

## Measuring Working Memory in Audiologic Evaluations

**Sherri L. Smith**

Auditory Vestibular Research Enhancement Award Program  
Mountain Home, Tennessee VA Medical Center  
and  
East Tennessee State University



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## Disclaimers

- VA salaried employee
  - The views of this presentation do not represent those of the Department of Veterans Affairs or the US government.
- ETSU, paid (non-salaried) appointment
- Treasurer, Academy of Rehabilitative Audiology
- Editorial board member for AJA
- JMU provided travel for conference

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## Listeners with Hearing Loss

- Primary complaint is difficulty understanding speech, especially in noisy background
- Audiologic evaluation (ASHA, 2006)
  - Pure-tone audiogram
  - Immittance
  - Word recognition testing in quiet
- Word/Speech recognition in noise
- Self-report assessment of function

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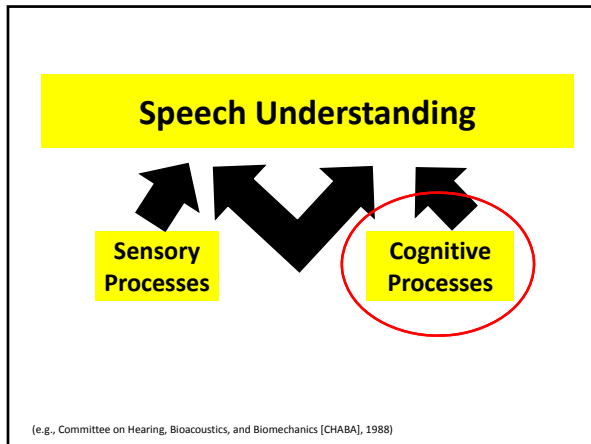
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**Working Memory**

- Shared system involved in the temporary storage of information and the USE of that information to perform a cognitive task (Baddeley and Hitch 1974; Daneman and Carpenter 1980; Shah and Miyake 1999; Pichora-Fuller et al., 1995)
  - Interpret running speech
  - Relate to information in long term memory
  - Relate to previous information heard
  - Relate to what will be heard next
- Capacity Limited (e.g., Just and Carpenter 1992)

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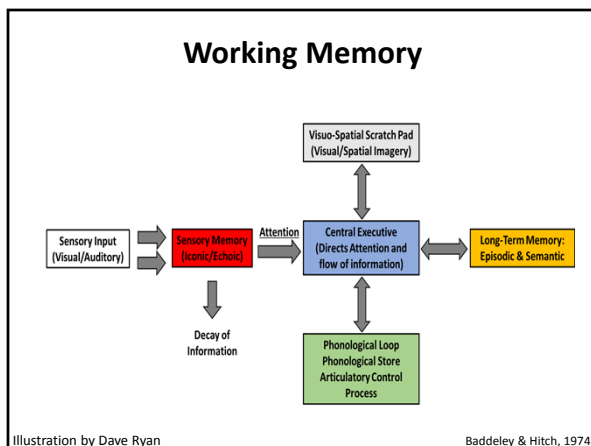
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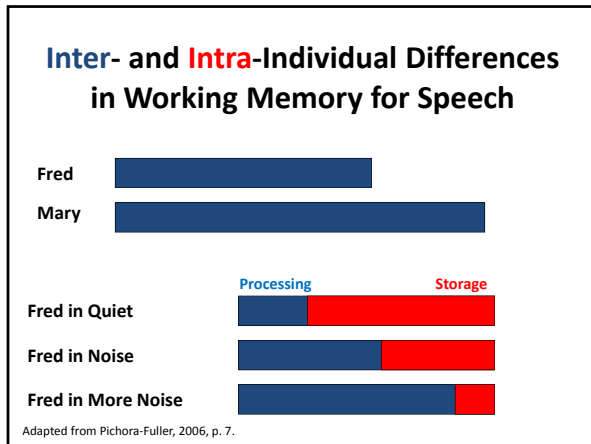
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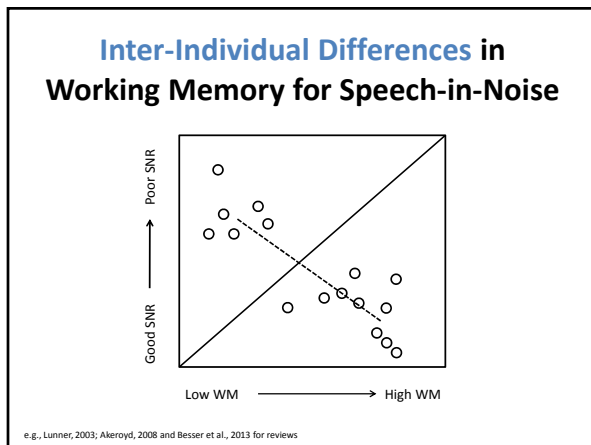
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### Inter-Individual Differences in Working Memory for Aided Speech-in-Noise

