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A Psychometric Exploration Of Visuo-Constructive Ability And Processing Speed

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A PSYCHOMETRIC EXPLORATION OF VISUO-CONSTRUCTIVE ABILITY AND PROCESSING SPEED

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Present to

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science, Clinical Psychology

By

Kayla M. LeJeune

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ABSTRACT

This study was conducted in order to explore the relationship between visuo-motor integration and processing speed; specifically, whether the WISC-V Coding B subtest is a better measure of visuo-motor ability. Visuo-motor ability and processing speed were assessed in a small, clinical sample (N = 13) of children and adolescents (ages 8-16 years). Results of correlation analyses indicated no significant relationship between visuo-constructive ability and processing speed, as measured by the Beery-Buktenica Developmental Test of Visual-Motor Integration (Beery VMI) and the Coding subtest of the Wechsler Intelligence Scale for Children- Fifth Edition (WISC-V). Results of one correlational analysis revealed that the Beery VMI was positively associated with the Full Scale IQ. Results of the qualitative analysis indicated a possible relationship between performances on the Coding subtest and Beery VMI within the low functioning group of subjects. Limitations of the study, particularly the small sample size and clinical nature of the sample, were discussed along with suggestions for further research.

KEYWORDS: WISC-V, coding, processing speed, Processing Speed Index, Beery VMI, visuo-constructive ability

This abstract is approved as to form and content

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TABLE OF CONTENTS

Introduction.....1
Historical Overview of Wechsler Scales.....1
Wechsler Intelligence Scale for Children- Fifth Edition.....6
Beery-Buktenica Developmental Test of Visual-Motor Integration.....8
Summary.....9
Hypotheses.....11

Methods.....12
Participants.....12
Exclusion Criteria of Research Sample.....12
Materials.....12
Experimental Design and Procedure.....14

Results.....16

Discussion.....20

References.....23

Tables.....27
Table 1. Means, standard deviations, and ranges of participants' standard scores.....27
Table 2. Standard scores and percentile ranks for FSIQ, PSI, Coding subtest, Symbol Search subtest, and Beery-VMI.....28

Appendix.....29
Appendix A. Permission to Access Data.....29
Appendix B. IRB Approval.....30

INTRODUCTION

Historical Overview of the Wechsler Scales

Historically, a number of revisions have been made to the Wechsler Intelligence Scale for Children. As the test's acceptance in the field and usage in clinical settings increased, several components needed to be adjusted in order to maintain strong psychometric properties. Normative data were re-collected for each version of the WISC in order to ensure the test adequately measured the construct of interest in both the general and clinical populations. Updated normative data also were necessary in order to account for the "Flynn effect," a phenomenon that had been observed throughout the field of applied psychological assessment. The "Flynn effect", a gradual and continual rise in measured IQ scores, has been observed with each version of the Wechsler Intelligence Scale for Children. This phenomenon results in an approximate gain of 3 IQ points per 10 years (Trahan, Stuebing, Fletcher, & Hiscock, 2014). James Flynn (1984) has largely been credited with the discovery and description of the trend; however, it appears to have been referred to, if not documented, decades prior to his recognition (e.g. Roesell, 1937; Smith, 1942; Wheeler, 1942). These early studies provide evidence for measured increases in IQ score points over time and individual differences in IQ point increases at different age levels (Wheeler, 1942). Further, it appears non-verbal abilities are characterized by higher IQ point increases (Smith, 1942). It is important to note that these trends have been replicated across multiple IQ tests and populations across the globe (Lynn, 2013). The results of these seminal studies have been supported by subsequent research, including that of James Flynn (Flynn & Weiss, 2007; te Nijenhuis, Cho, Murphy, & Lee, 2012).

David Wechsler developed his original intelligence test with the belief that general intelligence (g) is best measured by an interaction of various verbal and nonverbal abilities (Wechsler, 1958). The Wechsler-Bellevue (W-B) Intelligence Scale was published during an era when the field was becoming increasingly dissatisfied with the shortcomings of the Binet scales (e.g. over-emphasis of verbal ability and schooling experience, inappropriate distribution of item difficulty within the age levels, and unreliability of mental age calculation) (Frank, 1983). Wechsler expanded the structure of the Binet test by establishing norms for children and adults, creating a standardized deviation score in lieu of the global IQ, and grouping the subtests in such a way as to produce a Verbal/Nonverbal performance dichotomy (Boake, 2002; Flanagan, McGrew, & Ortiz, 2000). Unlike the Stanford-Binet, the W-B distributed item difficulty throughout each subtest, allowing for the entire age range to complete each subtest (Flanagan, McGrew, & Ortiz, 2000). He also introduced an innovative way of scoring each subtest by utilizing a point system. Points were awarded for successful responses on each subtest item. However, the need for a measure of children’s intelligence became evident over the course of the following decade, and in 1949 the Wechsler Intelligence Scale for Children (WISC) was created.

