Using the Brain when the Ears are Challenged Helps Healthy Older Listeners Compensate and Preserve Communication Function

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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

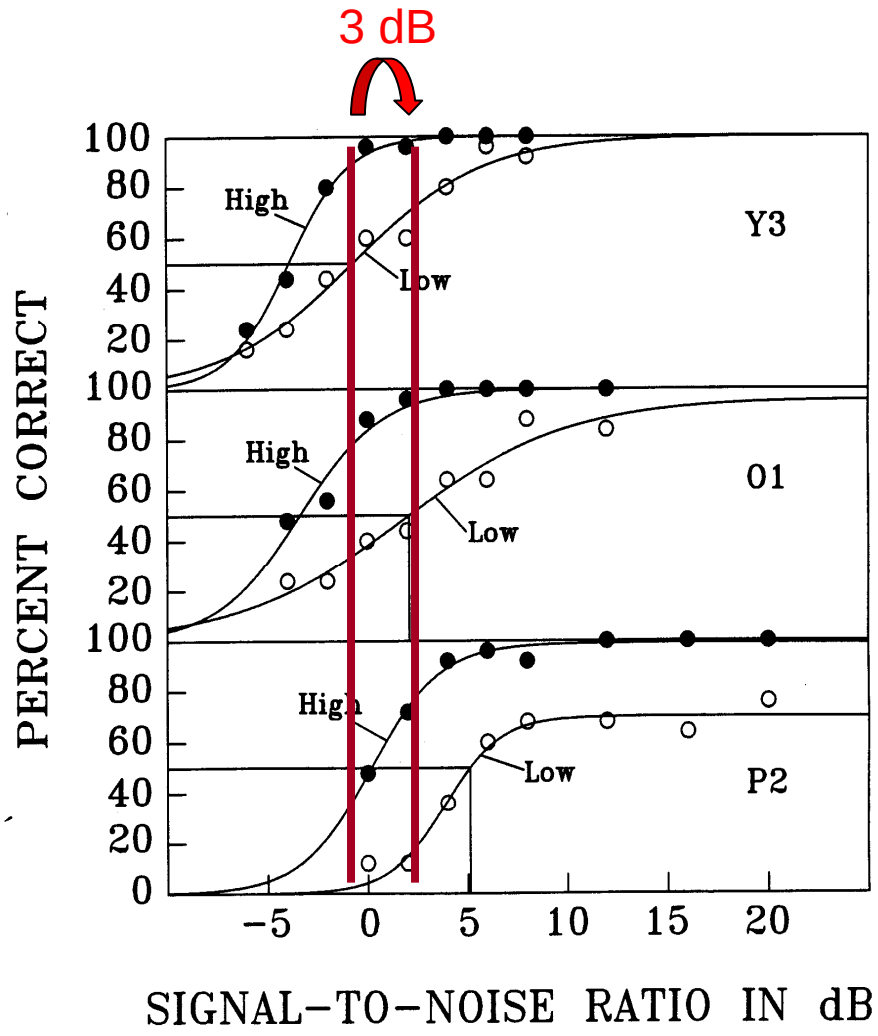
- Avoid by withdrawal from social interaction!

Speech Perception in Noise Test

- 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
- Vary S:N
- Old need 3 dB better S:N
- Context helps



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 better S:N than younger listeners

- **Cognitive factors important in challenging conditions!!!**
  - Regardless of age
  - Regardless of audiogram

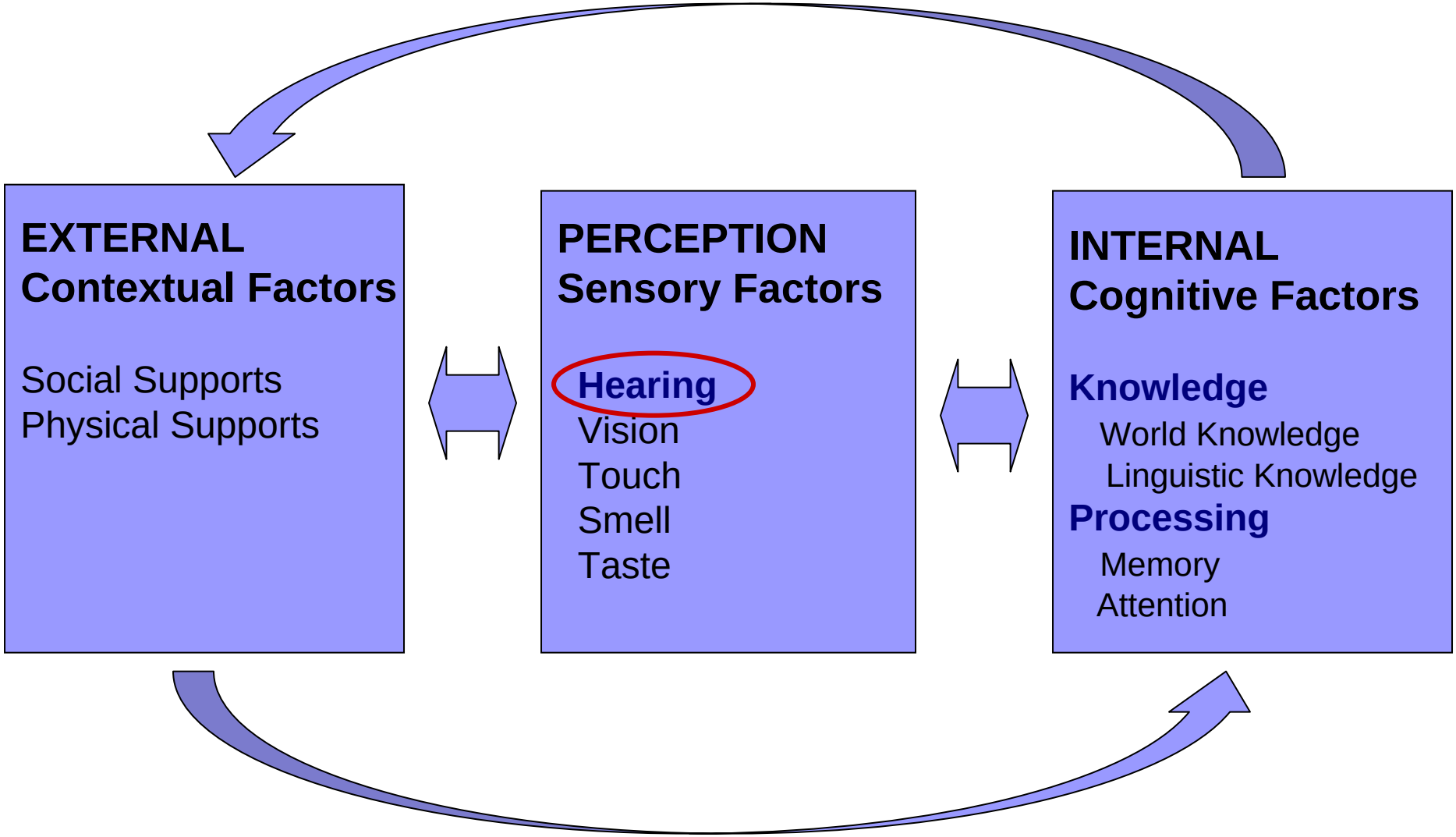
Cognition & HA Benefit Correlated

- Landmark 2003 studies
  (Gatehouse et al.; Humes; Lunner)
  - Those with higher cognitive function
    - do better to 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

Review – When & Why Cognition Counts
(coming in *The Hearing Journal*, Nov 2009)

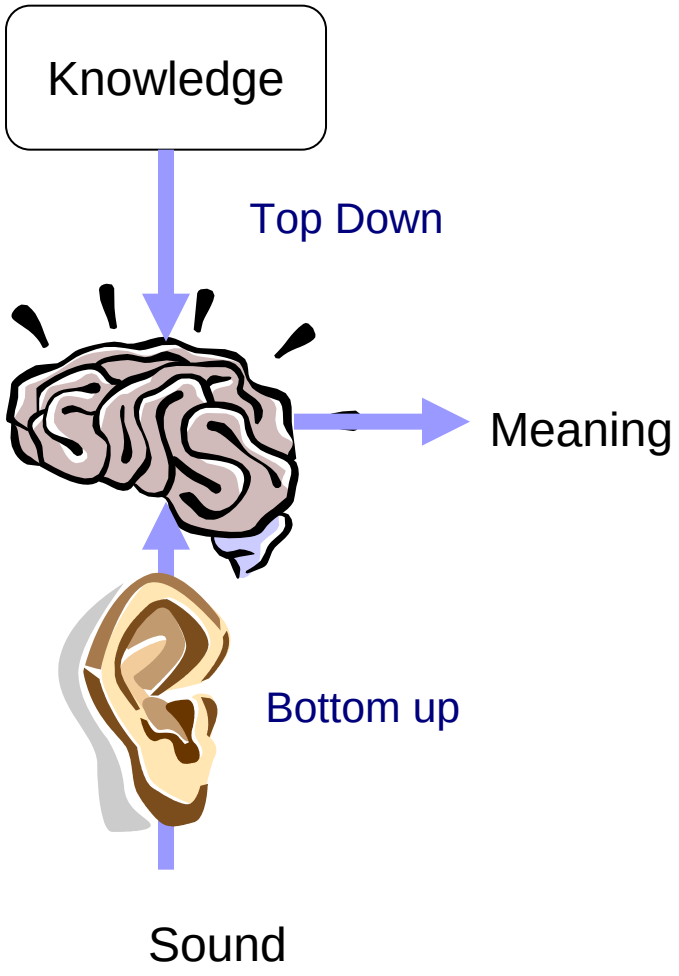
- Speech in noise (unaided vs aided)
- Ecology demanding (modulated noise; competing talkers)
- Differentiates individuals
  - Awareness of HA processing differences
  - HA usage (more if cognition poorer)
  - Benefit from complex HA in complex conditions (more if cognition better)
  - Benefit from various HA features
    - Fast-acting compression
    - Noise reduction
    - Directional hearing aids
  - Learning
    - Performance with new or changed HA processing (vs already learned)