- Research suggests that individuals with higher working memory can benefit from more aggressive forms of signal processing to a greater extent than those with lower working memory
  - Compression
  - Frequency lowering
  - Noise reduction

e.g., Arehart et al., 2013; Gatehouse et al., 2006a, b; Koelewijn et al., 2012; Ng et al., 2013; Foo et al., 2007; Samparalis et al., 2009

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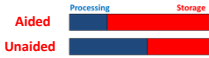
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### Intra-Individual Differences in Working Memory for Speech

- Less is known about **intra-individual differences**
- Important in clinical audiology to quantify the trade-off between processing and storage *within* an individual
  - E.g., if hearing aids reduce processing load due to improved audibility (re: unaided), then recall should improve
- Considered an “outcome” measure for a given hearing aid feature or auditory intervention



Pichora-Fuller et al., 2006

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### Clinical Application

Inter-Individual


**Low WM**

**High WM**

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**Rehabilitation Strategies**

Intra-Individual



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**Rehabilitation Outcome**

Pichora-Fuller, 2006; Souza, 2012

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### Working Memory Tests in Research

**Reading Span**

(Daneman & Carpenter, 1980, 1983; Rönnerberg et al. 1989)

**Digit Span**

(WAIS, 1997; 2008)

**Woodcock Johnson**

(Woodcock, McGrew, & Mather, 2001)

**‘Simon Says’**

(Humes & Flyod, 2005)

Listening Span

(Pichora-Fuller et al., 1995; Baldwin & Ash, 2011)

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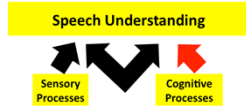
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### Working Memory Tasks: Theoretical Viewpoints

- Limited working memory capacity system shared by all cognitive tasks (e.g., Daneman and Carpenter 1980)
  - Visually-presented materials
    - Speech or non-speech stimuli
    - Avoids contamination by hearing loss
  - Reading span measure




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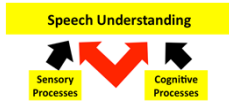
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### Working Memory Tasks: Theoretical Viewpoints

- In the limited capacity system, resources are consumed depending upon the degree of sensory processing used to accomplish the cognitive task
- Modality-specific factors may influence the degree of processing needed for auditory vs visual tasks (Pichora-Fuller et al., 1995; Baddeley and Logie 1999; Cocchini et al. 2002; Baldwin and Ash, 2011)
  - Auditory processing demand MAY depend on
    - Target (and masker) signal factors (acoustic, linguistic)
    - Individual's auditory processing (dis)abilities




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### Working Memory Tests in Research

**Reading Span**

(Daneman & Carpenter, 1980, 1983; Rönnerberg et al. 1989)

**Digit Span**

(WAIS, 1997; 2008)

**Woodcock Johnson**

(Woodcock, McGrew, & Mather, 2001)

**'Simon Says'**

(Humes & Flyod, 2005)

**Listening Span**

(Pichora-Fuller et al., 1995; Baldwin & Ash, 2011)

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**Reading Span**

(Daneman & Carpenter, 1980; 1983)

- A popular **visual** WM measure
- 100 sentences set sizes (2, 3, 4, 5, and 6), each set size has 5 trials
  - Read
  - Judge
  - Recall
- 20-30 minutes to administer

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READY

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The murky swamp slipped into the waters of the crocodile.