The WISC scale emerged as a revision to Form II of the Wechsler-Bellevue, adjusting for more child-appropriate language and tasks. Individual subtest items were specifically developed, and placed at the beginning of each subtest, to allow for the assessment of children aged 5-15 years (Woolger, 2001). Wechsler continued the tradition of classifying subtests as either verbal or non-verbal (performance) measures of ability. A total of three standardized scores could be obtained: Verbal IQ (VIQ), Performance IQ (PIQ), and a Full Scale IQ (FSIQ). He used a normative sample accounting for varying geographical areas, urban and rural locations, and parental occupations (Wechsler, 1949). The scores produced by this scale have a mean of 100 and a standard deviation of 15.

The WISC-Revised was published in 1974 as an update to the original WISC battery. Revisions included an expansion of the age range (6-16 years), and an enhancement of the visual presentation of several subtests. This latter change was done with the intent to make the subtests' items more visually appealing to the younger age levels (Wechsler, 1972). This version retained the previous test structure, which included the verbal/performance dichotomy and Full Scale IQ as well as the gradual increase of easy to hard items on each subtest.

The third edition of the WISC scales (WISC-III) was published in 1991. Substantial changes were made to the overall WISC structure in this battery including updated normative data, inclusion of floors and ceilings for each subtest, improved subtest appearance, new subtest items, and revised factor dimensions (Kezer & Arik, 2012). These dimensions included Verbal Comprehension (VC), Perceptual Organization (PO), and Freedom from Distractibility (FFD). The revision of individual subtest items was prompted by the need to better account for gender and cultural differences (Wechsler, 1991). This version retained the familiar verbal/performance structure of the WISC-R, as well as the easy-to-difficult item gradient. Three indexes were included: Verbal Comprehension Index (VCI), Perceptual Organization Index (POI), and Freedom from Distractibility Index (FDI). One additional index emerged during this revision as a result of the inclusion of the subtest "Symbol Search." This allowed for a Processing Speed (PSI) factor index to emerge when paired with the Coding subtest.

Researchers have been interested in the measurement of an individual's reaction time to particular stimuli since the inception of intelligence testing. Over time, this concept has evolved into what is now termed *processing speed*. While exact definitions may vary between theoretical perspectives, processing speed is generally defined as the rapidity and accuracy with which an individual can process visual and auditory stimuli. The Wechsler scales only utilize visual stimuli to measure processing speed. Therefore, low processing speed scores on a Wechsler test may indicate the presence of deficits in visual discrimination, attention, decision making, cognitive speed, or motor abilities (Wechsler, 2014). Current research (e.g. Coyle, Pillow, Snyder, & Kochunov, 2011; Kail & Ferrer, 2007) has provided support for the theory that processing speed is a fluid construct that increases throughout childhood and adolescence. It has also been established as a crucial component of overall intelligence.

Standardized psychometric tests allow for not only the assessment of an individual's intelligence, but also a comparison to same-aged peers. In general, each is created with the intention to predict an individual's intellectual performance, while having the ability to compare standardized scores across different age groups. The Wechsler scales mirror elements of the Cattell-Horn-Carroll (CHC) theory of intelligence. The primary elements of this theory are that intelligence is hierarchical and consists of three distinguishable levels. These three levels measure abilities from general to more specific; they are identified as *general intelligence (g), broad abilities,* and *narrow abilities*. The *g* factor originated with the work of Charles Spearman in (1904). It is defined as a measure of an individual's overall cognitive performance. Processing speed would be considered one of the broad abilities, subsumed by "g", and further divided into the following "narrow" abilities: perceptual speed, rate of test taking, and number facility (Alfonso, Flanagan, & Radwan, 2005).