Factors Influencing Comprehension



Bottom-Up &Top Down Processing

- 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)



Possible Cognitive Factors in Aging

- Knowledge is preserved and context is helpful

BUT Processing is less efficient

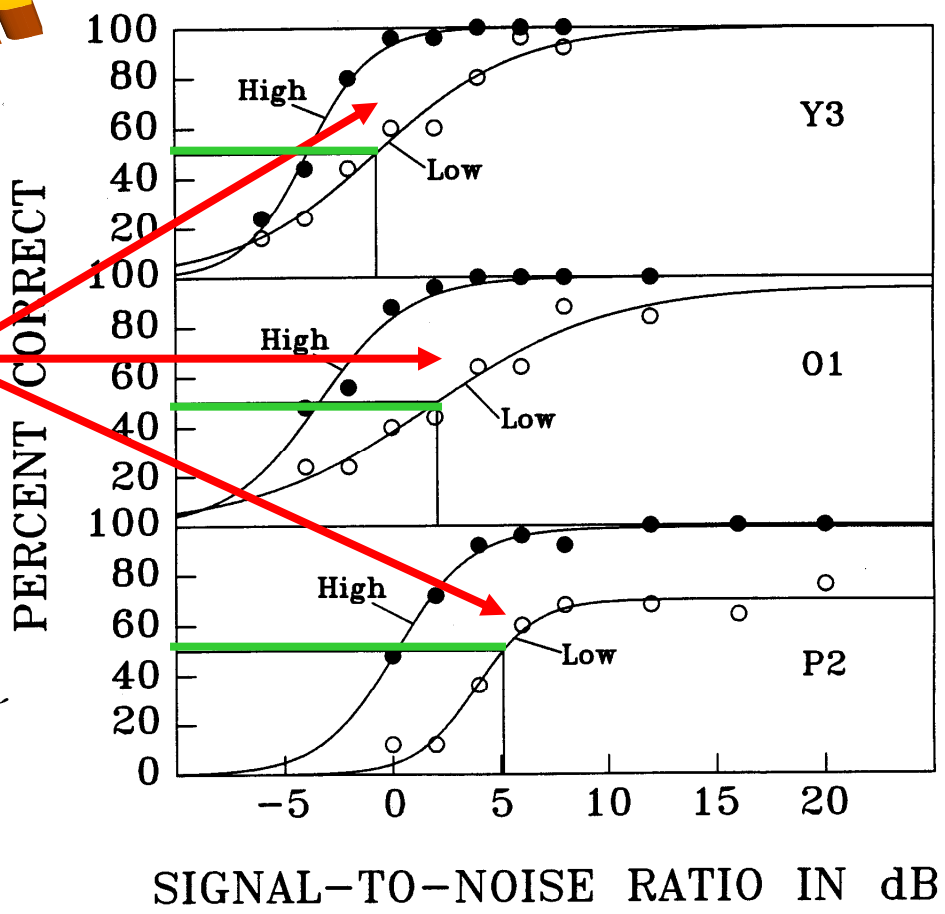
- Slowing
- Working memory
- Attention

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

Equating for Perceptual Difficulty

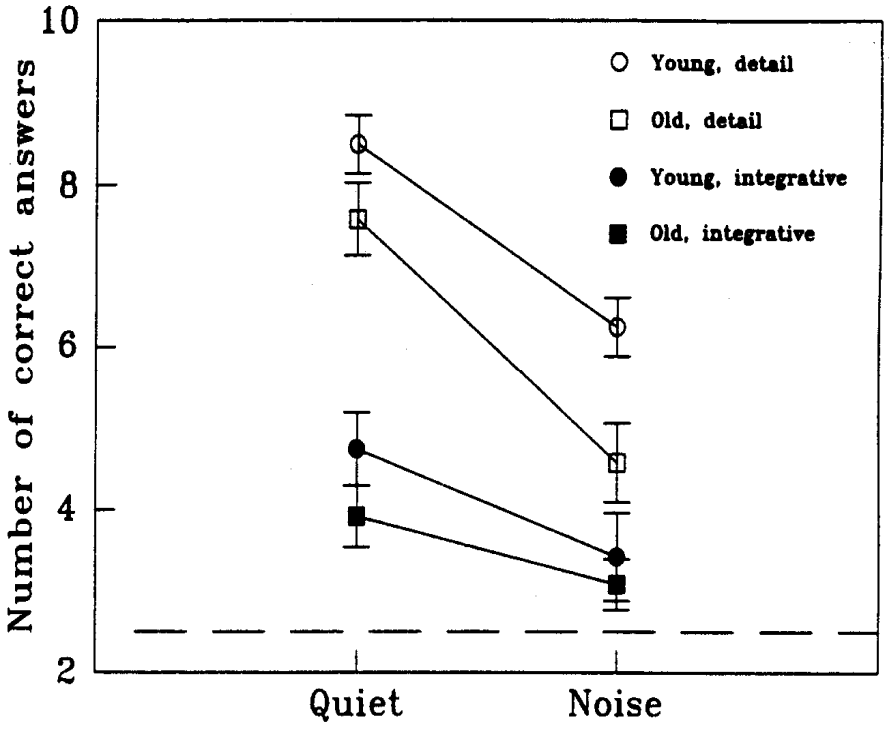
S:N for 50% correct in low-context

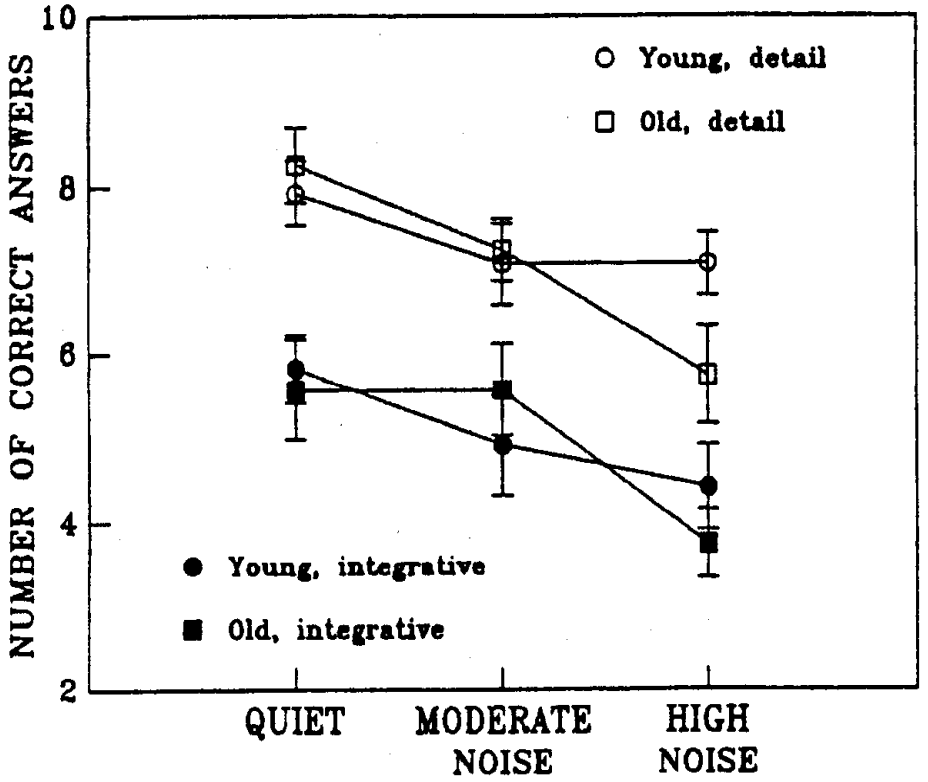
- Effortful listening zone
  - Low-context and high-context curves separated
- Everyone remembers less in this zone than in easy S:N conditions