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The castle sat nestled in the refrigerator above the tiny village.

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It wasn't all her fault that her marriage was in trouble.

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### Reading Span

- May be used to assess *inter-individual* differences in speech understanding
  - if reading = listening
- Cannot be used to assess *intra-individual* differences to auditory signals

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### Listening Span

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

- a complementary measure to the reading span measure, but with SPIN sentences
- Administered at a given SNR (e.g., 50%, 80%)
- 20-30 minutes to administer

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### Development of a Word-Based Test

- Word Auditory Recognition and Recall Measure (WARRM)
- Basic working memory span test paradigm combined with a word-recognition test procedure
  - Word recognition score
  - Recall score
    - Span or percent correct

Smith, Pichora-Fuller & Alexander, 2016

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## Word Auditory Recognition and Recall Measure (WARRM)

- **Reading Span** (Daneman & Carpenter, 1980; 1983)
  - 100 sentences with set sizes (2, 3, 4, 5, and 6) with 5 trials of each set size
    - Read
    - Judge
    - Recall
  - 20-30 minutes to administer
  - May be used to assess **inter-individual** differences in speech understanding
    - if reading = listening
  - Cannot be used to assess **intra-individual** differences to auditory signals
- **WARRM** (Smith, Pichora-Fuller, & Alexander, 2016)
  - 100 words with set sizes (2, 3, 4, 5, and 6) with 5 trials of each set size
    - Recognition
    - Judge (First letter in the first or second half of the alphabet)
    - Recall
  - 10-15 minutes to administer
  - Can measure **inter- and intra-individual** differences

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## WARRM

(Smith, Pichora-Fuller, & Alexander, 2016)



Word	Recognition	Judgment	Recall	
WEST	✓	✓	West, ✓	✓
FLAG	X, Lag	✓	Lag, ✓	
RISK	✓	✓	Risk, ✓	✓
GRACE	✓	✓	Grace, ✓	
BAR	X, Car	X	Card, X	X
SHOVE	✓	X	Shove, ✓	
WHAT	✓	✓	What, ✓	✓
MOON	✓	✓	Moon, ✓	
CALF	✓	✓	Rice, ✓	✓
THAT	✓	✓	That, ✓	

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## Scoring the WARRRM

- Percent correct recognition
  - As a function of set size and overall
- Percent correct judgment
  - Based on word repeated
  - As a function of set size and overall
  - >90% to confirm task engagement
- Recall
  - Based on word repeated
  - As a function of set size and overall
  - Via a partial span scoring

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### Recall Scores: Partial Span

Set Size	2	3	4	5	6
# trials passed in set size	4/5	3/5	2/5	1/5	0/5

3.67

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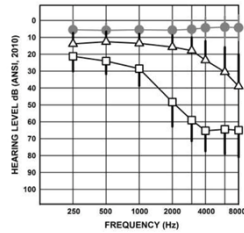
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### Initial Testing with the WARRM

- Three listener groups
  - Younger normal (YN)
  - Older 'normal' (ONH)
  - Older hearing loss (OHL)
- n = 48 each
- Administered WARRM
  - No processing
  - Alphabet processing