In a sample of 6,969 adolescents aged 13-17 years old, Coyle et al. (2011) found a significant, positive correlation between the processing speed construct and general intelligence. The authors also found a strong mediating effect between speed and age on general intelligence. This study's findings provided evidence to support the theory that increases in processing speed contribute to increases in *g* within this particular age group. Similar results were also found in a study conducted by Kail & Ferrer (2007). The authors used longitudinal models to determine whether or not there were significant increases in processing speed performance within child and adolescent populations. Their results proposed that while processing speed increases with age, it does not do so linearly across childhood and adolescence; the greatest increases were observed in childhood (Kail & Ferrer, 2007).

Evidence for a relationship between age, processing speed, working memory, and fluid intelligence was offered by Fry & Hale (1996). Their findings suggest that processing speed mediates increases in working memory, and that there are specific age differences in working memory (Fry & Hale, 1996). This, in turn, is believed to affect overall fluid intelligence (a broad factor of general intelligence). The authors further elaborate on this relationship in a literature review published on the same topic. They suggest that the quicker an individual processes information, the more likely it can be stored and retrieved from the working memory (Fry & Hale, 2000).

In 2003, the WISC was revised a fourth time (WISC-IV). The FSIQ and all four index scores were retained. The Verbal IQ (VIQ) and Performance IQ (PIQ), however, were removed from its structure. Two of the retained indexes were renamed; the Perceptual Organization Index became the Perceptual Reasoning Index (PRI), and the Freedom from Distractibility Index became the Working Memory Index (WMI). The indexes' name changes were made in order to better represent what each index was measuring, as well as subtests within (Wechsler, 2003). Ten core subtests were administered in order to obtain the four composite scores. Five additional supplemental subtests are included in the WISC-IV battery to allow for further clinical information.

According to Wechsler (2003), there were five prominent revision goals for the WISC-IV. These goals were to update the theoretical foundations, enhance its usefulness in clinical settings, improve content so it is better suited for all developmental levels, update normative data and subtests, and increase overall user friendliness (Wechsler 2003). Evidence-based adjustments were made to the WISC-IV in order to improve the measurement of the Fluid Reasoning, Working Memory, and Processing Speed indexes. Subtests were removed, added, or revised in order to facilitate a more precise measurement of these constructs.

Wechsler Intelligence Scale for Children- Fifth Edition. The latest revision to the Wechsler Intelligence Scale for Children (WISC-V) was published in 2014. This current version includes the ability to administer the entire battery via an Apple iPad. The WISC-V differs considerably from its predecessors, including fewer subtests needed to determine a Full Scale IQ, new ancillary index scores, and new subtests. One of the more notable changes, but perhaps the least addressed, is the changes made to the Coding B subtest (administered to ages 8-16). The nine symbols in this edition are either new or altered versions of the symbols on the previous edition. Despite the numerous changes made to this subtest, and the overall structure of the WISC-V, correlations between the two instruments remain moderate to high. This indicates that this subtest measures the same constructs as the previous version.

The item difficulty for this subtest was also revised. Individual item difficulty was determined during the item analysis phase of test construction. Item difficulty is ranked on a scale from 0.0 to 1.0; 0.0 indicating all participants failed to respond to an item correctly, and 1.0 indicating that all participants responded to an item correctly (Smith, Lane, and Llorente, 2007). Now, the more difficult items are dispersed throughout the test, rather than following the usual easy-difficult item progression as in the previous WISC editions. The examiner presents this subtest in its standard paper format, completing the first three empty Coding boxes as an example of what is expected of the subject. After given an opportunity to practice, the subject is instructed to copy each symbol that corresponds with the given number on the remaining test items. One hundred twenty seconds is allotted for this subtest. The Coding subtest produces a raw score, which is then converted into a standardized score (M= 10; SD= 3).

According to the Technical and Interpretative Manual for the WISC-V (Wechsler, 2014), correlations between the WISC-V and WISC-IV show that the each of the mean primary index scores reflect the continuation of the “Flynn Effect”, with the exception of the Processing Speed Index. The subtests within this index reflect an increase in overall mean scores, which is contradictory to this phenomenon. The Coding subtest has a standard difference of .24. Internal consistency for the Processing Speed Index is .88. The stability coefficient for Coding is good (.81), good for the Processing Speed Index (.83), and excellent for the overall FSIQ (.91).