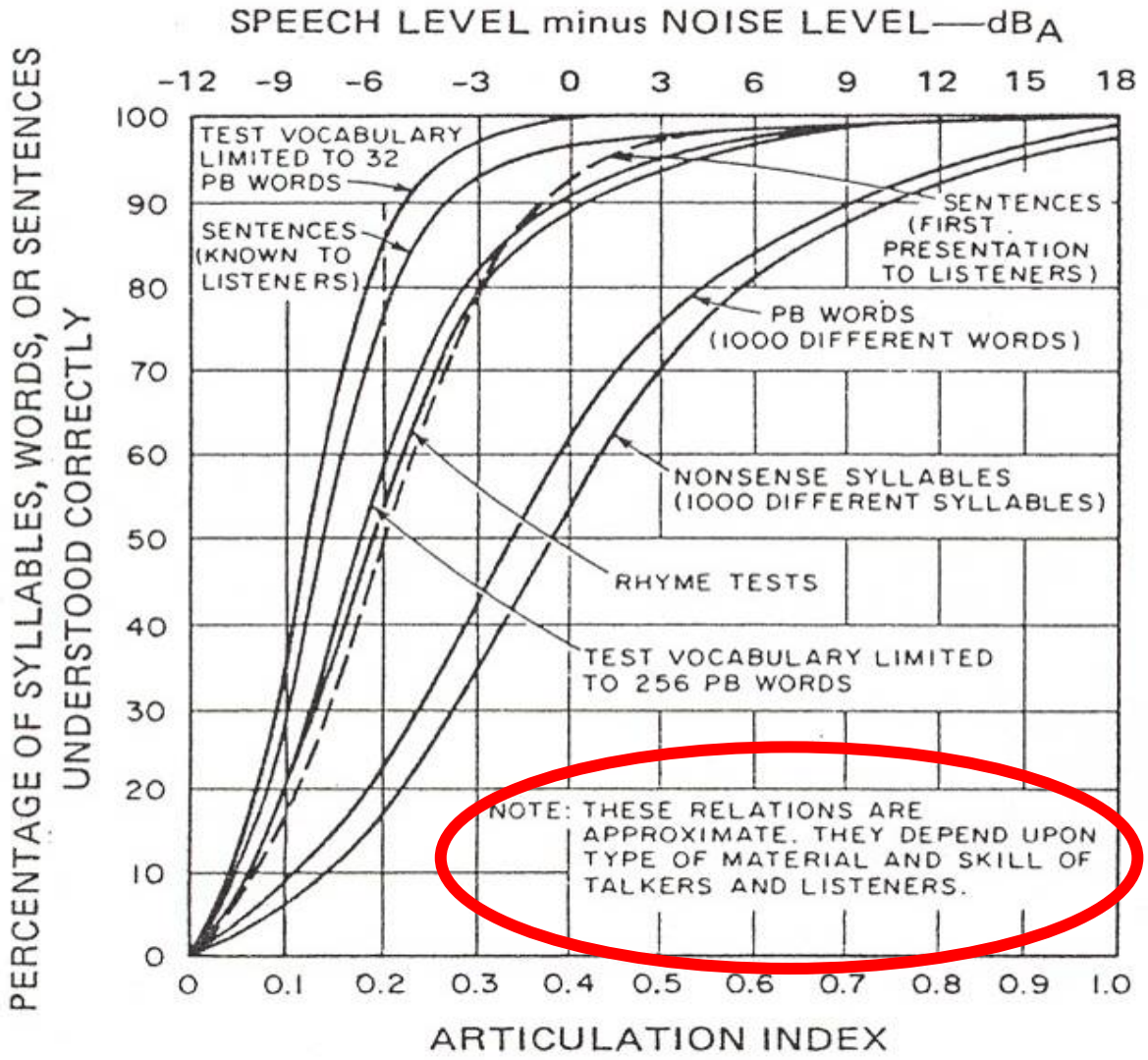
Noise and Discourse Comprehension

(Schneider, Daneman, Murphy, Kwong See, 2000)



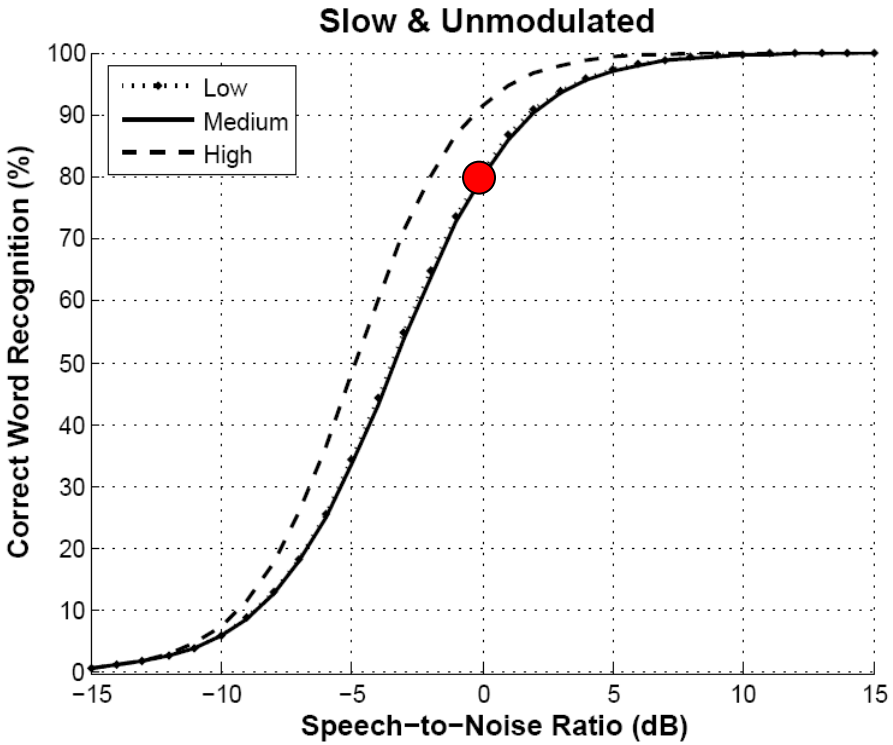


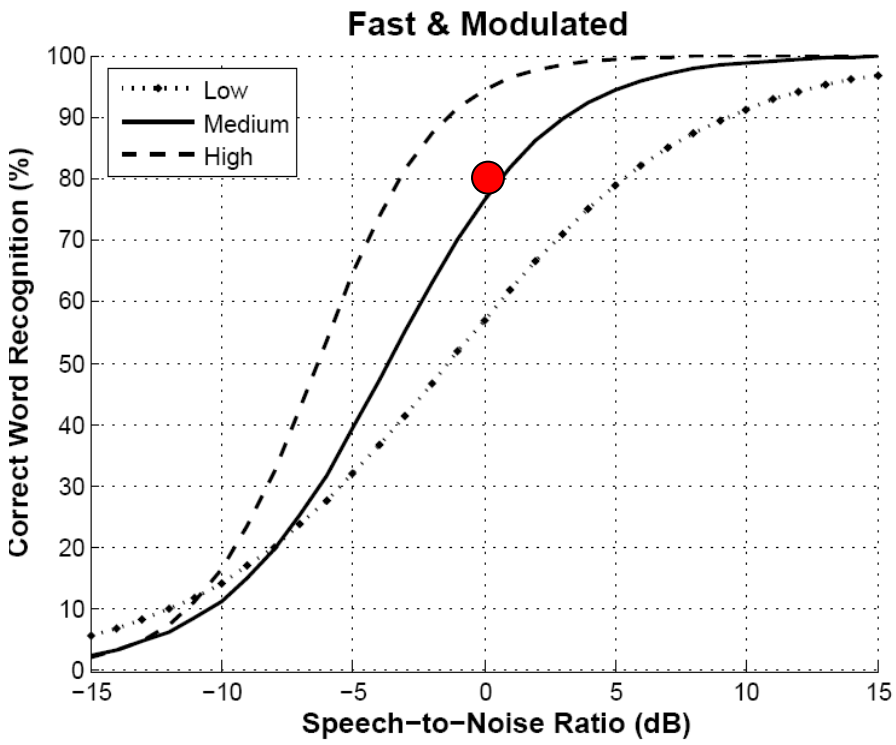
Speech Intelligibility in Noise



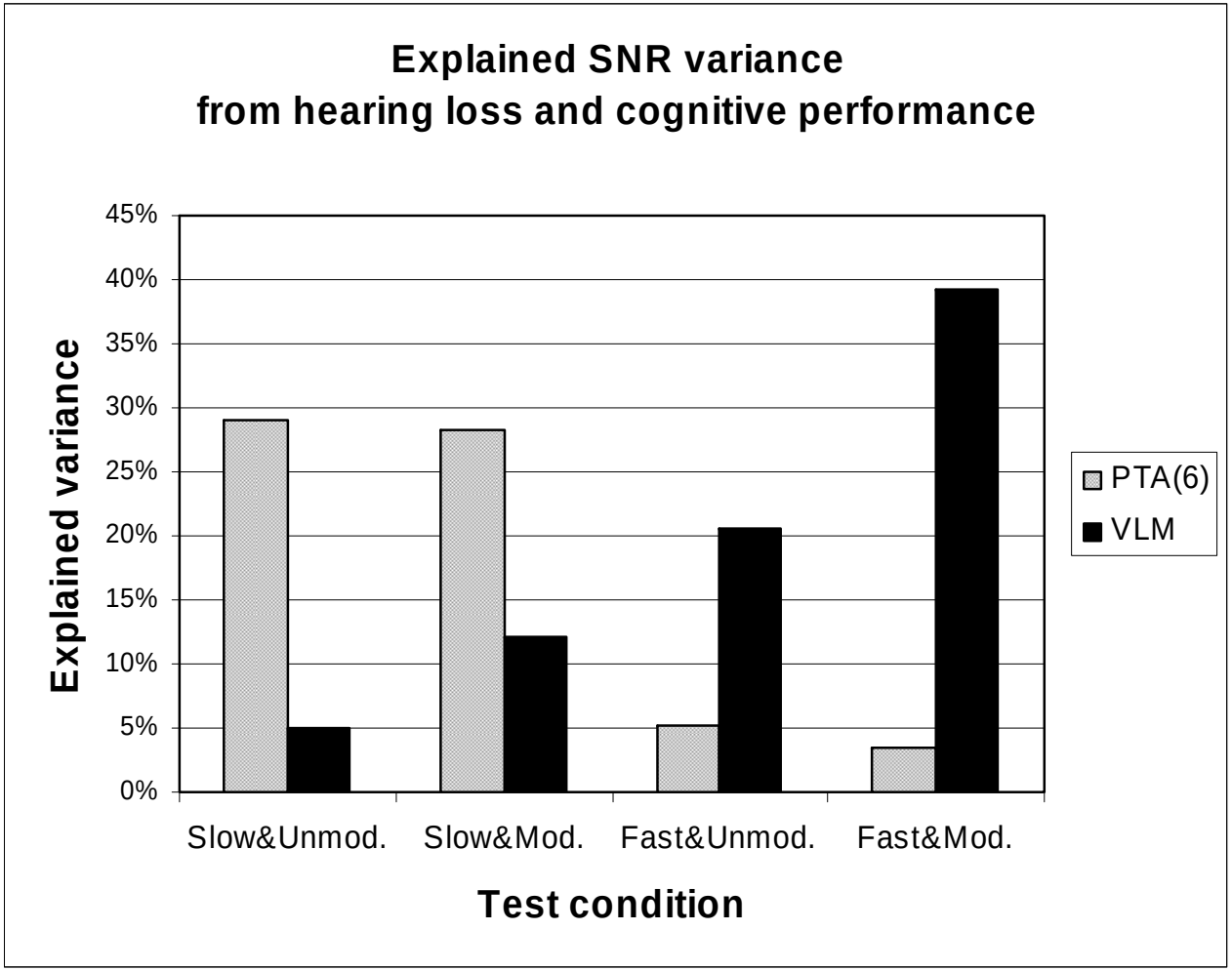
Kryter 1994 – based on ANSI 1969

Intelligibility and Cognitive Ability
(Lunner & Sundewall-Thorén, JAAA 2007)





