



One Cheer for Digit Span: Alternate Administration & Scoring Methods May Improve Working Memory Measurement

Erica L. Wells, Sherelle L. Harmon, Elia F. Soto, Nicole Ferretti, Matthew Casarico, Briana Francis, Brian Menard, Kayla Saunders, & Michael J. Kofler, Ph.D.
Department of Psychology, Florida State University



Introduction

- Working memory (WM) is a limited capacity system for temporarily storing and processing internally held information for use in guiding behavior (1).
- Children with ADHD exhibit large magnitude WM deficits ($d \geq 2.0$; 4) but do not perform comparatively worse than non-ADHD children on digits backward relative to digits forward (6).
- Digit span backward is frequently interpreted as a measure of WM, but decades of evidence from cognitive psychology indicate that digits backward is better characterized as a measure of verbal short-term memory (STM; cf. 3).
- STM and WM constructs predict non-overlapping variance in outcomes such as IQ (10).
- Performance on simple span tasks (e.g. digit span forward & backward) appears to predict WM only at list lengths that exceed STM capacity (i.e. during the trials omitted by standardized administration; 9).

Method

Participants

- Thirty-six children with ADHD (13 female, 23 male), ages 8-13
 - M age = 10.35, SD = 1.42
 - Final N = 33 (three excluded due to administration error)
- Diagnosed using DSM-5 criteria based on comprehensive K-SADS diagnostic interviews and multiple parent/teacher ratings (BASC, CSI)

Measures

- WISC-IV Digit Span (DS) Backward
- PH and VS WM tasks, as described by (7) and depicted in the Figure below.

