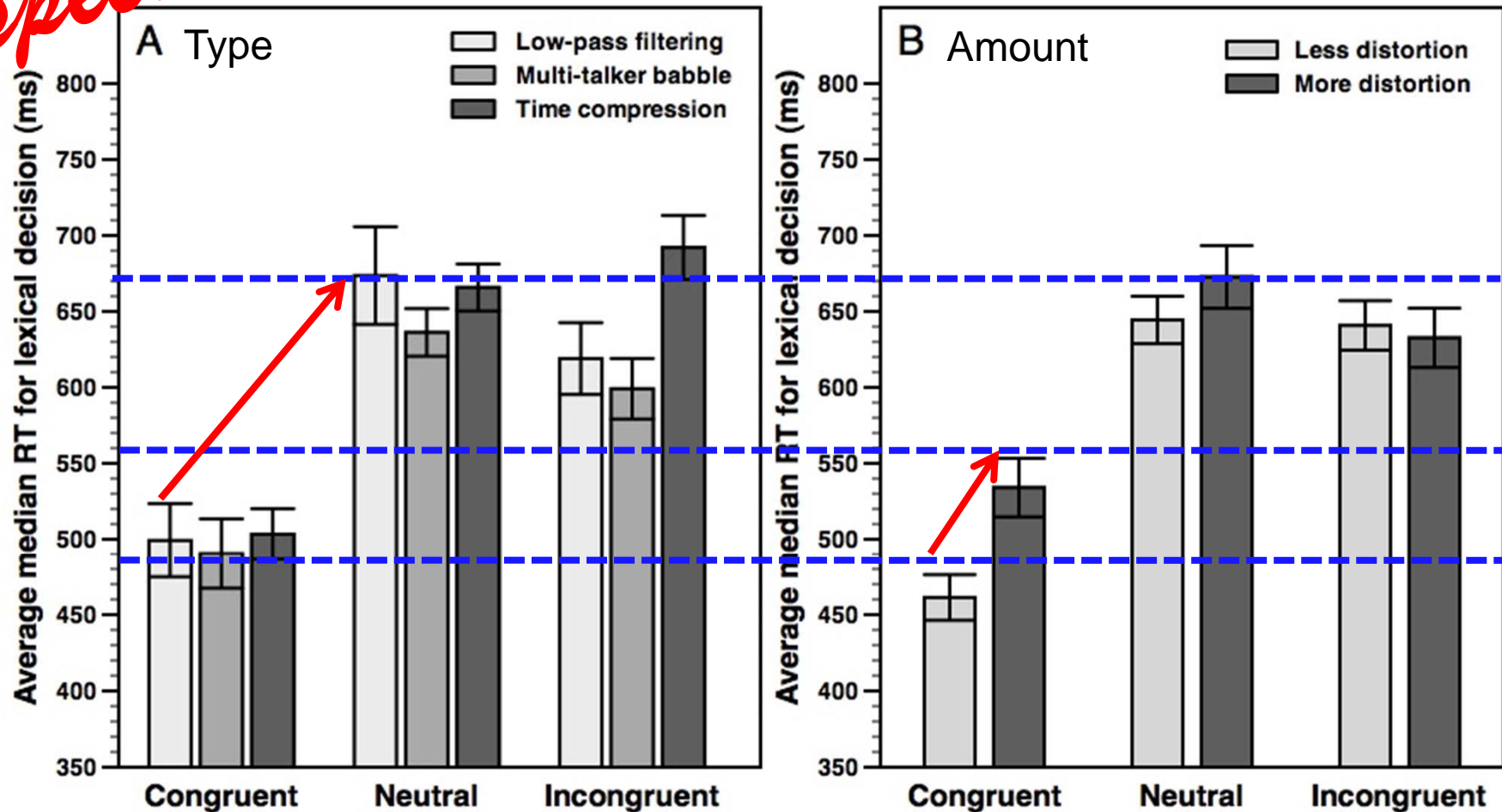


2-3 dB SNR

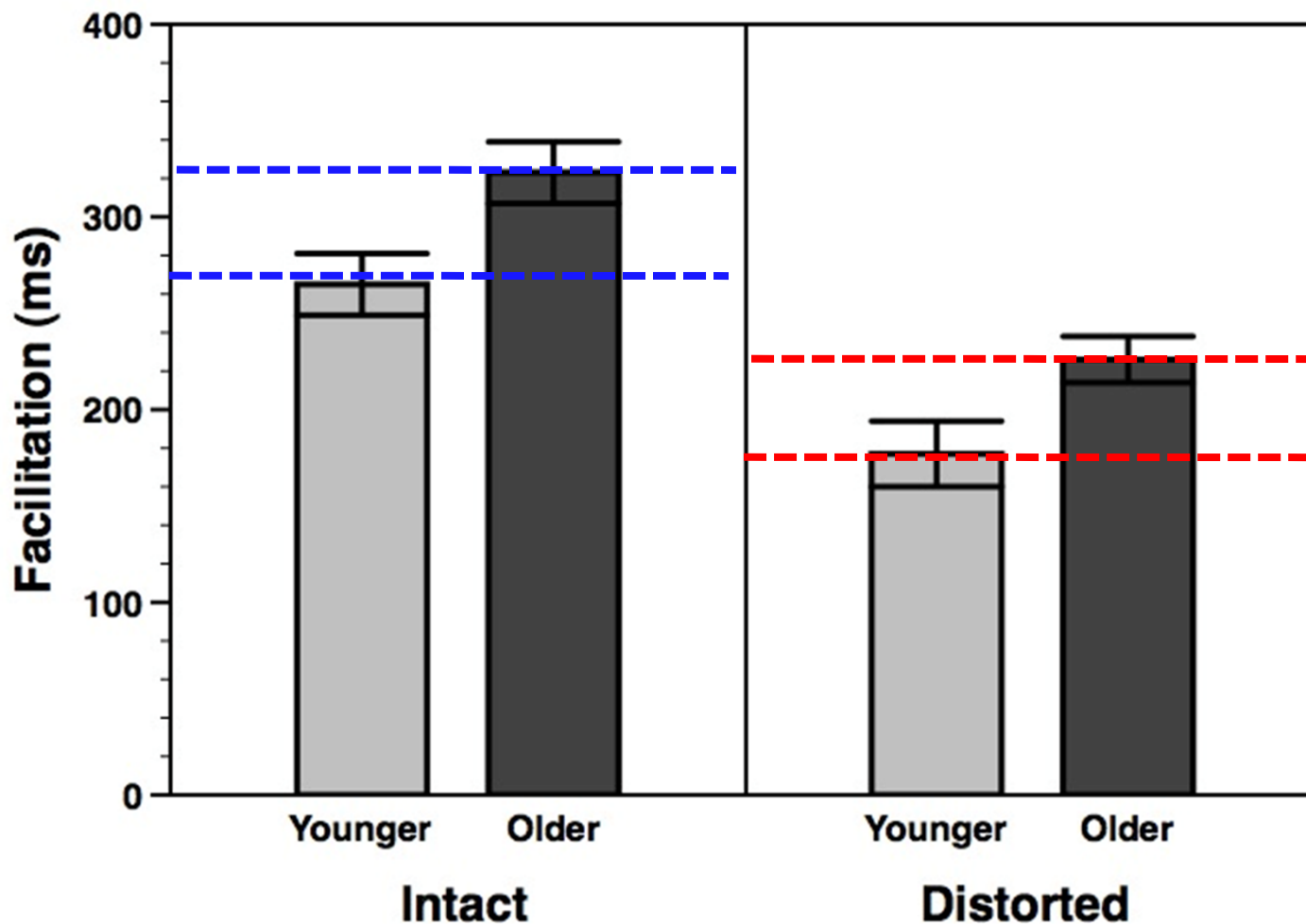
Increasing Acoustic Distortion of Context Slows Lexical Decision for Later Intact Word

Goy, H., Pelletier, M., Coletta, M., & Pichora-Fuller, M.K. (submitted).

speed



Facilitation by Congruent Context is Reduced by Signal Distortion but is Greater for Older than Younger Adults



