Working memory problems of the elderly arise in the central processor, not the phonological loop

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BACKGROUND

Aging is commonly associated with declines in sensory functions, including audition. The extent of auditory decline has been correlated with the extent of decline in cognitive function (e.g., Harrison Bush et al., 2015), leading to suggestions that the loss of auditory function is the cause of cognitive decline (e.g., Humes et al., 2013).

Cognitive function is often evaluated with working memory (WM) tasks, including ones of a verbal nature.

Verbal working memory has been modeled as a two-stage process, involving (1) a phonological loop that stores items in a buffer with a phonological code and (2) a central executive that operates on those stored items (Baddeley, 2007).

In spite of substantial investigation, the relation between declining audition and cognition is not completely understood.

This study tested three hypotheses:

1. Poor audition might affect verbal WM by impairing phonological capacities, and so the quality of stored representations (Andersson, 2002).

2. Poor audition might affect verbal WM by an extra-phonological route, by degrading the auditory code itself, which has been shown to affect verbal WM (Martin et al., 1989).

3. Declining sensory functions may just accompany declines in cognitive functions, and the real culprit in the latter may be slowing processing speeds (Schneider et al., 2010).

METHOD

PARTICIPANTS

Young adults, ages 18-32 (20) and older adults, ages 60-80 (25). Mean 4-frequency PTAs (in dB HL) were 16.5 (8.8 SD) for older adults and 0.4 (0.7 SD) for younger adults.

MEASURES

Verbal Working Memory

- Forward and reverse digit span
- Serial recall: CVC word lists consisting of two lengths (6 and 8 words) and three conditions (nonrhyming nouns, rhyming nouns, and nonrhyming adjectives)

Phonological Capacities

- Final Consonant Choice (Awareness) & Backwards Words (Processing)
- Lexical Decision (Recoding)

For all tasks, accuracy and response times were measured. Response time on the verbal working memory task was adjusted according to performance on a calibration task.

RESULTS

DIGIT SPAN

- Digit spans were similar for younger and older adults.
- Response times were slower for older adults, $t(43) = 2.46$, $p = .018$, for reverse digit span only.

SERIAL RECALL

Accuracy

- Condition was significant for both list lengths. Eight: $F(2,86) = 24.67$, $p<.001$, $\eta^2=.37$. Six: $F(2,86) = 7.57$, $p=.001$, $\eta^2=.15$. The nonrhyming noun condition was best, then nonrhyming adjectives, then rhyming nouns.
- Position was significant for both list lengths. Eight: $F(7,301) = 165.97$, $p<.001$, $\eta^2=.79$. Six: $F(5,215) = 72.99$, $p<.001$, $\eta^2=.63$. Primacy and recency effects were observed.
- Age was significant for both list lengths. Eight: $F(1,43) = 11.13$, $p<.001$, $\eta^2=.21$. Six: $F(1,43) = 16.84$, $p<.001$, $\eta^2=.28$). Younger adults were more accurate than older adults.

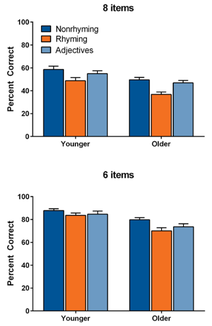

Figure 1: Accuracy.

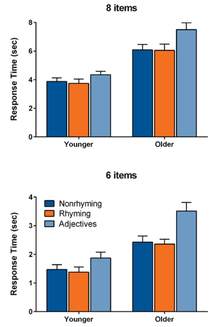

Figure 2: Response time.

Response Time

- Condition was significant for both list lengths. Eight: $F(2,86) = 17.99$, $p<.001$, $\eta^2=.30$. Six: $F(2,86) = 21.07$, $p<.001$, $\eta^2=.33$. Response times were slower for adjectives than the other two conditions.
- Age was significant for both list lengths. Eight: $F(1,43) = 26.95$, $p<.001$, $\eta^2 = .39$. Six: $F(1,43) = 20.70$, $p<.001$, $\eta^2 = .33$. Older adults were slower.
- The Age x Condition interaction was significant for both list lengths. Eight: $F(2,86) = 3.64$, $p=.030$, $\eta^2 = .08$. Six: $F(2,86) = 3.87$, $p=.024$, $\eta^2 = .08$. Older adults were disproportionately slower for adjectives.

Covariates

When ANOVAs were rerun using PTA or response time as covariates, age effects on accuracy of serial recall were eliminated for both list lengths, with the exception of 8-item lists when response time is covariate; then it is only reduced, $F(1,40) = 5.01$, $p=.031$, $\eta^2=.11$.

PHONOLOGICAL CAPACITIES

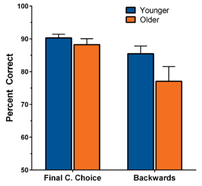

Figure 3: Awareness & Processing

Percent correct scores on phonological awareness, processing, and recoding were the same for both age groups. Response times for phonological recoding were slower for older adults, but pattern across conditions was the same.

