Is two better than one? Examining auditory, visual, and dual encoding processes on phonological working memory performance in children with ADHD

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Introduction

- ADHD is associated with working memory difficulties and variable performance (1, 2).
- In children with ADHD, phonological WM deficits are large, predicting many learning-related outcomes (3).
- Most studies of phonological WM performance in ADHD use tasks requiring that to-be-recalled material be encoded via auditory input, most commonly using digit span tasks (1) .
- However, because material may also be encoded into phonological WM through visual encoding or dual (simultaneous auditory + visual input) encoding inputs, the impact of these different encoding presentations may impact phonological WM.

Present Study

- The current study is the first to examine the extent to which different encoding modalities (auditory, visual, or their combination) influence ADHD-related PHWM performance and performance variability.

Method

Participants

- *N=25 aged 8-13 years*
- Children (10 female, 15 male) with diagnosis of ADHD based on:
  - Independent diagnostic using K-SADS semi-structured interview with parent
    - Parent and teacher ratings ≥ 1.5 *SD*s on BASC-2 Attention Problems and/or Hyperactivity Scales

    OR
  - Exceeding parent / teacher criterion score on Child Symptom Inventory-IV
- ADHD Presentations (14 Combined, 8 Inattentive, & 3 Hyperactive / Impulsive)
- Exclusion: Neurological impairment, seizures, psychosis, or WASI VCI IQ < 85 (Table 1)

Primary Measures

- Three conditions of a phonological WM task similar to the WISC-IV Letter-Number Sequencing. All tasks were counterbalanced. Stimuli presented at 1 s intervals. All conditions identical except encoding presentation.
  - (1)Auditory Encoding: Stimuli presented audibly using pre-recorded stimuli
  - (2)Visual Encoding: Stimuli presented as alpha-numeric numbers in center of screen
  - (3)Dual Encoding: Stimuli presented from Auditory and Visual encoding conditions simultaneously
  - Conditions administered at four set sizes (3,4,5,6). Each set size included 12 trials presented in ascending order.
- Tasks administered at 4 unique set sizes (3, 4, 5, 6) for a total of 48 trials.

Dependent Variables

- Phonological working memory **performance**
  - Number of stimuli correctly recalled per trial
- Phonological working memory **performance variability**

Analyses

- Preliminary analyses
- Repeated-measures ANOVAs with LSD-post hocs
- Effect size contrasts (See Tables 2 and 3)

Results

Preliminary Analyses

- No univariate / multivariate outliers

Primary Analyses

Performance

- Overall (Figure 1a): Differences among the encoding modality conditions were observed (p<.001).
  - Performance was significantly lower with Auditory encoding relative to Visual and Dual conditions (ps<.001), which did not differ significantly (p>.05).
- Set Size (Figure 2a): Significant main effects for encoding modality (p<.001), set size (p<.001) and their interaction (p<.001) were observed indicating performance differed according to encoding modality and cognitive load.
  - Table 2 presents data for post hoc contrasts

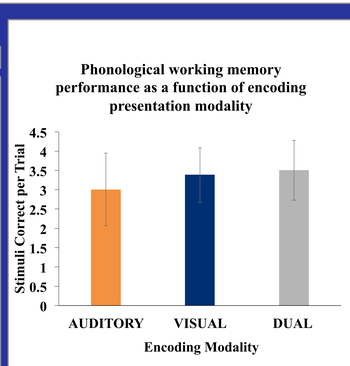
Performance Variability

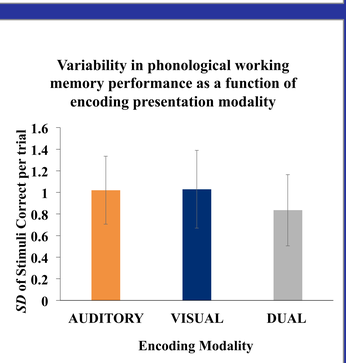
- Overall (Figure 1b: Differences among the encoding modality conditions were observed (p<.001).
  - Variability was significantly lower with Dual encoding relative to Auditory and Visual conditions (ps<.001), which did not differ significantly (p>.05).
- Set Size (Figure 2b): Significant main effects for encoding modality (p=.002), set size (p<.001) and their interaction (p=.009) were observed indicating performance differed according to encoding modality and cognitive load.
  - Table 3 presents data for post hoc contrasts

