Working Memory, Attention, and Processing Speed Predict Academic Achievement

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Objective and Introduction

The purpose of this study was to determine if the relationship among working memory, attention, and processing speed differentially contributes to areas of academic achievement (i.e., reading, writing, mathematics, and oral language). It has been found that working memory, attention, and processing speed often influence each other (Baddeley, 2003; Burns, Nettelbeck, & McPherson, 2009; Vergauwe, Camos, & Barrouillet, 2014). The literature also suggests that working memory, attention, and processing speed differentially impact various areas of academic achievement (Kail, 2007; Miller, 2013). A study conducted by Fournier (2014) indicated a significant relationship between working memory and attention that was predictive of other cognitive processes. The current study focused on the collective impact of all three neurocognitive constructs on academic achievement to determine if similar results would be observed.

Method

This study incorporated archival data from the KIDS, Inc. School Neuropsychology Post-Graduate Certification Program. Participants included 955 children ages 6-18 with various clinical diagnoses. The predictor variables comprised children's performance on working memory (WM), attention (AT), and processing speed (PS) tasks. Two subtests for each cognitive skill were selected. The following subtests were used from the *Woodcock-Johnson Tests of Cognitive Abilities, 3rd Edition – Normative Update* (Woodcock, McGrew, & Mather, 2001, 2007b): Auditory Working Memory, Memory for Words, and Retrieval Fluency. The remaining subtests were used from the *Wechsler Intelligence Scale for Children – 4th Edition* (Wechsler, 2003) and the *Wide Range Assessment of Memory and Learning – 2nd Edition* (Sheslow & Adams, 2003): Symbol Search, Digit Span Backwards, and Finger Windows. The outcome variables comprised children's performance on tasks of academic achievement from the *Woodcock-Johnson Tests of Achievement, 3rd Edition – Normative Update* (Woodcock, McGrew, & Mather, 2001, 2007a). These tasks included Letter-Word Identification, Reading Fluency, Passage Comprehension, Calculation, Math Fluency, Applied Problems, Spelling, Writing Fluency, Writing Samples, Picture Vocabulary, and Oral Comprehension. Eleven stepwise regression analyses were computed to determine how much working memory, attention, and processing speed together predicted areas of academic achievement.

Conclusions

- Although reading decoding and fluency were significantly predicted by the relationship among working memory, processing speed, and attention, these cognitive skills only accounted for approximately 10% of the variance in reading decoding and fluency.
- Math problem-solving was significantly predicted by the relationship among the three cognitive processes. However, these cognitive skills only accounted for 7.1% of the variance in Applied Problems.
- Although writing fluency was also significantly predicted by all three cognitive processes, these cognitive skills only explained 8% of the variance in writing fluency.
- Only the relationship between working memory and attention predicted Picture Vocabulary, which was consistent with Fournier's (2014) findings.
- Finger Windows and Retrieval Fluency were included as significant predictors in all of the final regression models, with the exception of Picture Vocabulary.
- Working memory was included as a significant predictor in all of the final regression models. This finding has implications for learning disabilities.
- The potential overlap of cognitive processes used as predictors is a limitation of the study.

Results

Eleven stepwise regression analyses were ran to determine how much working memory, attention, and processing speed predicted areas of academic achievement. The six subtests for all three cognitive domains were entered simultaneously as the predictor/independent variables. Each academic achievement subtest was entered separately as the outcome/dependent variable. Results confirmed that four areas of academic achievement were significantly predicted by all three constructs.

Reading Fluency.
Digit Span Backwards ($\beta = -.169$, $p < .001$), Retrieval Fluency ($\beta = .151$, $p < .001$), and Finger Windows ($\beta = .095$, $p = .003$) explained 6.1% of the variance in Reading Fluency, $F(3, 946) = 20.408$, $p < .001$, $R^2 = .061$.

Writing Fluency.
Memory for Words ($\beta = .183$, $p < .001$), Retrieval Fluency ($\beta = .139$, $p < .001$), Finger Windows ($\beta = .109$, $p = .001$), and Digit Span Backwards ($\beta = .097$, $p = .002$) explained 8.4% of the variance in Writing Fluency, $F(4, 945) = 21.624$, $p < .001$, $R^2 = .084$.

Letter-Word Identification.
Memory for Words ($\beta = .127$, $p < .001$), Finger Windows ($\beta = .072$, $p = .026$), Retrieval Fluency ($\beta = -.111$, $p = .001$), Symbol Search ($\beta = .080$, $p = .013$), and Auditory Working Memory ($\beta = .085$, $p = .018$) explained 4.7% of the variance in Letter-Word Identification, $F(5, 949) = 9.444$, $p < .001$, $R^2 = .047$.

Applied Problems.
Auditory Working Memory ($\beta = .164$, $p < .001$), Retrieval Fluency ($\beta = .131$, $p < .001$), Finger Windows ($\beta = .084$, $p = .008$), and Symbol Search ($\beta = -.081$, $p = .011$) explained 7.1% of the variance in Applied Problems, $F(4, 950) = 18.134$, $p < .001$, $R^2 = .071$.

Picture Vocabulary.
Interestingly, attention and working memory accounted for the most variance in Picture Vocabulary. Finger Windows ($\beta = .256$, $p < .001$), Memory for Words ($\beta = .199$, $p < .001$), and Auditory Working Memory ($\beta = .105$, $p = .002$) explained 14.1% of the variance in Picture Vocabulary, $F(3, 951) = 52.235$, $p < .001$, $R^2 = .141$; however, processing speed was excluded from the model.

Reading Fluency: Predictor Variables	R^2	Beta
Digit Span Backwards (WM)	.028	-.169
Retrieval Fluency (PS)	.052	.151
Finger Windows (AT)	.061	.095

Writing Fluency: Predictor Variables	R^2	Beta
Memory for Words (AT)	.042	.183
Retrieval Fluency (PS)	.064	.139
Finger Windows (AT)	.075	.109
Digit Span Backwards (WM)	.084	.097

Letter-Word Identification: Predictor Variables	R^2	Beta
Memory for Words (AT)	.019	.127
Finger Windows (AT)	.028	.072
Retrieval Fluency (PS)	.035	-.111
Symbol Search (PS)	.042	.080
Auditory Working Memory (WM)	.047	.085

Applied Problems: Predictor Variables	R^2	Beta
Auditory Working Memory (WM)	.045	.164
Retrieval Fluency (PS)	.059	.131
Finger Windows (AT)	.065	.084
Symbol Search (PS)	.071	-.081

Picture Vocabulary: Predictor Variables	R^2	Beta
Finger Windows (AT)	.075	.256
Memory for Words (AT)	.132	.199
Auditory Working Memory (WM)	.141	.105