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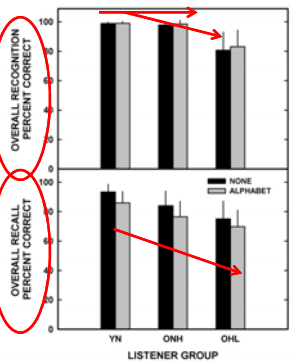
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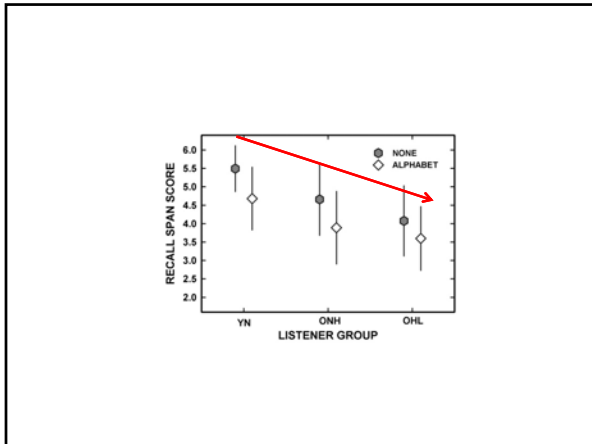
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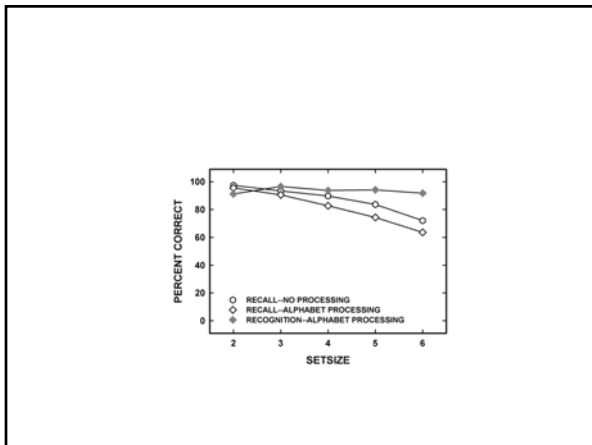
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**Summary**

- Recognition was not affected by increasing setsize, but recall was
- Alphabet task induced processing for all listener groups
  - Recall worse for alphabet processing relative to no processing task
- WARRM is giving us more information than simple word recognition
  - Also provides a recall score
    - Partial span

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**Clinical Utility of the WARRM**

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- Important Considerations for Audiology Clinical Tests**
- Theoretical basis
  - Standardized and easy test administration
  - Reasonable administration time
  - Adequate psychometric properties
    - Validity
    - Reliability
  - Informative

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**Comparing WARRM and Reading Span**

Portions of data from  
Smith & Pichora-Fuller (2015). Associations between speech understanding and auditory and visual tests of verbal working memory: Effects of linguistic complexity, task, age and hearing loss, *Frontiers in Psychology*.  
doi: 10.3389/fpsyg.2015.01394

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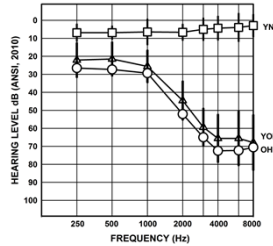
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## Participants

- Three groups of participants (n = 24 each)
  - Younger normal (YN)
    - 23.5 years (SD = 2.8)
  - ‘Young-old’ listeners with hearing loss (YOHL)
    - 66.3 years (SD = 2.0)
  - Older listeners with hearing loss (OHL)
    - 74.3 years (SD = 3.2)
- All groups had similar education (at least some college on average)
- All passed a cognitive screening (MoCA) to rule out dementia




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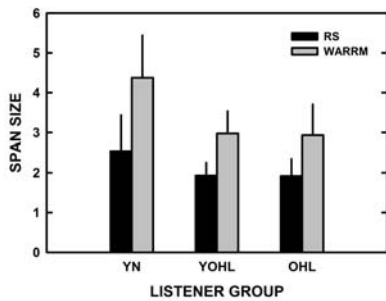
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## Results: Comparison between Reading Span and WARRM




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## Summary & Conclusions

- Did see a relation between the measures
  - WARRM had more range in performance
- Modality of working memory
  - Effect of modality: auditory higher than visual
    - May be easier (all monosyllabic words)
      - Less linguistically demanding

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## Effects of Modality with Linguistically Matched Materials

Pattison, J., Pichora-Fuller, M. K., & Smith, S. L. (2016). Effects of modality and linguistic materials on memory. *Canadian acoustics*, 44(3).