Hearing Aid Compression & Cognition (Lunner & Sundewall-Thorén, JAAA 2007)

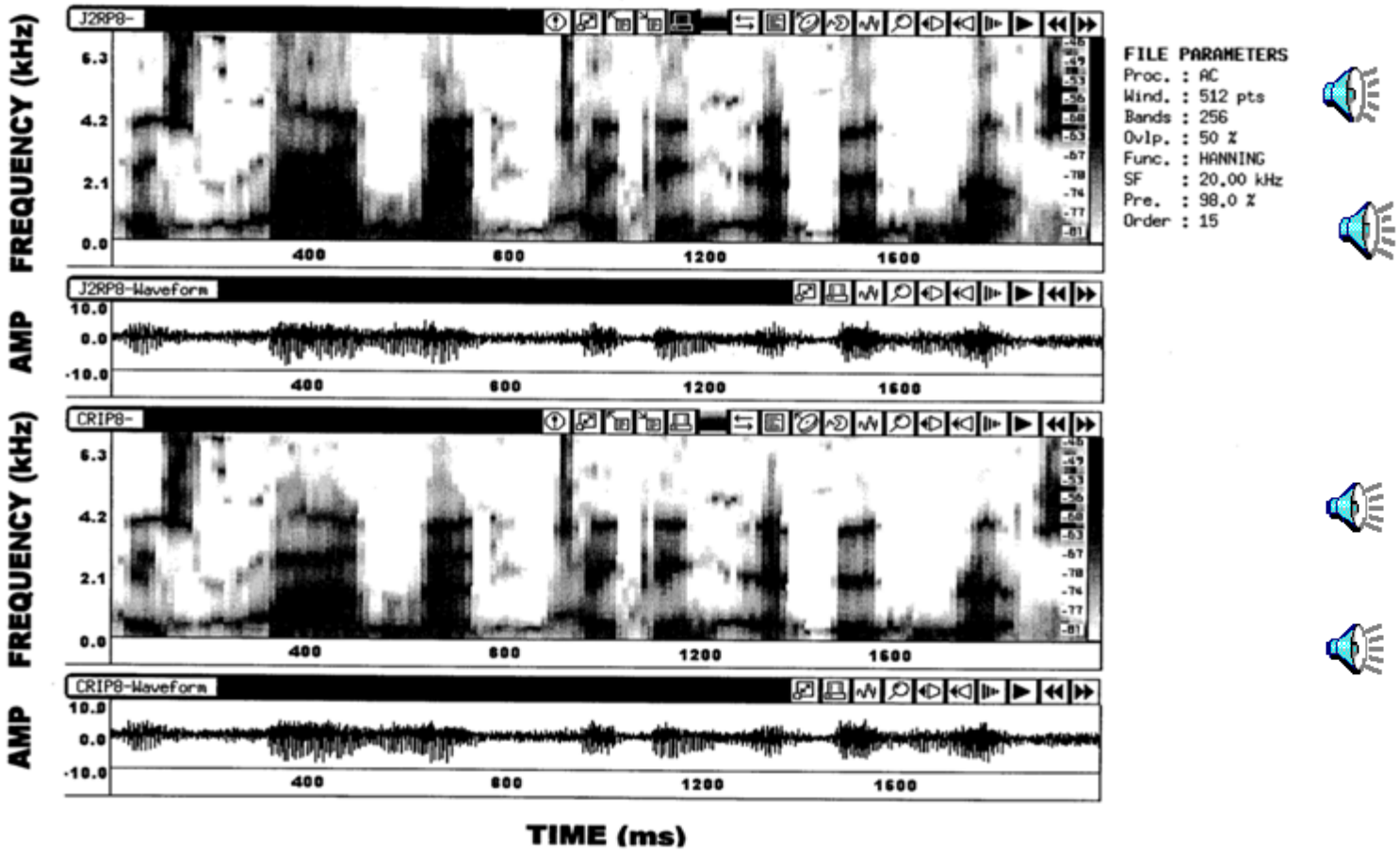


Contextual Support & Compensation

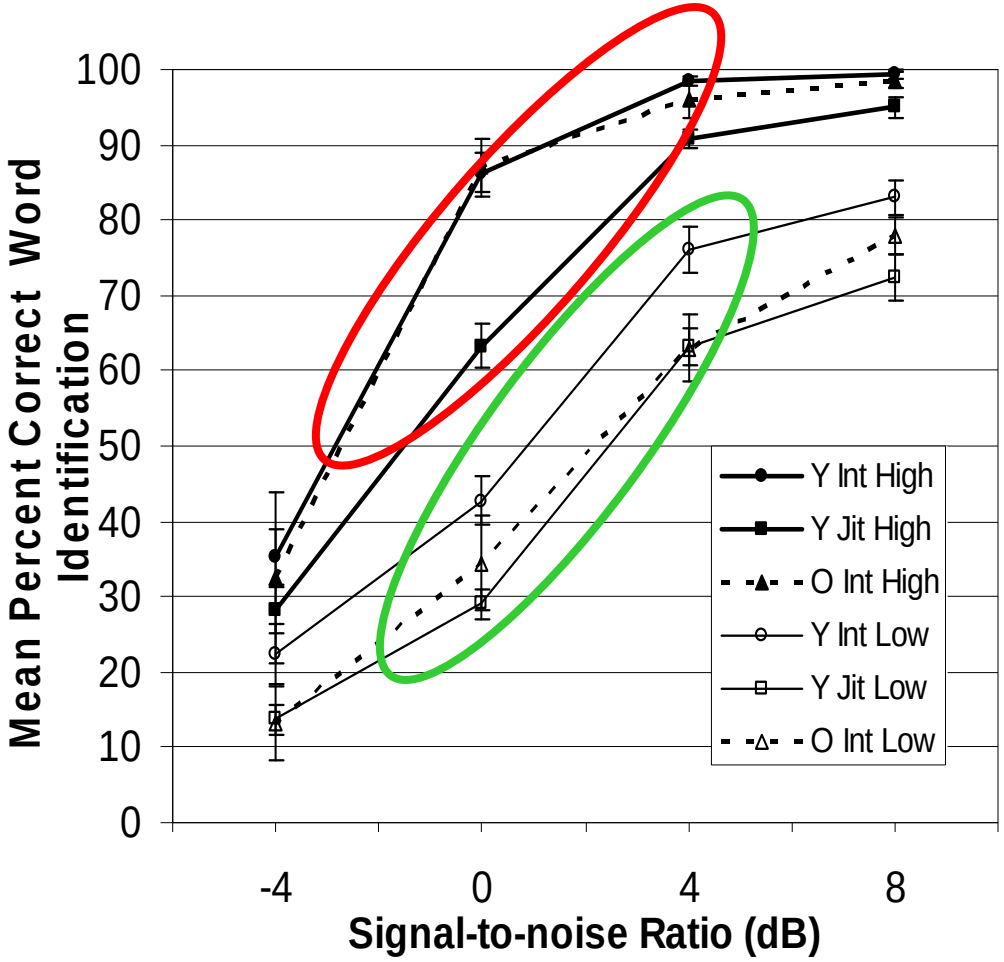
- Semantic-Syntactic
- Lexical
- Phonological

Sentence Level: Semantic-Syntactic

Spectrograms for Jittered and Intact Sentence in Babble



Use of Context



Older = younger jittered in LOW-CONTEXT

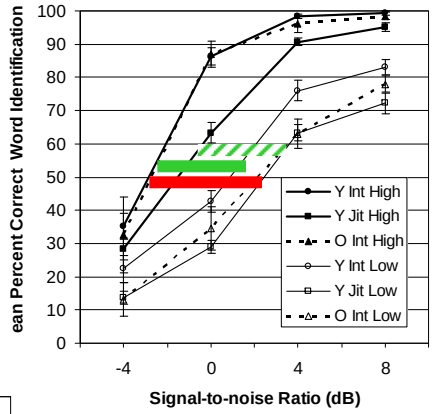
- Equates for quality of input for bottom-up processing