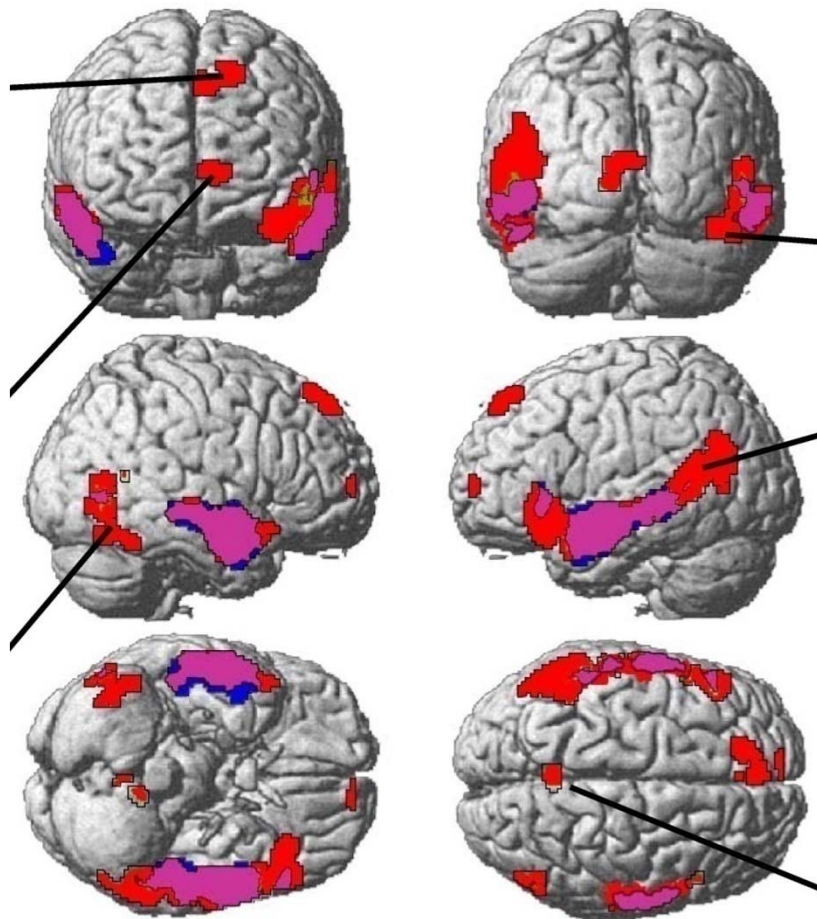


Speed (and Ease) of Listening

- 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)



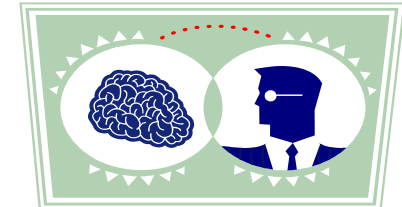
High vs. low predictability at intermediate signal quality for younger adults listening to distorted (noise-vocoded) SPIN sentences