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## Materials and Procedures

- complementary auditory and visual working memory tests with matched word-level (WARRM) and sentence-level materials (R-SPIN)
  - Four conditions
    - word auditory
    - word visual
    - sentence auditory
    - sentence visual
- Presented over 2 sessions (order counterbalanced)

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## Participants

- 32 young adults
  - mean age = 19.9 years (SD = 1.8, range = 18-26)
- Normal pure-tone thresholds
- Native English speakers

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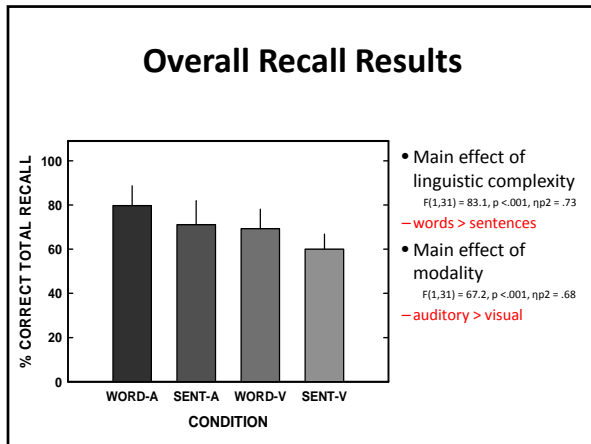
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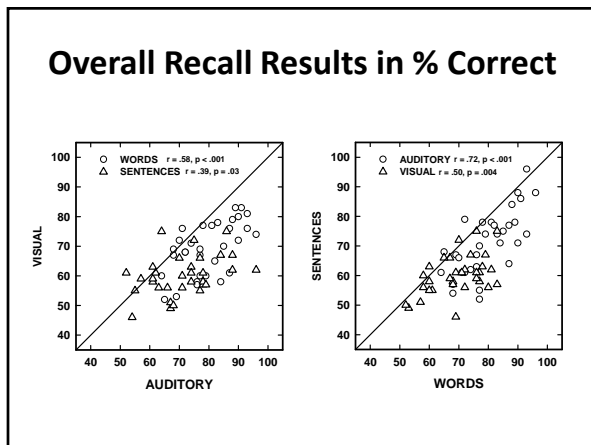
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### Summary & Conclusions

- Overall, auditory stimuli are easier to recall than visual stimuli, regardless of linguistic complexity of speech materials
  - Cognitive demand
    - Auditory stimuli have direct access to the phonological loop and are less cognitively demanding (Ruchkin et al., 1997)
    - Reading is more cognitively demanding
  - More range in scores with auditory modality

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## Intra- and Inter-session Test- Retest Reliability of the WARRM

*Shock, D. Smith, S. L., & Pichora-Fuller, M. K. Test-retest reliability of the Word Auditory Recognition and Recall Measure (WARRM). Poster presentation at the American Academy of Audiology Convention. Indianapolis, IN. April 5-8, 2017.*

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### Purpose

- To evaluate intra-session test-retest reliability of the WARRM, which could reveal a practice effect
- To evaluate inter-session test-retest reliability and determine if the WARRM is stable over time, which would be important if used as an outcome measure

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### Participants

- 30 younger listeners with normal hearing
  - 22 female, 8 male
  - Mean age = 22.7 years (SD = 2.5, 18-30 years)
  - Mean years of education = 16.6 years (SD = 2.5, 13-20 years)
  - All passed a cognitive screener (MoCA) with a mean score of 28.8

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### Procedures

- Administered 3 randomizations of the WARRM
  - Two WARRMs in session one (*intra-session* test-retest reliability)
  - About 2 weeks later, a third WARRM (*inter-session* test-retest reliability)
  - Presented binaurally through insert earphones at 70 dB HL

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### Results

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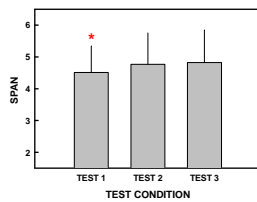
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### Partial Span