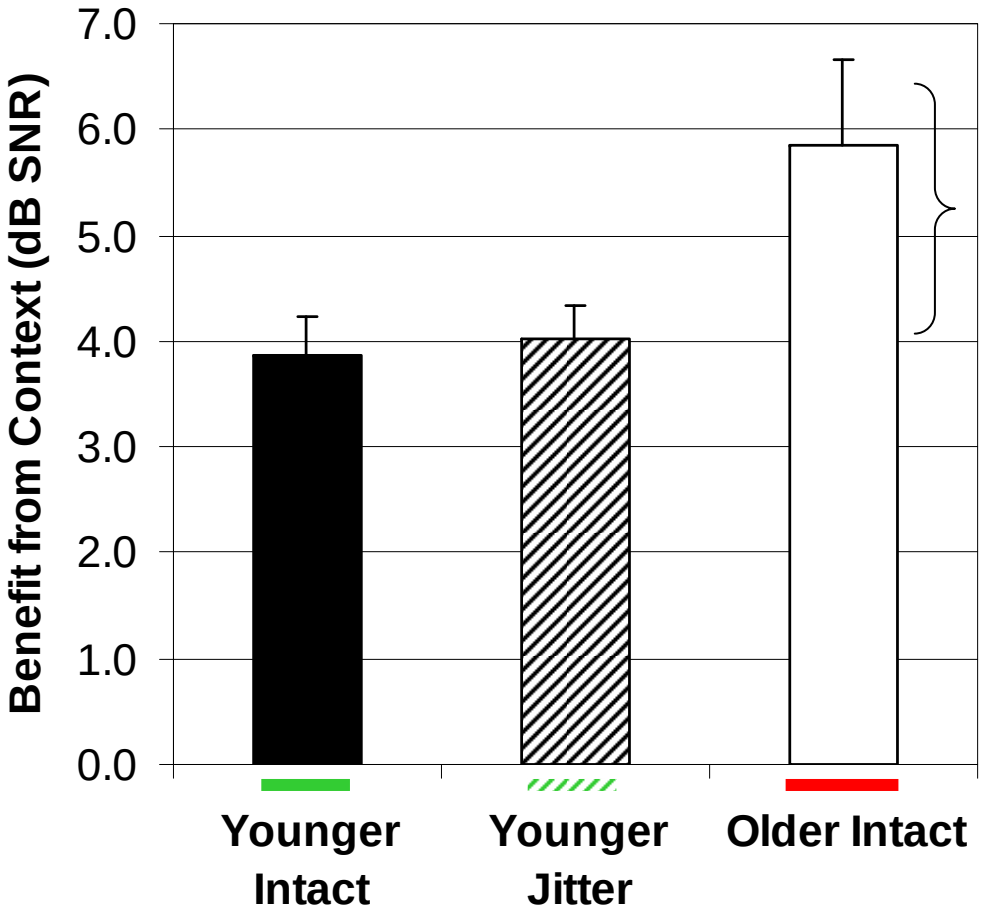
Older better than younger jitter in HIGH-CONTEXT

- More expert at top-down processing

Benefit from Context

Older benefit from context more than younger.

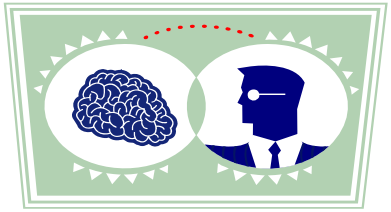




2-3 dB SNR

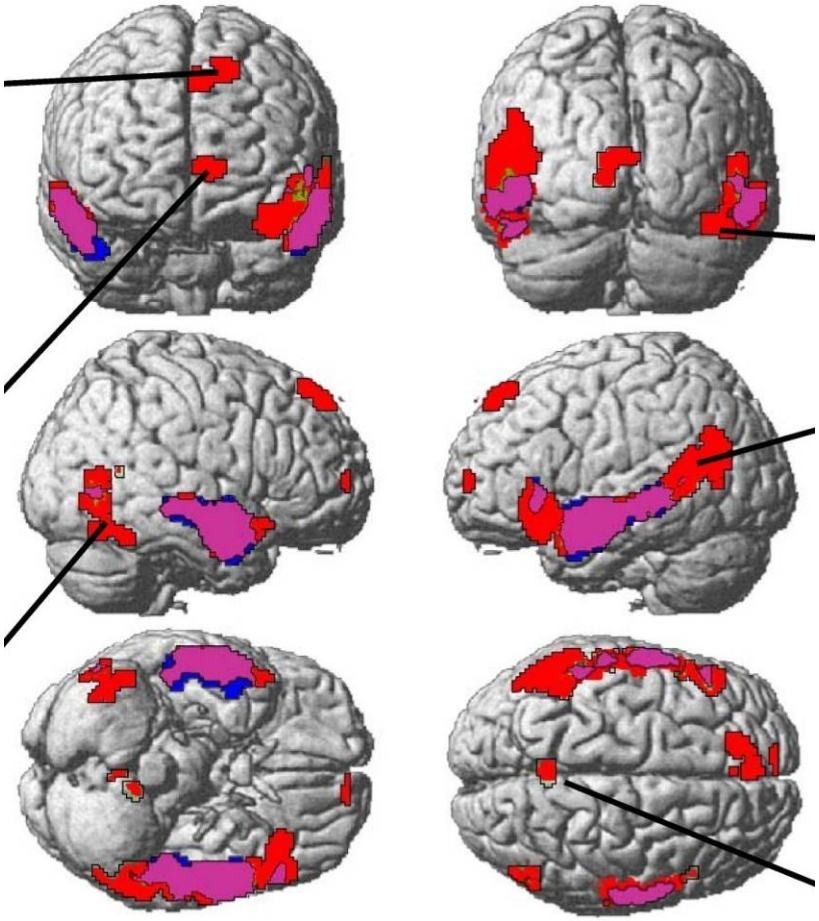
Cognitive Neuroscience of Aging

- 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)

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



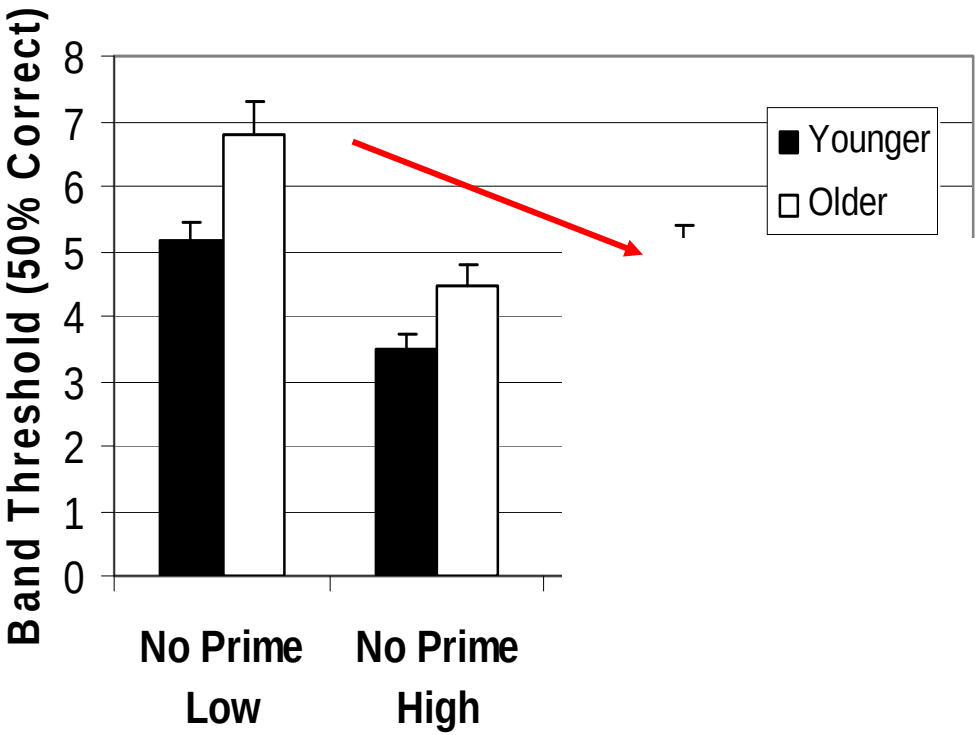
High vs. low predictability at intermediate signal quality for younger adults listening to distorted (noise-vocoded) SPIN sentences

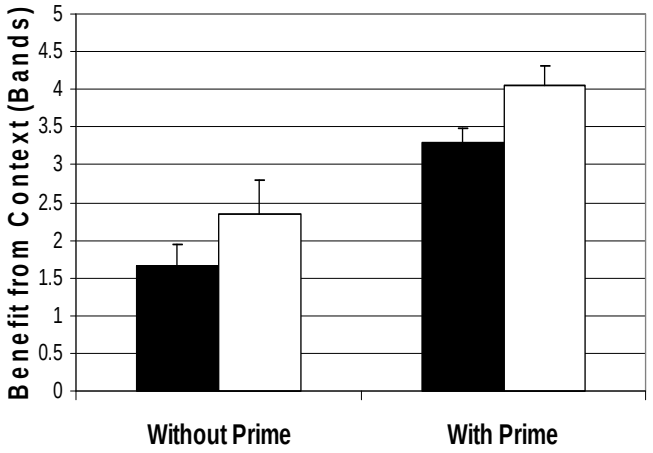
Activation to **HIGH-CONTEXT** > **LOW-CONTEXT** speech

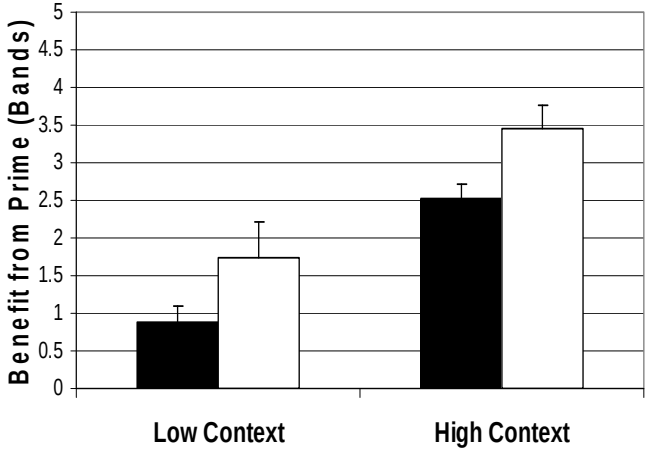
Various areas activated including the **left dorsolateral prefrontal cortex (working memory & semantic processing)**

Noise-vocoded SPIN with Priming

(Sheldon, Pichora-Fuller, & Schneider. JASA. 2008)