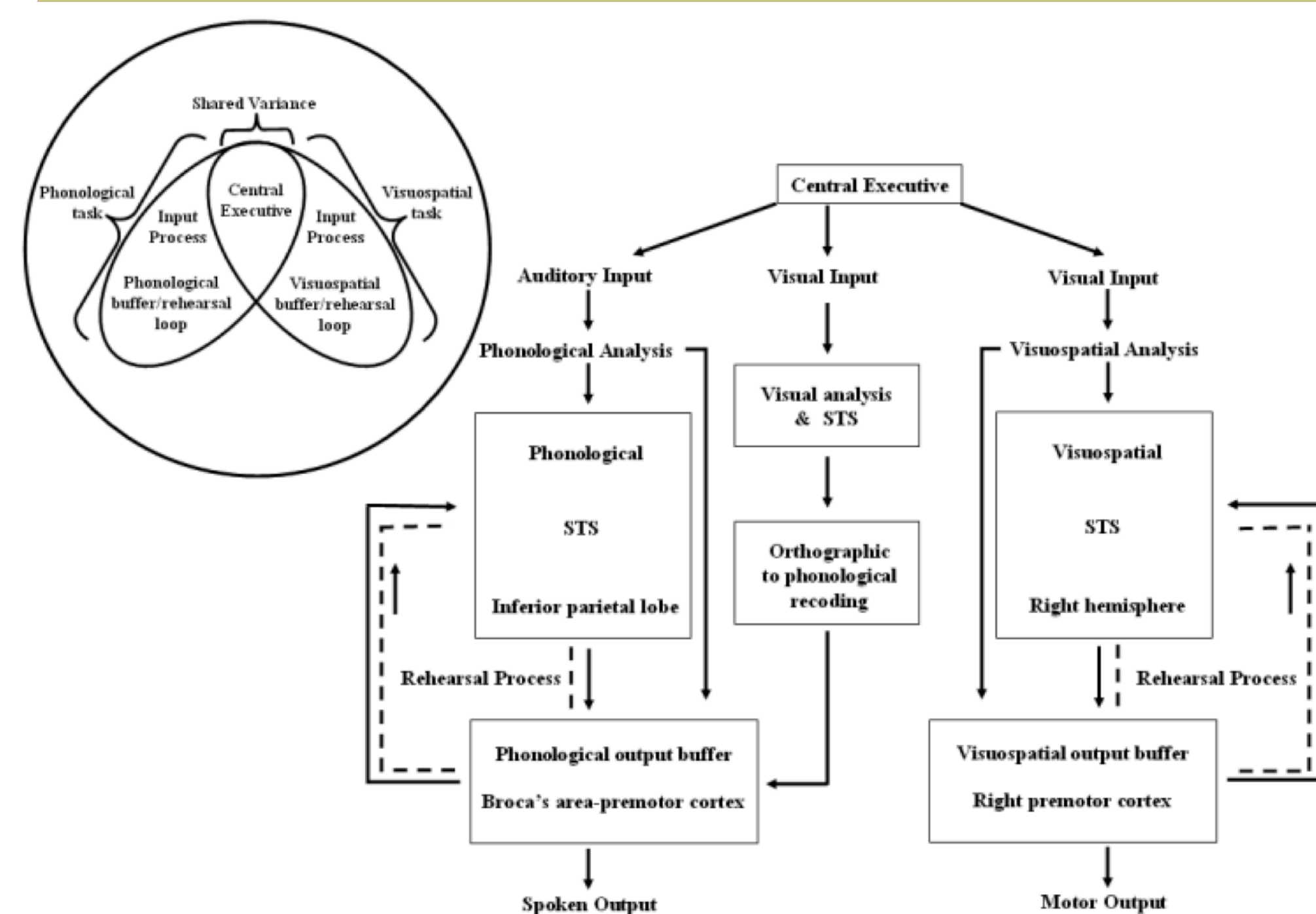
Administration & Scoring Procedures

- Participants completed *all* trials of WISC-IV digit span backward (i.e. no discontinue rule).
- Performance on DS was evaluated using both traditional (discontinue rule; all-or-nothing scoring) and recommended (no discontinue; partial-credit unit scoring) methods (9).
- A latent index of central executive WM served as the criterion as recommended, to reflect shared variance between PH and VS WM (cf. 8).