Beery-Buktenica Developmental Test of Visual-Motor Integration

The Beery- VMI is used to screen for possible visual-motor integration deficits, and is primarily used in educational, research, and clinical settings (McCrimmon, et al., 2012). The visual-motor integration construct measures an individual's ability to integrate both visual perception and motor skills. Mervis, Robinson, and Pani (1999), define visuo-constructive cognition as an individual's ability to visually deconstruct an object into individual parts, then physically reconstruct the object's parts. Examples include assembling a table, sketching a portrait, and building a model of a car. The Beery VMI assessment requires subjects to visually identify and discriminate between different geometric designs, and successfully operate a pen or pencil in order to replicate each design by drawing it underneath the presented stimuli. The Administration, Scoring, and Teaching Manual (Beery & Beery, 2004) contains the standard scoring criteria for each item; one point is awarded for satisfaction of all criteria. Examples of score/no score responses are also provided for each item. A basal is established when the examiner determines that the subject would have successfully completed items one through six. This is determined when the subject successfully completes items seven through nine. If the subject does not successfully complete these items, then the first six should be administered. Items below the basal are counted in the overall raw score. Scoring stops when a child has failed to successfully reproduce three consecutive items. While there are item standards that must be met to be awarded one point, the manual provides a “when in doubt” rule, giving the examiner flexibility when scoring. This rule applies when the examiner is unsure if the reproduced form is meeting all criteria. The examiner is encouraged to award full credit. Several of the items require adequate line and angle orientations, warranting the use of a protractor when scoring. This version of the Beery is untimed.

The current version of the Beery-VMI was published in 2010. Two important revisions were made in this version: an update to the normative data to include children aged 2-18, and the integration of the child and adult response forms. The geometric designs gradually increase in complexity, according to developmental level (i.e. item 30 is associated with a developmental level of 18+ years). Special populations (i.e. disabilities) were included in the standardization sample, but they were not assessed exclusively. Therefore, there is no data from the standardization phase that specifically highlights their performances. Since then, however, the Beery-VMI has been used to evaluate several clinical disorders including Prader-Willi syndrome, Traumatic Brain Injury, and Attention-Deficit/Hyperactivity Disorder (Lo, Collin, & Hokken-Koelega, 2015; Sutton, et al., 2011). Results from these studies indicate that individuals from these populations exhibit greater deficits in visual-motor integration, than the standardization sample.

Summary

According to the WISC-V Technical & Interpretive Manual (Wechsler, 2014), the test-retest correlation between the WISC-V and WISC-IV Coding subtest was high (.70), indicating that both versions measure similar constructs and produce similar scores, despite the structure change. However, based on anecdotal evidence from list serves, email correspondence, and the first author's applied clinical experience, it appears that the WISC-V Coding B subtest may not provide an accurate reflection of the processing speed abilities in the lower-functioning population. Individuals performing at a low level of intellectual functioning have demonstrated difficulty copying the symbols on the WISC-V Coding subtest, thus substantially reducing the number of items they were able to successfully complete before the time limit expired. This low performance is believed to result from the dispersion of difficult items throughout the WISC-V subtest, as well as difficulty reproducing the more complex symbols (e.g. the symbol associated with the number five).

It was determined that it is of value to explore the relationship between visual-motor integration and processing speed using the WISC-V Coding B subtest and the Beery VMI. It is believed that the clinical sample's performance on the Beery VMI will be comparable to their performance on the WISC-V Coding subtest, highlighting their overall ability to reproduce its symbols. The Beery VMI was selected, because it highlights potential deficits in visual-motor integration; a possible explanation for a lower-functioning population's performance on the Coding subtest.

A comparison of the standard scores for each test may help illuminate a possible bias in Coding scores within clinical populations. Individuals with neurologically based disorders often present with poor visual-motor coordination (i.e. Calhoun & Dickerson-Mayes, 2005; Jacobson, et al. 2011), which could affect their overall ability to reproduce the symbols presented on the WISC-V Coding subtest. If the participants' Beery scores are shown to have predictive ability of their WISC-V Coding scores, it would seem that the Coding subtest is weighing more on visuo-constructional ability, rather than the rate at which an individual processes visual stimuli. In other words, it may be that the Coding B subtest is a better measure of visuo-constructional ability (a more complex construct) than of processing speed.