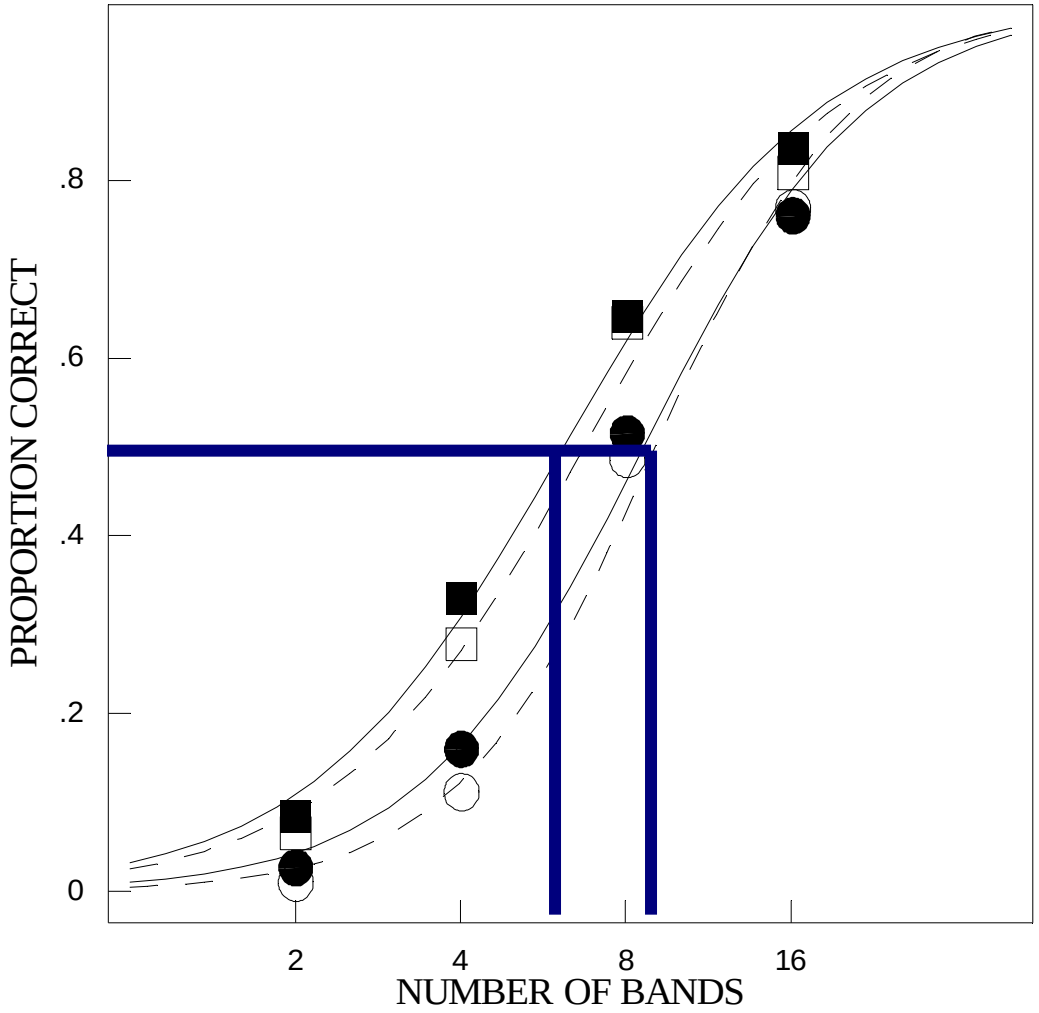


Lexical

Experiment 2: Blocked by Band

(Sheldon, Pichora-Fuller, & Schneider, JASA, 2008)

- Age differences
  - 6.13 vs 8.55 bands



Experiment 1:Increment Bands

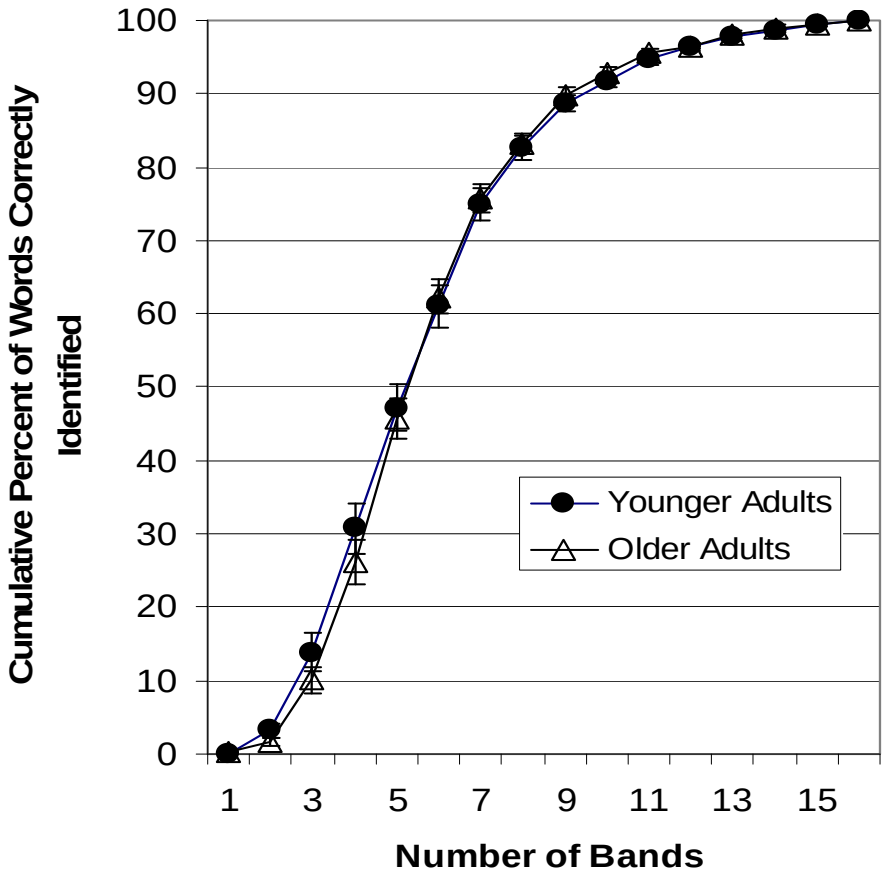
(Sheldon, Pichora-Fuller, & Schneider, 2008)

- Monosyllabic words (NU-6)
- Cumulative % correct

- No age differences
  - 5.25 bands for 50%

- Repetition
- Feedback

- Younger
  - Word freq -.225 ($p < .0007$)
- Older
  - Word freq -.267 ($p < .00007$)
  - Word fam -.119 ($p < .047$)
- Young & Old .768 ($p = .000001$)



Phonological

Non-speech Gap Detection

(Schneider, Pichora-Fuller, Kowalchuk & Lamb, 1994)

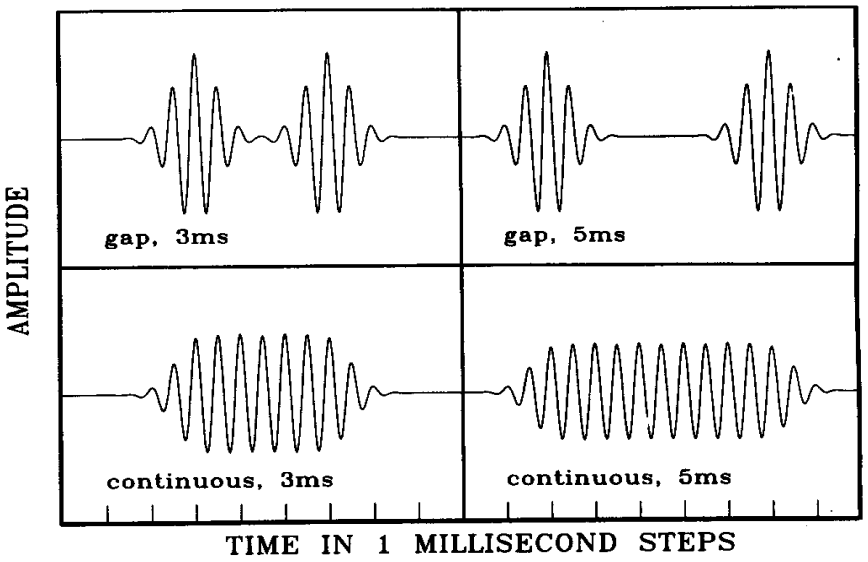
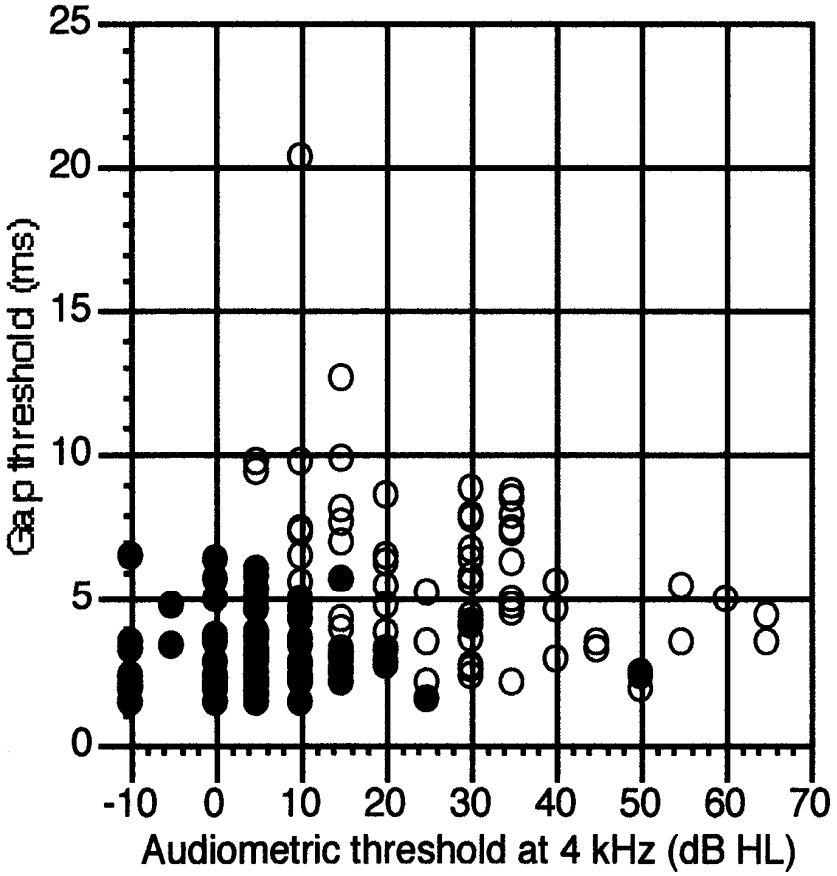
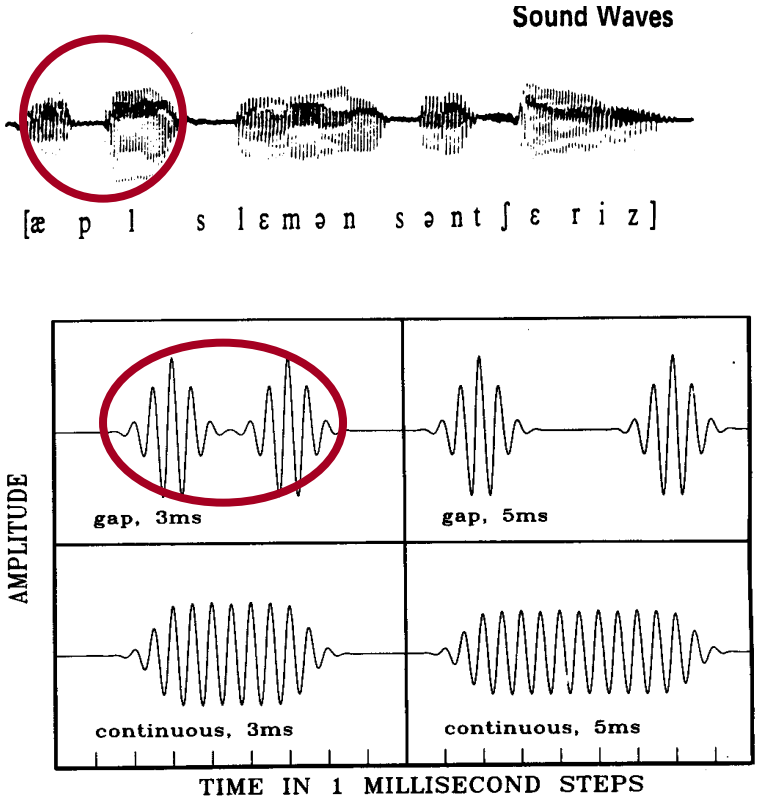