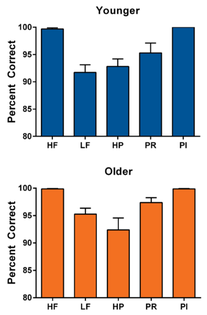

Figure 4: Recoding accuracy

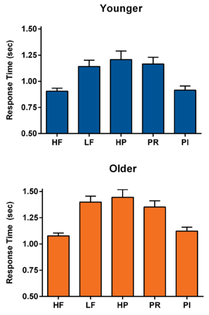

Figure 5: Recoding time

HF: high-frequency real words
LF: low-frequency real words
HP: homophones of real words
PR: phonologically regular nonwords
PI: phonologically irregular nonwords

There was no difference in phonological capacities between age groups; PTA did not explain phonological capacities for older adults.

EXPLAINING VARIANCE IN WM ACCURACY FOR OLDER ADULTS

- Six stepwise linear regressions were conducted, one for each of the three conditions at each list length.
- Four measures served as predictor variables: Processing speed (response time for that condition), percent correct scores for FCC and BW, and audibility (better-ear, 4-frequency PTAs). Significant β coefficients are listed in Table 1.

	Phonological		Processing Speed	Audibility
	FCC	BW	(Response Time)	(PTA)
6 items				
Nonrhyming		β= .410*		
Rhyming	β= .456*		β= -.357*	
Adjectives		β= .399*	β= -.417*	
8 items				
Nonrhyming	β= .449*			
Rhyming				β= -.398*
Adjectives				β= -.622**

Table 1. Significant standardized β coefficients for recall accuracy scores. * $p < .05$; ** $p = .001$.

- Phonological capacities explained much of the within-group variance for older adults.

SUMMARY

- Older adults showed cognitive deficits, defined here as poor verbal WM.
- Group differences were related to slower processing by older adults, and poorer signal audibility.
- Mean phonological abilities were similar across age groups, but within-group variability for older adults explained within-group variability on verbal WM: Better phonological skills appear to buffer the effects of aging.
- Tasks with greater processing demands disproportionately affected older adults: reverse digit span, serial recall for adjectives, backwards words.
- In the end, all three hypotheses received support. Cognitive functions are multifactorial in origin.

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Methodological Details and Additional Results

Verbal Working Memory

Digit span task

- From the WAIS-III (Wechsler, 1997)
- Presented on a computer platform
- Digits presented over headphones, participant responded by tapping digits on a touchscreen monitor

Serial recall task

- Stimuli have been used previously (Nittrouer et al., 2013).
    - Nonrhyming nouns: ball, coat, dog, ham, pack, rake, seed, teen
    - Rhyming nouns: bat, cat, hat, mat, Pat, rat, gnat, vat
    - Nonrhyming adjectives: big, deep, full, hot, sad, wet, neat, thin
- Participants were familiarized with the words used before testing and were required to accurately tap the picture that went with each word both before and after testing.

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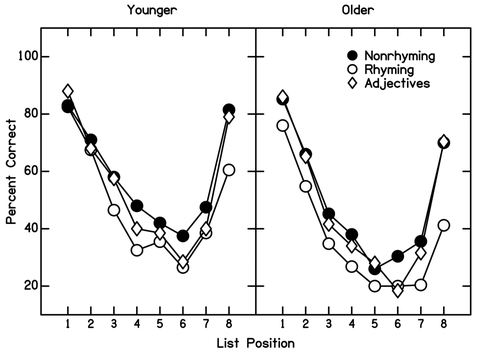


Phonological Capacities

Awareness: Final Consonant Choice

- Has been used previously (Nittrouer et al, 2011)
- Participant hears and repeats a target word, then is presented with three words. The participant has to select which word ends in the same sound as the target word. (say “hand”-hail, *lid*, run)

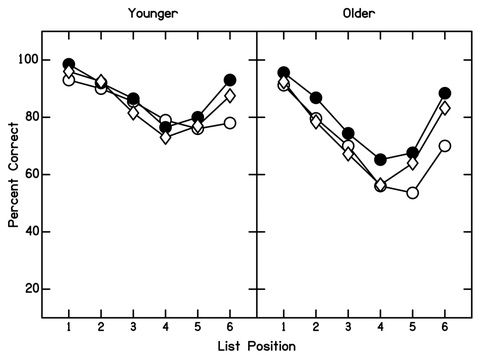
Processing: Backwards Words

- Participant hears and repeats a target word, then says the word that results when the order of phonemes are reversed. (nips-*spin*)

Recoding: Lexical Decision

- Reading task consisting of 160 1-and 2-syllable words and nonwords.
- Five categories:
    - High-frequency real words (HF)
    - Low-frequency real words (LF)
    - Homophones of real words (HP)
    - Phonologically regular nonwords (PR)
    - Phonologically irregular nonwords (PI)

- Items appeared on the computer monitor in large letters. The participant’s task was to decide as quickly as possible whether the item was a real word or not. Participants responded by hitting a green or red labeled key on the keyboard.



	FCC	BW
Older	.73 (.41)	1.87 (1.63)
Younger	.66 (.23)	1.42 (1.33)

This table presents response times (in seconds) for the Final Consonant Choice and Backwards Words tasks