Hypotheses

1. WISC-V Coding B standard scores will correlate more with Beery-VMI standard scores, than with WISC-V Symbol Search scaled scores

2. WISC-V Coding B and Beery-VMI standard scores will not be significantly different within the "average" and "low average" FSIQ groups

3. Larger discrepancies will be observed between WISC-V Coding B and Beery-VMI standard scores in the "very low" and "extremely low" FSIQ groups

4. WISC-V Coding B standard scores will be lower than the Symbol Search standard scores

METHODS

Participants

Data were collected from archival records of individuals who have had previous neuropsychological assessment at a local hospital. Permission was obtained from the lead psychologist at the hospital (see Appendix A). The sample used in this study consisted of 13 individuals aged 8 to 16 years old at the time of testing (mean age = 10.12 years, *SD* = 2.33).

Exclusion Criteria of Research Sample

1. English is not the primary language spoken
2. Behavior during testing disrupts or otherwise invalidates the assessment
3. Inability to complete both assessments
4. Completion of any Wechsler scales within the past six months
5. Completion of the Beery-VMI within the past six months
6. Friend, relative, or any other close affiliation with examiner
7. Uncorrected visual impairment
8. Uncorrected hearing impairment

Materials

Based on prior assessments conducted at a local hospital, age, WISC-V Full Scale IQ score, Processing Speed standard score, WISC-V Coding standard score, WISC-V Symbol Search standard score, and Beery-VMI standard score of each subject were collected. Each WISC-V and Beery-VMI assessment was administered either by a licensed psychologist, or licensed psychometrician. Neither assessor was aware of the details of this study. It was determined by the IRB that the risk involved in this research was no more than minimal (see Appendix B).

The Coding (Form B) subtest of the Wechsler Intelligence Scale for Children, Fifth Edition (Wechsler, 2014) was utilized in this study. Prior to data collection, the examiner introduced the subtest and demonstrated how to complete the first few items. The subject then was asked to complete the remaining sample items in order to ensure that he/she understood the task completely. The examiner was able to provide immediate feedback during that time to correct any mistakes. After successful completion of the sample items, the subject was given further instruction, and asked if he/she was ready to begin. The examiner then immediately began timing upon giving the command, “go”. The subject was prompted to stop after two minutes (120 seconds) had expired.

Coding Form B of the WISC-V consists of a key containing the digits 1-9, and nine accompanying symbols. The examiner completed the first three sample items, prior to having the subject complete the remaining six sample items. There is a total of 117 test items that had the potential to be completed within the two minute (120 seconds) time limit. The WISC-V Coding subtest is normed for ages 8-16 years. The Coding subtest is included in the Wechsler scales as one of two core subtests that contribute to the Processing Speed Index.

The Beery-Buktenica Developmental Test of Visual-Motor Integration, Sixth Edition (Beery & Beery, 2010) was also used in this study. The full form Beery-VMI, Sixth Edition consists of 30 items, each depicting a different geometric design. Prior to data collection, the examiner presented each item, using the instructions provided in the manual. The first six items required the subject to imitate the examiner drawing the items.

These items are typically only administered to subjects under the functional age of five years. The remaining items required the subject to copy the presented drawings in the blank space beneath each item. All figures were drawn with a pen or pencil; the use of an eraser was not permitted There is no time limit, though administration averaged 10-15 minutes for the full form.

Experimental Design and Procedure

The aim of this exploratory study was to determine if a relationship exists between Coding performance and visual-motor integration ability. Specifically, the relationship between the clinical sample's performances on the WISC-V Coding Form B and the Beery-VMI was examined, as well as the relationship between Coding and Symbol Search standard scores. The two subtests are used together to form the Processing Speed Index on the WISC-V. Each raw Coding score was converted into a standard score and accompanying percentile rank. Each raw Symbol Search score was also converted into a standard score and percentile rank. The overall Full Scale IQ and Processing Speed standard scores were also included for each participant. Each raw Beery score was converted into a standard score and accompanying percentile rank. Table 1 displays the means, standard deviations, and ranges of participants' standard scores. Due to the small sample size, the use of descriptive statistics was helpful to establish a more qualitative understanding of the data. Bivariate and partial correlations were used to determine whether there was a significant correlation between the Beery-VMI and WISC-V Coding variables.

It was originally expected that the difference between the Coding and Beery-VMI scores would not be significant within the "average" and "low average" samples of participants. These groups of participants were expected to perform approximately equivalent on both assessments. It was expected, though, that as overall intelligence decreases, greater discrepancies between standard scores would be observed between the two assessments; particularly greatest within the “extremely low” group. Strong visuo-constructive abilities, as evidenced by higher normative scores on the Beery-VMI, would indicate that the participants were able to successfully reproduce the symbols on the Coding B subtest. Weak visuo-constructive abilities would indicate a decreased ability to reproduce the symbols on the Coding subtest. Furthermore, it was expected that the Coding standard scores would be lower than the Symbol Search standard scores, particularly for the lower functioning groups. This was expected, based on the hypothesis that the Coding subtest relies more upon visuo-constructive ability than processing speed.