FIG. 1. Top left: Two Gaussian-enveloped, 2-kHz tones whose peaks are separated by a 3-ms gap. The Gaussian envelope for these tone pips has a standard deviation of 0.5 ms. Bottom left: A 3-ms, continuous (no-gap), 2-kHz tone with the same total duration and energy as the two tones immediately above it. Right top: Two Gaussian-enveloped, 2-kHz tones whose peaks are separated by a 5-ms gap. The Gaussian envelope for these tone pips also has a standard deviation of 0.5 ms. Bottom right: A 5-ms, continuous (no-gap), 2-kHz tone with the same total duration and energy as the two tone pips separated by a 5-ms gap.



Relating Gap Detection to Speech Perception



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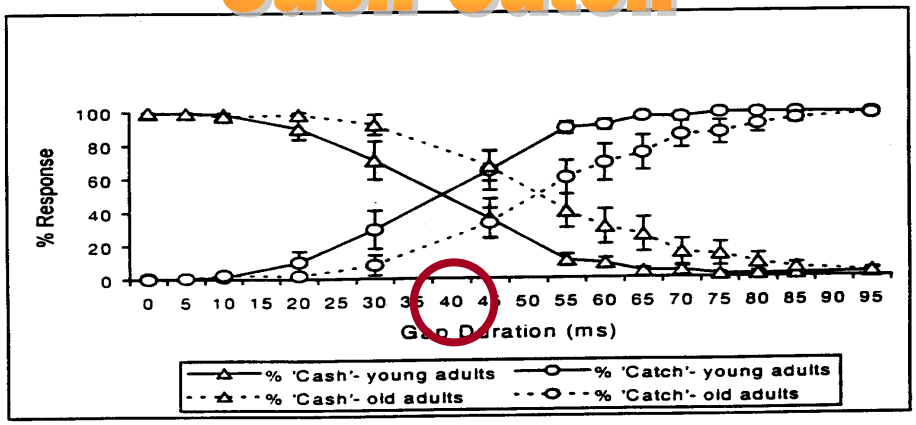
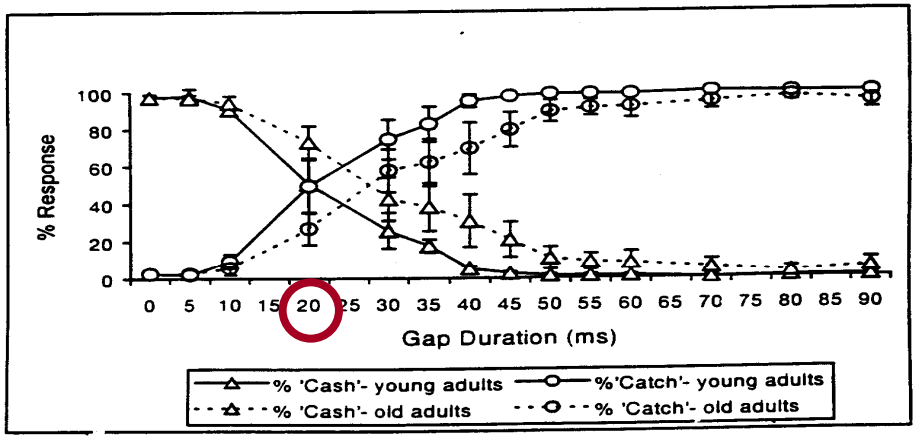
Cash-Catch



SLOW RATE



FAST RATE

Short (40 ms) Long (250 ms)

