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The effects of Wechsler Intelligence Scale for Children—Fourth Edition cognitive abilities on math achievement

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ABSTRACT

This study used structural equation modeling to examine the effect of Stratum III (i.e., general intelligence) and Stratum II (i.e., Comprehension-Knowledge, Fluid Reasoning, Short-Term Memory, Processing Speed, and Visual Processing) factors of the Cattell–Horn–Carroll (CHC) cognitive abilities, as operationalized by the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003a) subtests, on Quantitative Knowledge, as operationalized by the Wechsler Individual Achievement Test, Second Edition (WIAT-II; Wechsler, 2002) subtests. Participants came from the WISC-IV/WIAT-II linking sample ($n = 550$). We compared models that predicted Quantitative Knowledge using only Stratum III factors, only Stratum II factors, and both Stratum III and Stratum II factors. Results indicated that the model with only the Stratum III factor predicting Quantitative Knowledge best fit the data.

1. Introduction

The Cattell–Horn–Carroll (CHC; McGrew, 2005; Newton & McGrew, 2010) theory of cognitive abilities is becoming an increasingly influential method of psychometric test development and interpretation. As a result, there is a need to understand how the CHC-defined cognitive abilities relate to academic achievement. To date, much of the prior research in this area has used the Woodcock–Johnson (WJ) instruments (Woodcock & Johnson, 1989; Woodcock, McGrew, & Mather, 2001) to operationalize CHC abilities, with McGrew and Wendling (2010) estimating that WJ instruments have been used in approximately 94% of the studies.

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Given that many cognitive ability instruments purportedly measure CHC abilities, but that these abilities are not necessarily as exchangeable as they may appear when compared across instruments (Floyd, Bergeron, Mccormack, Anderson, & Hargrove-Owens, 2005), more research from diverse cognitive batteries is needed to better understand the CHC cognitive and academic relations. In their meta-analysis of CHC factors and academic achievement McGrew and Wendling (2010) go so far as to state the following:

> Until additional CHC COG-ACH research is completed with other (non-WJ) intelligence batteries, users of these other batteries must proceed with caution when forming COG-ACH relations-based diagnostic, interpretative, and intervention hypotheses. (p. 668)

Consequently, this paper adds to the CHC knowledge base by examining the effects of CHC cognitive abilities, operationalized by the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Wechsler, 2003b), on Quantitative Knowledge operationalized by the Wechsler Individual Achievement Test, Second Edition (WIAT-II; Wechsler, 2002).

1.1. Cattell–Horn–Carroll theory of cognitive abilities

CHC theory has become a major influence in modern day test development, starting with the Woodcock–Johnson III (WJ III; Woodcock et al., 2001) and extending to the fifth edition of the Stanford–Binet Intelligence Scales (Roid, 2003), the second edition of the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 2004), and the second edition of the Differential Abilities Scales (Elliot, 2007). Besides influencing test battery development, CHC theory has also influenced the interpretation of cognitive ability instruments, most notably through the practice of Cross-Battery Assessment (Flanagan, Ortiz, & Alfonso, 2007).

CHC theory (McGrew, 1997, 2005) conceptualizes cognitive abilities as a higher-order taxonomy, reflecting an integration of the *Gf–Gc* theory (Horn & Cattell, 1966) and Carroll's (1993) three-stratum theory. Stratum III in CHC's taxonomy represents general cognitive ability (*g*; Jensen, 1998). Traditionally, at Stratum II there were 10 broad abilities (McGrew, 2005), although Newton and McGrew (2010) have expanded it to 16 "human abilities": Fluid Reasoning, Comprehension-Knowledge, General (domain-specific) Knowledge, Quantitative Knowledge, Reading and Writing, Short-Term Memory, Visual Processing, Auditory Processing, Long-term Storage and Retrieval, Processing Speed, Reaction and Decision Speed, Psychomotor Speed, Psychomotor Abilities, Olfactory Abilities, Tactile Abilities, and Kinesthetic Abilities. Stratum I includes over 100 narrow abilities, subsumed under each of the broader 16.[1]

1.1.1. Effects of Cattell–Horn–Carroll cognitive constructs on Quantitative Knowledge

One of the CHC Stratum II abilities that represents well one of the major curriculum areas in schoolings is Quantitative Knowledge, the "breadth and depth of a person's acquired store of declarative and procedural quantitative or numerical knowledge" (Newton & McGrew, 2010, p. 628). Multiple studies have investigated the CHC cognitive abilities that predict scores or abilities in this domain (for a review, see McGrew & Wendling, 2010), using a variety of data analysis techniques. For example, McGrew and Hessler (1995) and Floyd, Evans, and McGrew (2003) both used multiple regression with WJ cognitive and achievement instruments to investigate how well Stratum II scores explain Quantitative Knowledge. They found that Processing Speed, Comprehension-Knowledge, and Fluid Reasoning scores demonstrate moderate-to-strong effects on Quantitative Knowledge scores from childhood to adult age, although Floyd and colleagues also reported a moderate effect for Short-Term Memory scores. Proctor, Floyd, and Shaver (2005) used profile analysis to compare the cognitive ability scores of children with low math reasoning or calculation scores to the cognitive ability scores of their peers without such low scores. They observed no major differences on the cognitive ability scores between those with low and average math reasoning scores, they did find that children with problem-solving deficits demonstrated lower scores on measures of Fluid Reasoning and Comprehension-Knowledge, as well lower scores on an aggregated measure of cognitive ability. Structural equation modeling (SEM; Bollen, 1989) is a third way researchers have studied the effects of Strata II and III factors on Quantitative Knowledge. SEM has a number of

[1] There is much variety in the nomenclature used to describe the CHC abilities, especially those in Stratum II. Consistent with Newton and McGrew' (2010) goal of standardizing this nomenclature, we have used their terminology to label the CHC abilities.