RESULTS

The purpose of this study was to examine the relationship between processing speed and visuo-motor integration within a clinical sample of children and adolescents. Standard scores were obtained for each test and subtest administered. Three correlational analyses were conducted. The first analysis was conducted in order to determine whether there were any significant correlations between the variables used in this study (Full Scale IQ, Processing Speed Index, Coding Standard scores, Symbol Search standard scores, and Beery-VMI standard scores). The primary investigator was interested in the relationship between the Beery-VMI and WISC-V Coding standard scores. However, significant, positive correlations between the Full Scale IQ, Processing Speed Index, Coding subtest scores, and Symbol Search scores would help to establish a minimal amount of reliability of the analysis used, due to extant previous research establishing relationships between these variables (e.g. Wechsler, 2014).

The second analysis compared the Beery-VMI and Processing Speed Index variables, while controlling for the Coding variable. This analysis reflected our hypothesis that the Coding subtest relies more on an individual's ability to successfully reproduce items (visuo-constructive ability), rather than the rate with which they can produce them (processing speed). The third analysis was to determine the strength of the correlation between the Coding standard scores and the Symbol Search standard scores, which was also established by Weschler's (2014) findings.

The first correlational analysis sought to determine whether the variables in this study correlated positively and significantly with one another. Consistent with past findings (Wechsler, 2014), there was a significant, positive correlation between Full Scale IQ (FSIQ) and the Processing Speed Index [$r = .79$, $p = .001$]. The Coding and Symbol Search subtests were also shown to have significant, positive correlations with FSIQ [$r = .77$, $p = .002$; $r = .62$, $p = .025$]. A moderate, positive relationship was found between the Beery-VMI and the FSIQ [$r = .65$, $p = .02$].

The first analysis also determined whether the Processing Speed Index, Coding Subtest, and Symbol Search subtest, significantly correlated with the Beery-VMI. The results of this analysis indicated that these variables did not correlate significantly. Due to the exploratory nature of this study, it may be important to note that while there were no significant effects, there was a larger effect present between the Beery-VMI and Processing Speed Index [$r = .52$, $p = .07$]. When the Coding variable was controlled for in the second analysis, there was no indication of a significant, partial correlation between the Beery-VMI and Processing Speed Index (I would report those numbers here). Results of the third correlational analysis indicated a strong, positive correlation between the Coding and Symbol Search subtests [$r = .58$, $p = .036$]. Was this correlation higher than the VMI/Coding correlation? You probably should report those numbers as well.

Due to the small sample size a qualitative analysis of the data was conducted. Table 2 lists the participants' standard scores and percentile ranks for Full Scale IQ, Processing Speed Index, WISC-V Coding subtest, WISC-V Symbol Search subtest, and Beery-VMI. They are listed according to ascending Full Scale IQ score.

An overall exploration of the data presented in Table 2 revealed mixed results. In our sample, the Processing Speed Index scores tended to be higher than the accompanying Full Scale IQ scores. Coding subtest scores tended to be higher in individuals who had higher FSIQ scores. The scores within the Symbol Search subtest and Beery-VMI assessment were variable across participants.

A more critical exploration was conducted, examining the data using Wechsler's (2014) Full Scale IQ qualitative categories (*extremely low*, *very low*, *low average* and *average*). Four participants fell within the *extremely low* category, and scored below the first percentile on the Coding subtest and Processing Speed Index. Three of the four participants performed in the 3rd percentile on the Beery-VMI, while the other participant performed in the 1st percentile. Performances on the Symbol Search subtest ranged from <1st to 5th percentiles.

Two participants' Full Scale IQ scores were considered *very low*. One participant could be considered an outlier, due to their high performance (91st percentile) on Symbol Search; their performance on Coding was in the 25th percentile. The difference between these two scores would indicate an abnormal scatter, making the Processing Speed Index a less reliable indicator of processing speed ability. The Beery-VMI score for this particular participant fell within the 1st percentile. The second participant's performance was relatively comparable across all variables. Their performance on the Coding subtest and Beery-VMI assessment was within the 16th and 13th percentiles, respectively.