	Mean	SD
WARRM 1	4.51	0.83
WARRM 2	4.77	0.99
WARRM 3	4.82	1.02



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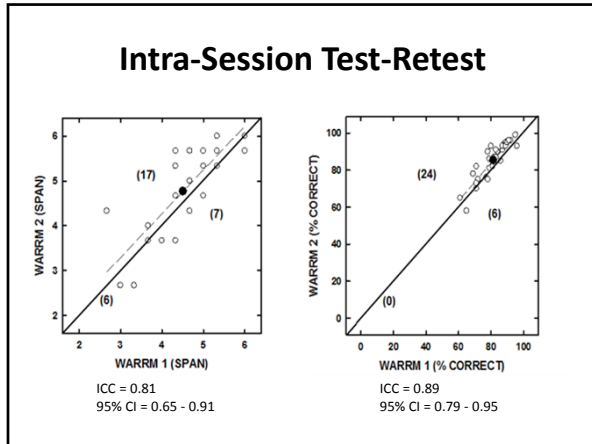
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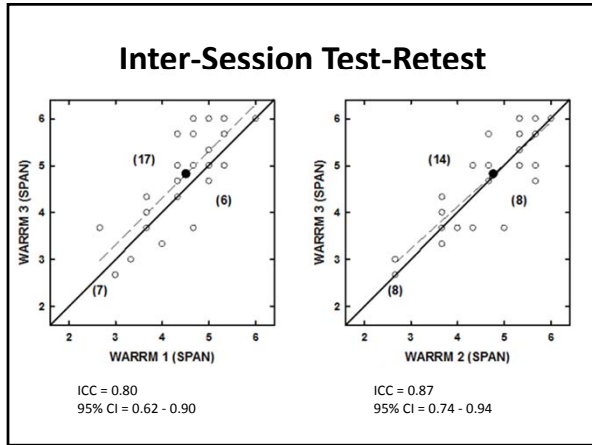
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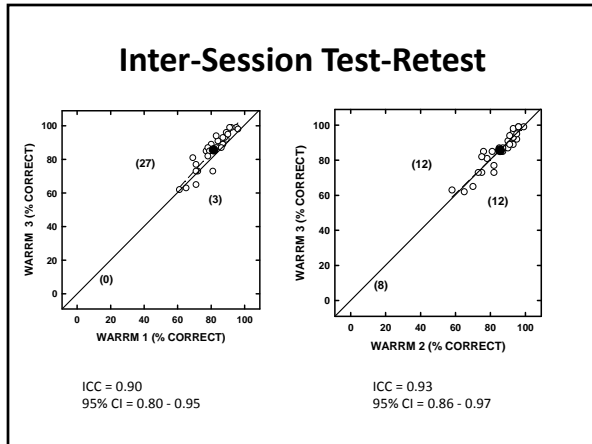
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### Summary & Conclusions

- Practice effects may explain better recall with between tests 1 and test 2
- Future research
  - More and different practice
  - Test, retest reliability on older listeners with hearing loss
  - Calculate the smallest real difference score

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### Can the administration of the WARRM be abbreviated?

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### Purpose

- Attempt to alter the presentation paradigm of the traditional WARRM with the goal of shortening the WARRM