Table 1. Sample Demographics

Variable	*M (SD)*
Age	10.46 (1.49)
WASI-2 VCI IQ	110.44 (14.62)
FSIQ	112.08 (14.73)
Hollingshead SES	47.00 (10.68)
BASC-2 Parent	
Hyperactivity	72.75 (13.81)
Attention Problems	68.50 (7.90)
BASC-2 Teacher	
Hyperactivity	61.00 (12.70)
Attention Problems	63.92 (8.49)
ADHD Current Presentation	*N (%)*
Combined	14 (56%)
Inattentive	8 (32%)
Hyperactive/Impulsive	3 (12%)
Gender	
Male	15 (60%)
Female	10 (40%)

Note. WASI-2 VCI IQ = Wechsler Abbreviated Scale of Intelligence–Second Edition: Verbal Comprehension Index; FSIQ = Full Scale Intelligence; SES = Socioeconomic Status; BASC-2 = Behavior Assessment System for Children–Second Edition





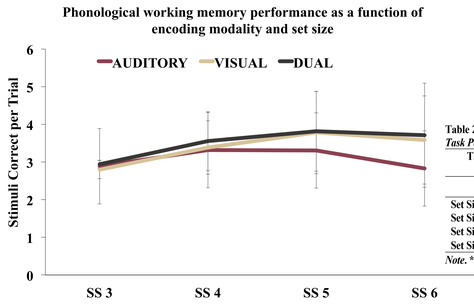


Table 2
Task Performance by Encoding Condition and Set Size

Task	Condition				
	Auditory	Visual	Dual		
	M (SD)	*M (SD)*	*M (SD)*	*Contrast*	*Cohen's d*
Set Size 3	2.88 (.29)	2.80 (.24)	2.94 (.10)	A=V=D	--
Set Size 4	3.31 (.75)	3.38 (.71)	3.55 (.78)	A=V=D	--
Set Size 5	3.31 (1.23)	3.78 (1.09)	3.82	A<V=D***	0.17, 0.44
Set Size 6	2.83 (1.51	3.58 (1.17)	3.71	A<V=D***	0.56, 0.61

Note. ** p < .01, *** p < .001; A = Auditory; D = Dual; V = Visual

Figure 2b.

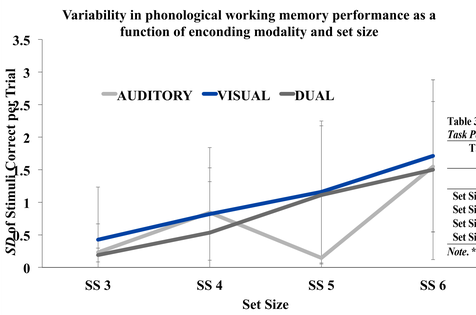


Table 3
Task Performance by Encoding Condition and Set Size

Task	Condition				
	Auditory	Visual	Dual		
	M (SD)	*M (SD)*	*M (SD)*	*Contrast*	*Cohen's d*
Set Size 3	0.23 (.29)	0.43 (.24)	0.19 (.11)	A=V=D	--
Set Size 4	0.84 (.75)	.081 (.71)	0.54 (.79)	A=V>D*	1.22, 1.21
Set Size 5	0.15 (1.23)	1.16 (1.06)	1.11 (1.06)	A<V=D*	0.82, 0.86
Set Size 6	1.55 (1.51)	1.71 (1.17)	1.50 (1.38)	A=V=D	--

Note. ** p < .01; A = Auditory; D = Dual; V = Visual

Discussion

- Presentation of encoding modality impacts phonological working memory performance in ADHD.
- Auditory encoding associated with poorest WM performance, particularly at high cognitive loads.
- Visual and Dual encoding show similar performance patterns, but Dual presentation decreases variability in phonological WM performance.
- Has implications for assessing phonological WM and treatment recommendations focused on decreasing performance variability.

References

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