The *low average* group contained four participants. The Coding performance within this group ranged from the 25th to 37th percentile. The Beery-VMI scores for three of the four participants were higher than their Coding scores. The remaining participant could be considered an outlier, due to their high performance (91st percentile) on Coding; their performance on Symbol Search was in the 5th percentile. The difference between these two scores would also indicate an abnormal scatter. The Beery-VMI score for this particular participant fell within the 12^{th} percentile.

The remaining three participants were considered to be in the *average* range of intellectual functioning. There was more variability within scores in this category. The first participant fell within the 25^{th} percentile for both Coding and the Beery-VMI. The second participant scored much higher on the Coding subtest (37^{th} percentile), when compared to their Beery-VMI performance (4^{th} percentile). The third participant's Coding score fell within the 37^{th} percentile, while their Beery-VMI score was in the 55^{th} percentile. Symbol Search scores were also variable, ranging from the 9^{th} to the 50^{th} percentile.

DISCUSSION

This study is the first to explore the relationship between visuo-motor integration and processing speed, utilizing the WISC-V Coding subtest in clinical populations. Data from two standardized psychometric tests (Wechsler Intelligence Scale for Children-V and Beery-Buktenica Developmental Test of Visual-Motor Integration) were gathered from a sample of 13 individuals who presented for neuropsychological assessment at a local hospital. The participants' ages ranged from 8-16 years. The level of intellectual functioning of this sample ranged from "extremely low" (FSIQ = 69 and below) to "average" (FSIQ = 90 – 109).

Results failed to support the primary hypothesis that successful performance on the WISC-V Coding subtest requires a greater ability to visually deconstruct stimuli into individual parts; and subsequently, physically reconstruct the stimuli's parts, rather than the *rate* at which the individual can process the visual stimuli. Valid and reliable relationships between an individual's Full Scale IQ, Processing Speed Index, Coding and Symbol Search subtests were established during the standardization phase of the fifth edition of the Wechsler Intelligence Scale for Children. While the sample used in the standardization phase was from a normative population, our results appeared to further support Wechsler's (2014) model in which Processing Speed, and the Coding and Symbol Search subtests, significantly contribute to overall FSIQ. The strength and direction of the relationship between the Coding and Symbol Search indicated that they were likely measuring the same overall set of abilities (i.e. processing speed). If this is truly the case, this could be one explanation as to why visuo-motor ability was not significantly related to the Coding subtest, or the overall Processing Speed Index.

The Beery-VMI assessment does not have an inherent time pressure under which the subject must work, while the subtests within the Processing Speed Index do. There is no time limit imposed upon the Beery-VMI; subjects may theoretically take as much time as needed to replicate the items. The pressure to successfully reproduce each stimuli on the Coding subtest may be a factor in some subjects' difficulty in doing so.

Our qualitative exploration of the data reported in Table 2 revealed some patterns consistent with our original hypotheses. All Beery-VMI scores in the *extremely low* group were significantly lower than the rest of the sample's Beery-VMI scores. This observation could provide support for the hypothesis that individuals within this group would not have adequate visuo-constructive abilities that would enable them to reproduce the symbols on the Coding subtest. Overall, the remaining participants performed similarly, if not higher, on the Beery-VMI when compared to their performances on the Coding subtest. This could indicate that these participants had the visuo-constructive abilities to successfully reproduce the Coding symbols. According to Wechsler's (2014) model, performance on the Symbol Search subtest is a stronger indicator of processing speed ability. This was potentially reflected in the data; as expected, the majority of participants scored higher on Symbol Search than Coding.

It must be noted that all results should be interpreted with caution, due to the number of participants used in the study. The small sample size decreases the ability to accurately find meaningful effects or determine if the overall sample distribution was normal. This indicates that though a relationship was found between the Beery-VMI and

Full Scale IQ variables, its reliability should be interpreted with caution. Ultimately, further research with a larger sample size is needed in order to explore this issue with greater accuracy.

Because the results did not reveal a significant relationship between the Beery-VMI and Coding subtest, a different approach may need to be taken in order to examine why a portion of the clinical population is unable to successfully reproduce some of the items on this subtest. Multiple examiners were involved in administration of the assessments included in this study. Therefore, interrater reliability must also be taken into account as a possible limitation. While both assessments have standardized methods of presentation and scoring, the Beery-VMI has more room for interpretation error, which could have ultimately affected the way it was scored for each participant.