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# Results

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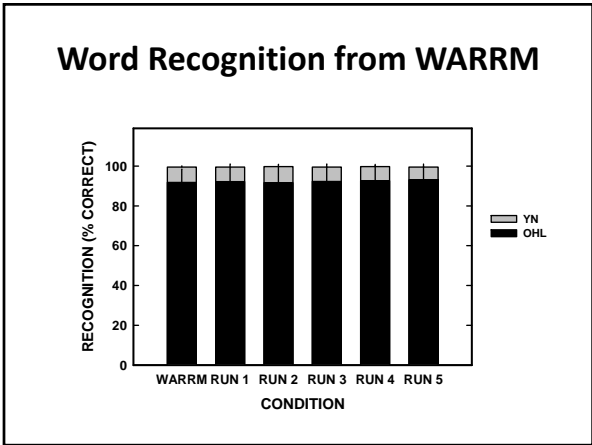
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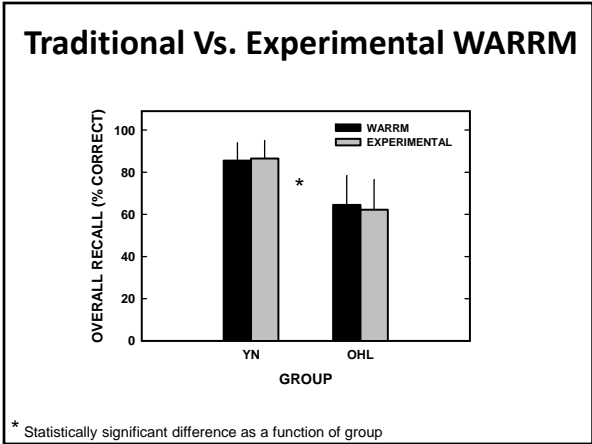
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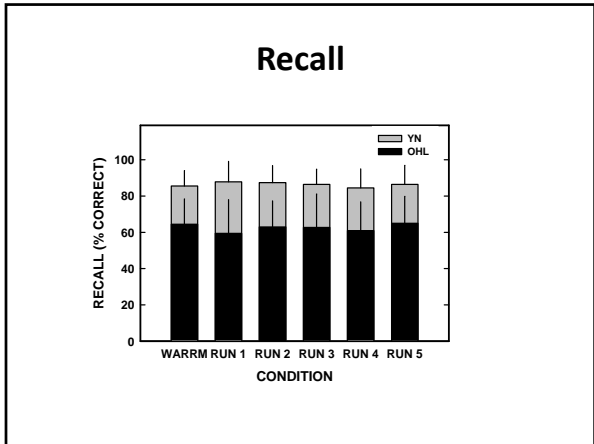
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### Summary & Conclusion

- **Less than 5 minutes** to administer
- Recognition AND recall score

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### Research Questions

1. Will improved audibility through amplification allow for improvements on the WARRM recall (span and/or percent correct)?

Aided

Processing

Storage

Unaided

2. Are there any associations between the unaided WARRM and self-report/hearing aid outcomes measures?

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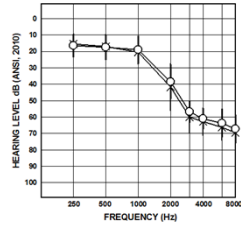
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## Participants

- 20 older listeners with hearing loss and bilateral hearing aids
  - PTA  $\leq$  40 dB HL, 2 and 4 kHz  $\leq$  75 dB HL
  - One brand of BTE hearing aid with current technology
- $M_{age}$  = 68.9 yrs,  $SD$  = 5.5, 60-79 yrs
- All passed a cognitive screener (MoCA)
- Word recognition in quiet  $\geq$  50% (65 dBA in soundfield)



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## Procedures

- Hearing aid verification
  - NAL-NL2
- Two WARRM conditions in the soundfield
  - Unaided WARRM (65 dB SPL)
  - Aided WARRM (65 dB SPL)
  - Order was counterbalanced
- Self-report/hearing aid outcomes
  - Abbreviated Profile of Hearing Aid Benefit (APHAB)