Non-speech

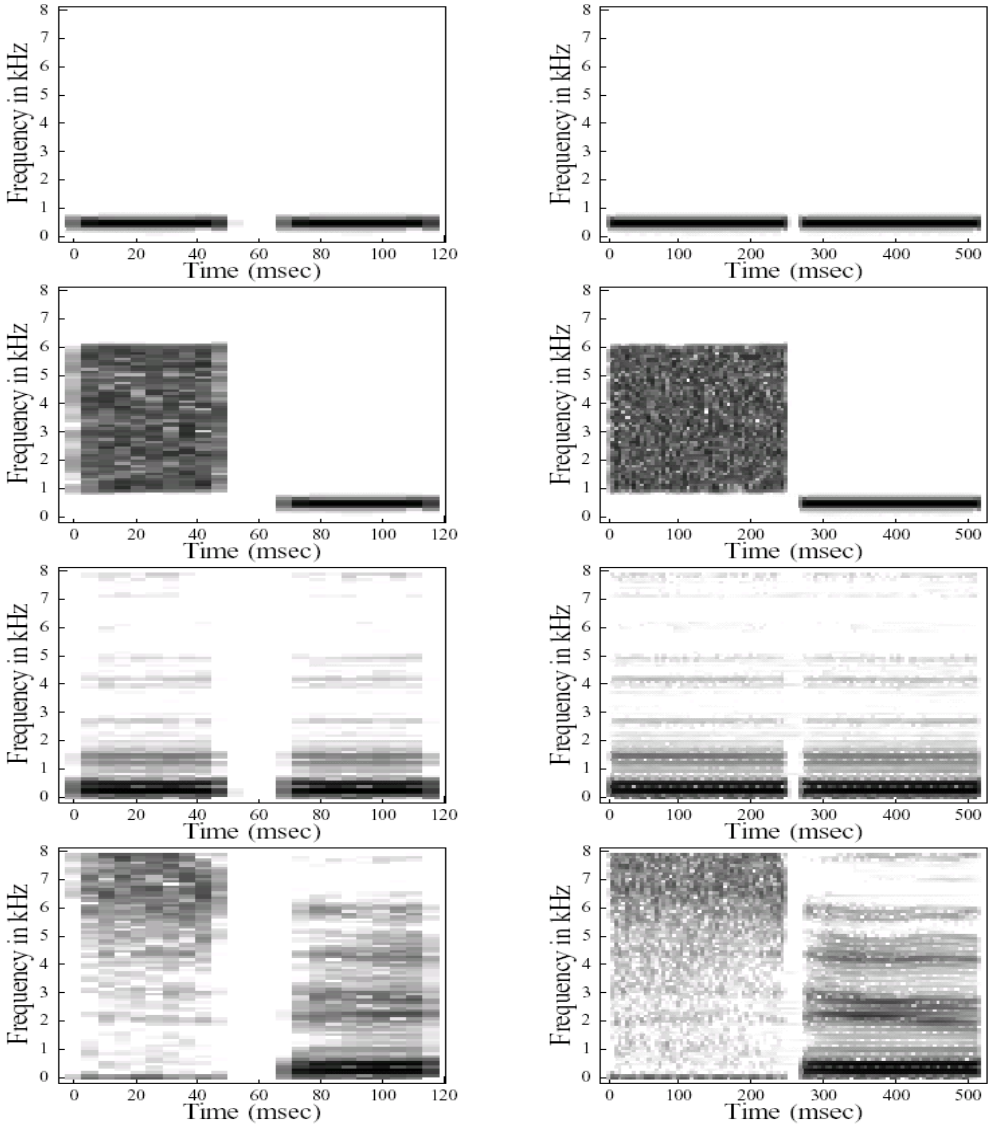
Symmetrical

Asymmetrical

Speech

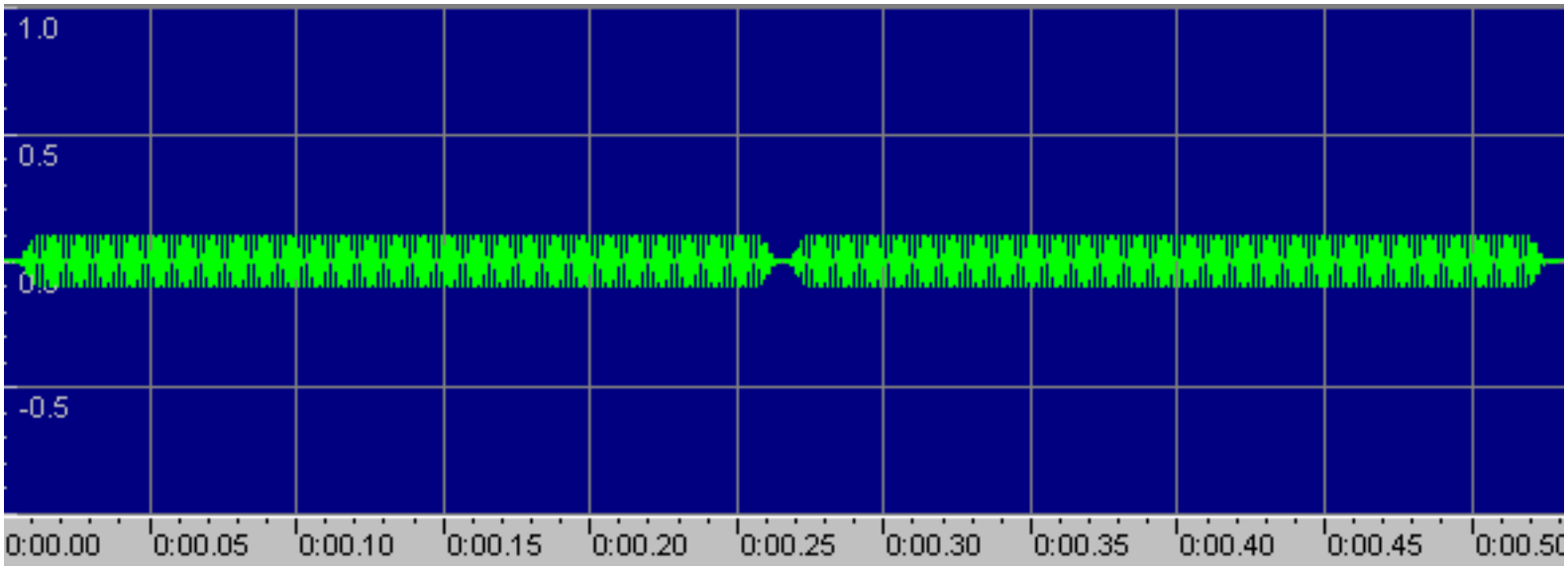
Symmetrical

Asymmetrical

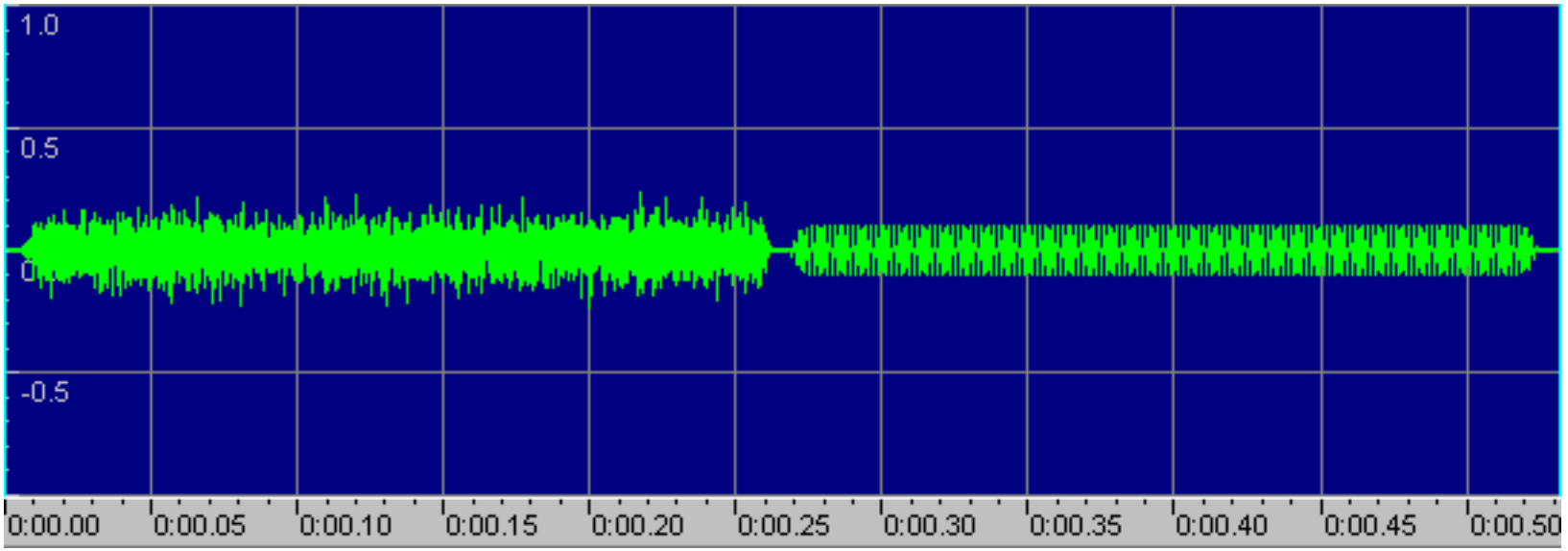


(Pichora-Fuller, Schneider, Benson, Hamstra, & Storzer, JASA, 2006)

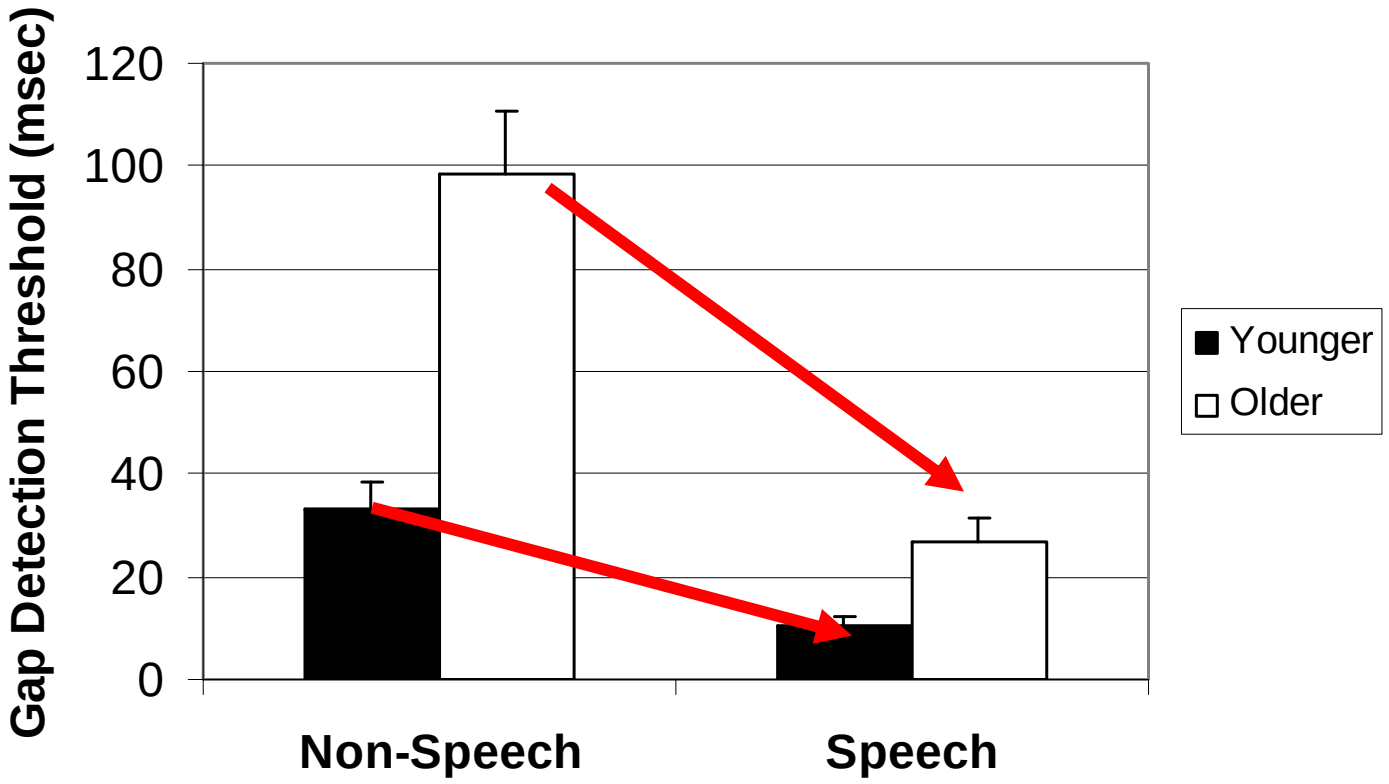
Non-speech, Long Marker,
Spectrally symmetrical
250ms marker 10ms gap



Non-speech, Long Marker,
Spectrally Asymmetrical
250ms marker 10ms gap



Phonological Immunization?



Summary

- Noise makes listening effortful
- Older listeners need about 3 dB S:N more (even if not HA candidates)
- If listening is effortful then cognition matters
- Inter-individual differences (ability to use context varies with cognition)
  - An input factor
- Intra-individual differences (effort varies with environment)
  - An outcome factor
- Older adults benefit as much (or more) than younger adults from use of knowledge
  - sentences (semantic-syntactic)
  - lexical (word frequency, familiarity)
  - phonological
- Context compensates for perceptual problems
  - Rehabilitation approach should emphasize use of context
  - Individual differences???

Conclusion

- Cognition helps hearing
- Hearing helps cognition
- ….. MCI?