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

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

Cognitive Neuroscience of Aging

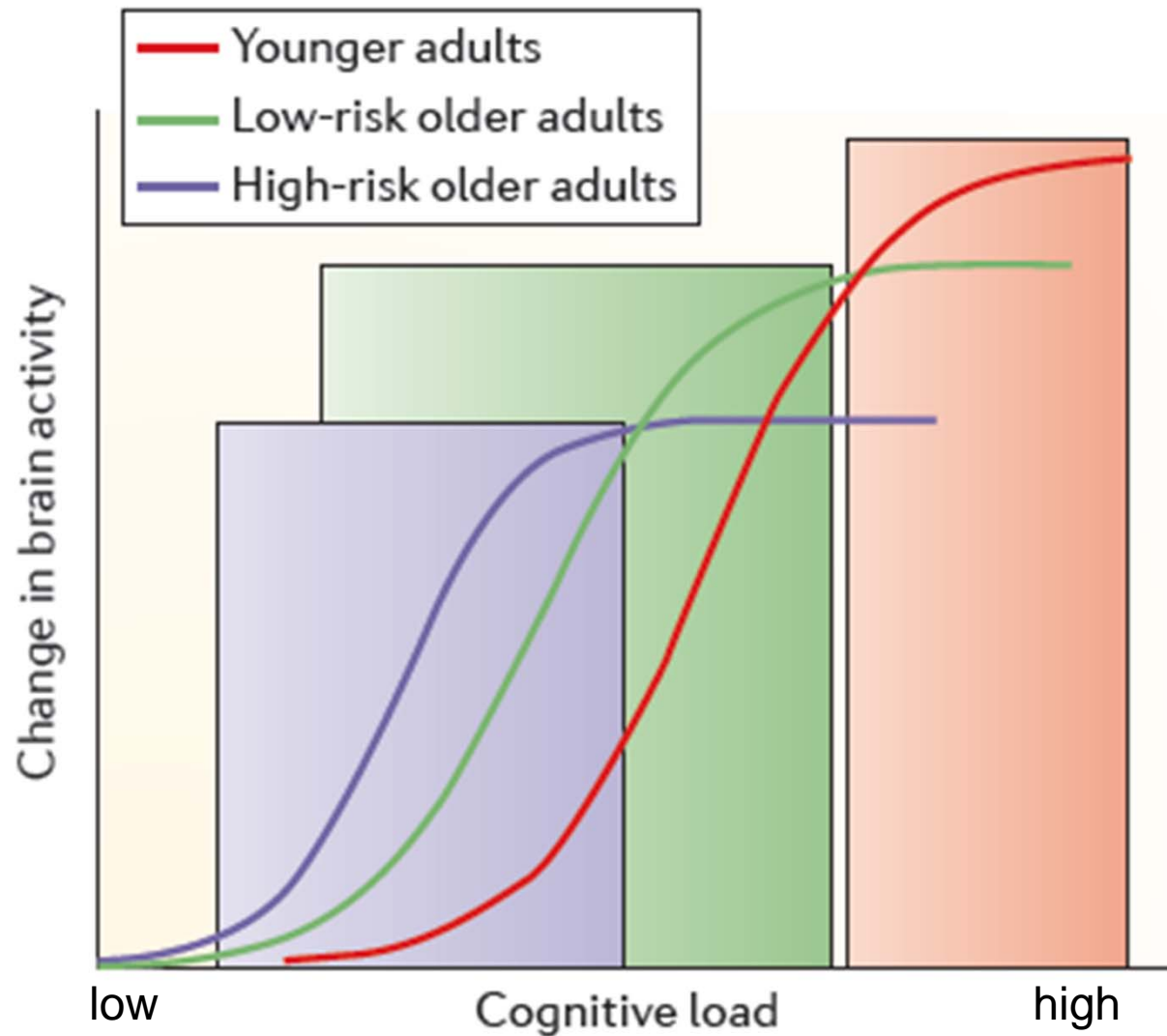
- Same performance achieved but with different processing (amounts of brain activation and extents of networks)
- More widespread activation ~ brain reorganization
 - Young brain activity more lateralized
 - Old brain activity more distributed
- **HAROLD**: Hemispheric asymmetry reduction in older adults (Cabeza, 2002)
- **PASA**: Posterior-anterior shift in aging (Davis, Dennis, Daselaar, Fleck & Cabeza, 2008)



Deterioration or compensation?