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## Results

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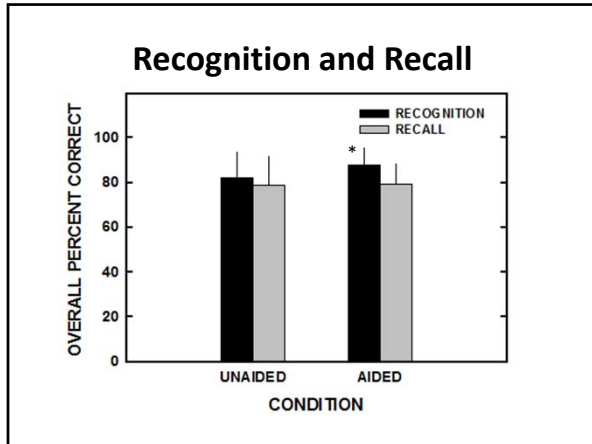
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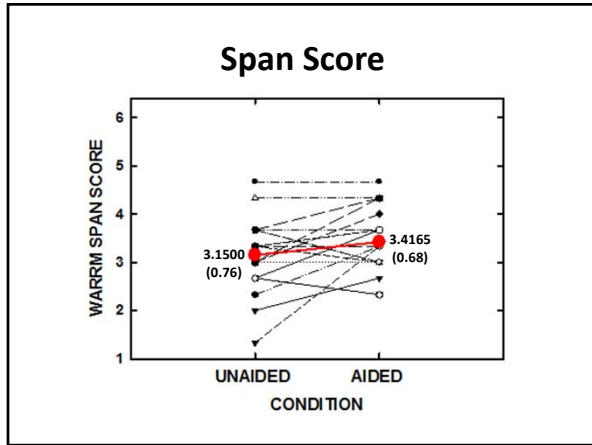
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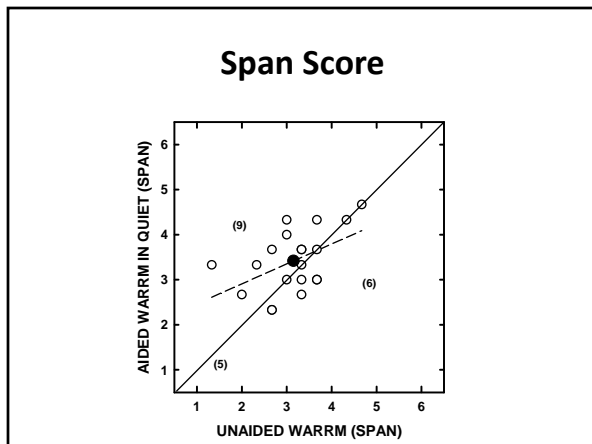
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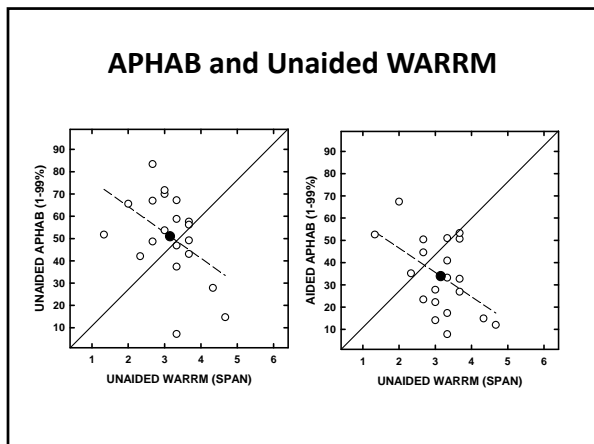
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### Summary & Conclusion

- Minimal improvement in recognition
- No significant improvement in recall
  - Hearing loss criteria (ceiling effect)
    - Little difference in processing load unaided to aided
  - Small effect
    - Significant difference in improvement and decline for span scores
- Significant correlations of unaided WARRM span score to unaided and aided APHAB
  - Identify individuals who might be 'at risk' for poor outcomes

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### Overall Summary & Conclusions

- Working memory plays a small, but important role in speech understanding
- Inter- and intra-individual differences in working memory may have clinical applications in rehabilitative audiology
  - Auditory-modality with speech stimuli to evaluate intra-individual differences
- WARRM is showing promise for clinical use
  - Standardized administration, test-retest, validity

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The contents of this presentation do not represent the views of the Department of Veterans Affairs or US Government.

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- Richard Wilson
- Ginny Alexander
- Dave Ryan



### Lab assistants

- Sam Hester
- Emerald Lauzon
- Devon Shock



## Thank you



sherri.smith@va.gov

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Potential post-doc opportunities available

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