The clinical nature of this sample could have also had an impact on the results. The diagnosis and referral question for each participant was not available; therefore, the overall heterogeneity of the sample is unknown. Also, different diagnoses could have had an effect on performance. For example, a child with ADHD may have a more difficulty maintaining concentration throughout the tasks, than a child without.

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TABLES

Table 1. Means, standard deviations, and ranges of participants' standard scores

Variable	*M*	*SD*	*Range*
Full Scale IQ	76.31	17.65	59
Processing Speed Index	79.62	21.18	60
Coding subtest	81.92	20.57	65
Symbol Search subtest	83.85	18.61	65
Beery-VMI	79.92	13.24	36

Note. $N = 13$

Table 2. Standard scores and percentile ranks for Full Scale IQ, Processing Speed Index, WISC-V Coding subtest, WISC-V Symbol Search subtest, and Beery-VMI

		Standard Scores and Percentile Ranks				
Participant	Age	*FSIQ*	*PSI*	*Coding*	*SS*	*Beery-VMI*
1	11.5	42 (<1st)	45 (<1st)	55 (<1st)	55 (<1st)	66 (1st)
2	10.4	55 (<1st)	45 (<1st)	55 (<1st)	55 (<1st)	72 (3rd)
3	9.11	55 (<1st)	56 (<1st)	55 (<1st)	70 (2nd)	71 (3rd)
4	8.2	69 (2nd)	60 (<1st)	55 (<1st)	75 (5th)	71 (3rd)
5	8.2	70 (2nd)	105 (63rd)	90 (25th)	120 (91st)	66 (1st)
6	10.6	74 (4th)	86 (18th)	85 (16th)	90 (25th)	83 (13th)
7	8.6	82 (12th)	98 (45th)	120 (91st)	75 (5th)	82 (12th)
8	12.6	84 (14th)	77 (6th)	80 (9th)	80 (9th)	111 (77th)
9	9.6	84 (14th)	89 (23rd)	85 (16th)	95 (37th)	96 (39th)
10	8.7	86 (18th)	98 (45th)	95 (37th)	100 (50th)	100 (50th)
11	9.4	94 (34th)	83 (13th)	90 (25th)	80 (9th)	90 (25th)
12	16.4	96 (40th)	95 (37th)	95 (37th)	95 (37th)	74 (4th)
13	8.2	101 (53rd)	98 (45th)	95 (37th)	100 (50th)	102 (55th)

Note. FSIQ = Full Scale Intelligence Quotient; PSI = Processing Speed Index; SS = Symbol Search; VMI = Visuo-Motor Integration; “Extremely Low” FSIQ = 69 and below; “Very Low” FSIQ = 70 – 79; “Low Average” FSIQ = 80 – 89; “Average” FSIQ = 90 - 109

APPENDIX A

Permission to Access Data

February 16, 2016

Re: Access to archived data from Mercy Neuropsychology Office

To Whom It May Concern:

I am writing this letter to verify that Kayla LeJeune has permission to use specific archived data from the Mercy Clinic Neuropsychology office for her Masters Thesis research project.

Feel free to contact me with any questions you might have.

Sincerely,

Philip Mothersead, Ph.D.
Mercy Clinic, Neuropsychology
2115 S. Fremont St.
Springfield, MO 65804

APPENDIX B

IRB Approval

IRB Notice

IRB <irb_no_reply@cayuse.com>

Thu 3/3/2016 10:58 AM

To:Deal, William P <PaulDeal@MissouriState.edu>;

Cc:LeJeune, Kayla <Kayla489@live.missouristate.edu>;

To: William Deal
Learning Diagnostic Clinic
Hill 437 901 S National Ave Springfield MO 65897-0027

Approval Date: 3/02/2016
Expiration Date of Approval: 3/01/2017

RE: Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
Submission Type: Initial
Expedited Category: 5.Existing or non-research data
Study #: 16-0323

Study Title: A Psychometric Exploration of Visuo-Constructive Ability and Processing Speed

This submission has been approved by the above IRB for the period indicated. It has been determined that the risk involved in this research is no more than minimal.

Investigator's Responsibilities:

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented (use the procedures found at http://orc.missouristate.edu). Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB following the adverse event procedures at the same website.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), 21 CFR 50 & 56 (FDA), and 40 CFR 26 (EPA), where applicable.

CC:
Kayla LeJeune, Psychology