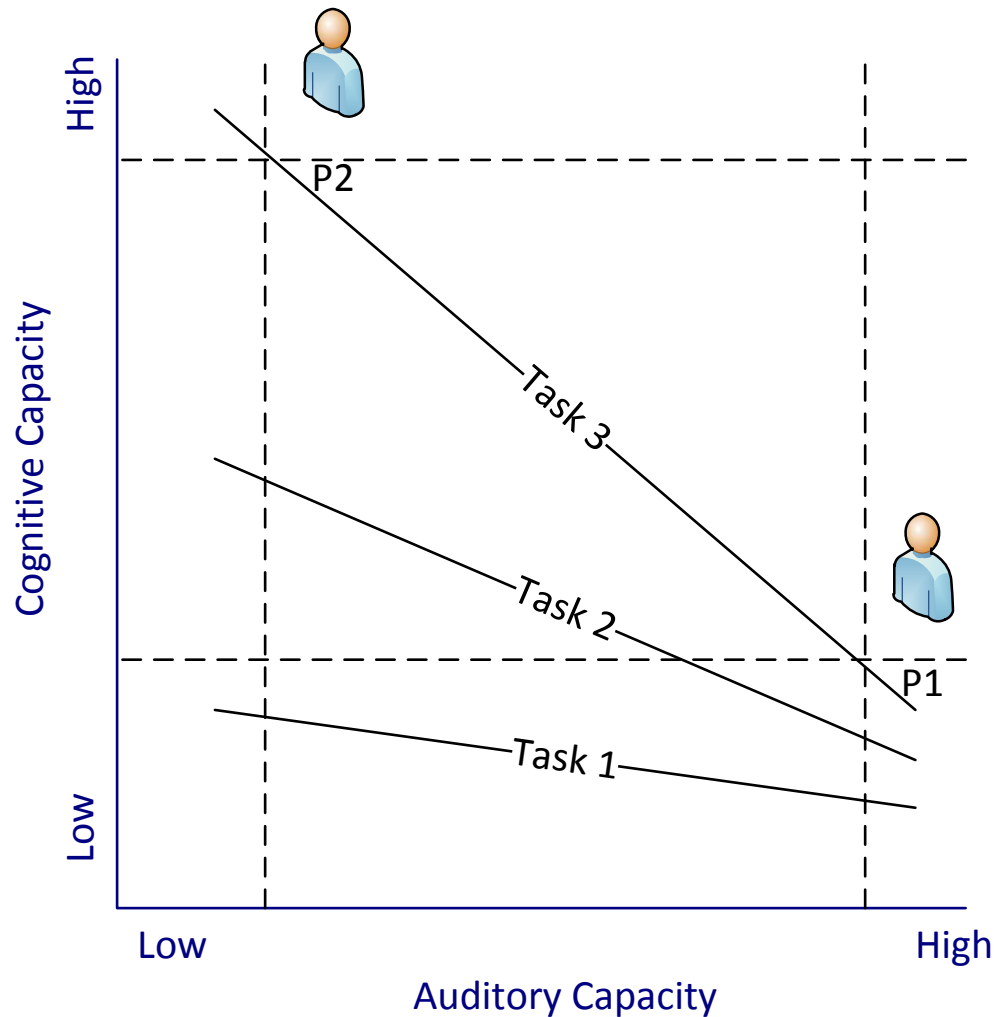
Compensation

(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???**



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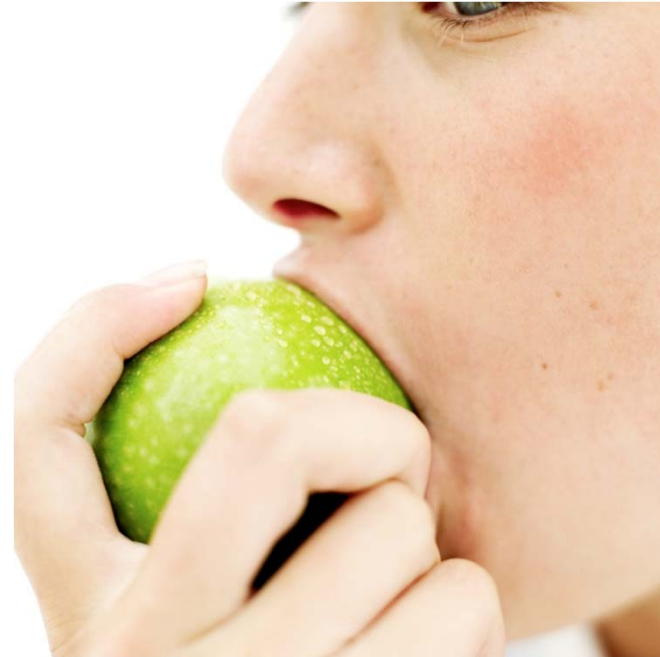
Implications for AR

- 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.....

Pichora-Fuller, M.K. (in press for 2013). Auditory and cognitive processing in audiologic rehabilitation. In J. Spitzer & J. Montano (Eds.), *Adult audiologic rehabilitation: Advanced practices (second edition)*. Plural Publishing, San Diego, CA.

<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)