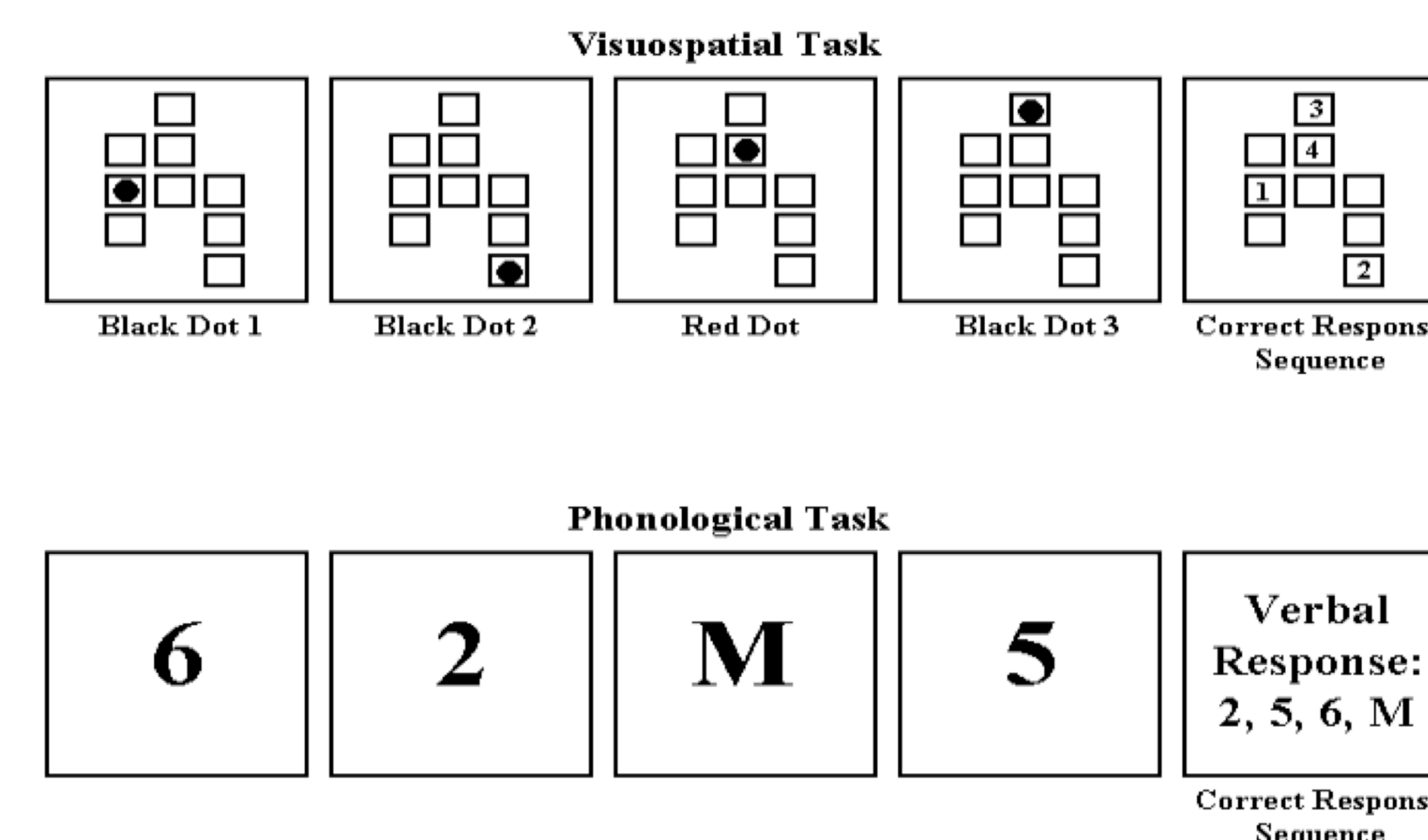
Discussion

- Our results extend findings from healthy populations to a clinical sample, and they further challenge traditional interpretations of digit span backward as a measure of WM.
- WM performance predicts constructs as varied as academic achievement, IQ, and social functioning (e.g., 3; 5).
- Firm conclusions regarding digit span's construct validity are limited by the lack of a typically developing (TD) comparison group; however, results were highly consistent with findings from healthy populations (3; 9).
- Future research that includes larger samples of TD and clinical comparison groups is needed to determine the extent to which DS Backward measures WM across groups.
- Accurate measurement of WM is useful in both research and clinical settings. This may be particularly relevant for clinical assessment of children with ADHD and other populations that exhibit impairments in working memory.

Baddeley Working Memory Model



Visuospatial (VS) and Phonological (PH) WM Tasks



Study Objectives

- One explanation for the poor correspondence between digit span backward and WM tasks is the former's discontinue criteria that omits trials above the child's span (i.e. longest perfectly recalled sequence).
- In addition, the all-or-nothing scoring approach has been criticized psychometrically, and may blunt individual differences relative to partial-credit scoring (2).
- To test these hypotheses, Unsworth & Engle (9) omitted a simple span task's discontinue criteria and scored each stimuli recalled in the correct serial position (partial-credit scoring). They found that simple span predicts complex span (WM) only at simple span list lengths that exceed STM capacity.
- The current study is the first to examine this hypothesis in a clinical sample of children.

Results

- Traditional DS Backward scores were not related significantly to the WM criterion ($r = 0.005$, 95% CI = -.45 to .56).
- A significant relation between DS Backward and WM emerged when using non-discontinue, partial-credit scoring methods ($r = 0.47$, 95% CI = .15 to .78).
- The improved correlation appeared specific to trials above span: Performance at the lowest list lengths failed to predict WM (2-4 digits; $r = .09$, 95% CI = -.32 to .56), whereas the highest list lengths showed strong association with WM (6-8 digits; $r = .60$, 95% CI = .35 to .83).
- The hierarchical regression was significant ($R^2 = .62$, $p = .001$). High-list performance ($\Delta R^2 = .39$; $\beta = .64$, $p = .001$) and SES ($\Delta R^2 = .23$; $\beta = .47$, $p = .006$) uniquely predicted WM. Traditional and low-list scores failed to account for additional variance (all $p > .05$).

References

- Baddeley, A. (2007). *Working memory, thought, and action*. Oxford University Press.
- Conway, A. R., Kane, M. J., Bunting, M. F., Hambrick, D. Z., Wilhelm, O., & Engle, R. W. (2005). Working memory span tasks: A methodological review and user's guide. *Psychonomic Bulletin & Review*, 12, 769-786.
- Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology: General*, 128, 309-331.
- Kasper, L. J., Alderson, R. M., & Hudec, K. L. (2012). Moderators of working memory deficits in children with ADHD: A meta-analytic review. *Clinical Psychology Review*, 32, 605-617.
- Kofler, M. J., Rapport, M. D., Bolden, J., Sarver, D. E., Raiker, J. S., & Alderson, R. M. (2011). Working memory deficits and social problems in children with ADHD. *Journal of Abnormal Child Psychology*, 39, 805-817.
- Martinussen, R., Hayden, J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit/hyperactivity disorder. *Journal of the American Academy of Child & Adolescent Psychiatry*, 44, 377-384.
- Rapport, M. D., Alderson, R. M., Kofler, M. J., Sarver, D. E., Bolden, J., & Sims, V. (2008). Working Memory Deficits in Boys with Attention-deficit/Hyperactivity Disorder (ADHD): The Contribution of Central Executive and Subsystem Processes. *Journal of Abnormal Child Psychology*, 36, 825-837.
- Swanson, L., & Kim, K. (2007). Working memory, short-term memory, and naming speed as predictors of children's mathematical performance. *Intelligence*, 35, 151-168.
- Unsworth, N., & Engle, R. W. (2006). Simple and complex memory spans and their relation to fluid abilities: Evidence from list-length effects. *Journal of Memory and Language*, 54, 68-80.
- Unsworth, N., & Engle, R. W. (2007). The nature of individual differences in working memory capacity: Active maintenance in primary memory and controlled search from secondary memory. *Psychological Review*, 114, 104-132.