ADHD, HANDWRITING, AND MATHEMATICAL ABILITY IN MIDDLE SCHOOL BOYS

A Thesis

Presented

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in

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by

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This work is dedicated to Alfie because every teacher needs a student like him.

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ABSTRACT

Although research has been done on handwriting and its relationship to academic achievement, as well as ADHD and mathematic achievement, there has been little research that ties these three concepts together; nevertheless, this paper contends that there is a relationship between all three of these domains. With the dual issues of high stakes testing and inclusion of students with Attention Deficit Hyperactivity Disorder (ADHD) in mainstream classes, their success in mathematics is crucial. The purpose of this study is to explore the relationship of ADHD and poor handwriting as it relates to achievement in mathematics. The results indicated that there is a positive relationship between the handwriting ability of boys and how well they perform academically in mathematics. This finding could lead to potential changes in teaching strategies for students with disabilities who are struggling in math.

CHAPTER 1

INTRODUCTION

How ADHD and Handwriting Affect Middle School Boys' Mathematic Skills

Of the major domains in public education, mathematics seems to be the core subject with the fewest students who claim to enjoy the material. Some find the subject boring, others find the regularity of homework tiresome, yet others never seem to be able to master the subject, claiming to get, "lost in the numbers." Communities take great pride in advertising their high achieving schools while teachers are recognized and rewarded for improvements in their students' scores through high stakes testing. Before the No Child Left Behind act was passed, between 45% and 75% of students in special education took the state standardized assessments (Fuchs & Fuchs, 2005). As recently as 2013, nearly 95% of students in special education programs participated in the California Assessment of Student Performance and Progress (Education, 2018). All of this rests on the shoulders of the students themselves, many of whom may be receiving special education services under the qualifier of Attention Deficit Hyperactivity Disorder (ADHD).

Today, a greater percentage of students identified as qualifying for special education services are included in the general education classroom (37th Report to Congress on the Implementation of the Individuals with Disabilities Act, 2015, 2017), and, it is, therefore, becoming even more imperative that these students succeed. It appears likely that the issue is not that the students are confounded by the numbers, but that they are possibly being sabotaged by their own poor handwriting. Anecdotal observations reveal that many middle school boys diagnosed with ADHD have very poor handwriting skills (Langmaid, Papadapoulis, Johnson, Phillips, & Rinehart, 2014). Students with ADHD have such poor handwriting that it can influence skills such as reading and writing numbers correctly and correct alignment. All of these can lower the ability of the student to demonstrate academic abilities and can lead to a lack of understanding of what was originally written. The lack of understanding and confusion related to handwriting can have detrimental outcomes (Tosto, Momi, Asherson, & Malki, 2015).

With the addition of ADHD as a qualifying condition for a child to receive special education services, the percentage of students with ADHD has become the largest category of children in special education (Attention Deficit/Hyperactivity Disorder: Data and Statistics, 2017); thus, their proficiency will have a great impact on not only their achievement, but also on the success of their neighborhood school, their community, and society.

Further, these students may become frustrated, which leads to distracting behaviors, which also impacts the abilities of those other students in the general education classroom, as frustration levels commonly lead to behavior issues (Ghanizadeh & Haghighi, 2010). As research demonstrates, fully including these students in the general education classroom is beneficial to their academic success in the general education curriculum (Kirby, 2017).

Research Question

While society struggles to produce more educated individuals, students with ADHD, are struggling more and more with math curriculum. The question is: Does the occurrence of poor handwriting as displayed in students with ADHD correlate with their poor mathematics performance?

Purpose of Study

Current research has focused on the relationship between ADHD and poor handwriting skills (Shen, Lee, & Chen, 2012), but little has been found addressing the direct impact that this lack of ability has on the academic outcomes of students in math classes. The actual ability of creating legible written work has been studied (Langmaid, Papadapoulis, Johnson, Phillips, & Rinehart, 2014), and was the basis for determining what is legible and what is not within this study.

The purpose of this study is to provide some insight into the relationship between the handwriting ability of boys diagnosed with ADHD and their academic mathematical achievement. The results of this study has implications for classrooms, as teachers may be able to apply simple strategies to compensate for poor handwriting abilities and improve their students' success rates with math curriculum.

Theory

Students utilize many of their sensory modalities while learning in the classroom. They listen, see, and write. According to Howard Gardner, individuals have multiple intelligences: linguistic, musical, spatial, interpersonal, intrapersonal, mathematical/logical, and kinesthetic (Gardner, 1993).These intelligences are utilized to different degrees in the classroom, depending on the task provided. Gardner also concluded that students may be exceptional in one intelligence domain, without that exceptionalism carrying over to any of the other domains. This study looks at two of these intelligences and how they manifest themselves in a math classroom. Specifically, the mathematical/logical intelligence, or the ability to see patterns and the ability to follow long strings of reasoning and the kinesthetic intelligence or the ability to control one's own movements and objects with skill were studied in relationship to each other.

Definition of Terms

<u>Attention Deficit Hyperactivity Disorder (ADHD):</u> Attention deficit hyperactivity disorder is a neurodevelopmental disorder that is typically characterized as an inability to focus, impulsive behavior, and increased hyperactivity (Barkley & Biederman, 1998). While there are now three commonly recognized subsets of ADHD (Lange, Reichl, Lange, Tucha, & Tucha, 2010), this study did not differentiate the participants by type.

<u>Handwriting:</u> For the purpose of this study, handwriting is defined as the written mathematical work each student produced. As such, the writing was primarily numerals and mathematical operator symbols.

<u>Math Scores:</u> The students were graded on a scale of 1 to 4, based on the CMAST (Center for Math and Science Teaching) scoring method. CMAST was developed at Loyola Marymount University in Los Angeles, California.

CHAPTER 2

LITERATURE REVIEW

The purpose of this study was to determine if there was a relationship between the handwriting abilities of middle school boys diagnosed with Attention Deficit Hyperactivity Disorder (ADHD) and how those handwriting abilities translated to academic success in a math classroom. Mathematics is considered to be one of the two primary domains where students' success is deemed critical for future achievement as well as teacher evaluation (the other domain being English Language Arts), as mandated by high stakes testing (No Child Left Behind, 2018)

In tandem with the push for higher test scores, children with disabilities are returning to the general education classroom under the umbrella of inclusion, including students diagnosed with ADHD. As this subpopulation of students included in the special education population is the largest (37th Report to Congress on the Implementation of the Individuals with Disabilities Act, 2015, 2017), it is a population that deserves significant attention for academic success. These students bring to the classroom a particular challenge for teachers not only in terms of their attention, but through a comorbidity of ADHD and poor handwriting skills (Stray et al., 2009). As anecdotal observations have revealed, handwriting skills may be correlated to academic success.

Through a review of the current research in these areas, the following themes were revealed: (a) handwriting as it is related to children diagnosed with ADHD; (b) the relationship of handwriting and academic success, specifically in mathematics; and (c) the relationship of students diagnosed with ADHD and their success in mathematics.

Handwriting and ADHD

Current research led to the conclusion that handwriting ability and ADHD are related (Borella, Chicherio, Re, Sensini, & Cornoldi, 2011; Brossard-Racine, Majnemer, Shevell, & Snider, 2011; Shen, Lee, & Chen, 2012). Because much of the research addressed motor abilities with little direct studies of handwriting specifically, this study examined fine motor abilities. Stray et al. (2009) spearheaded a study which examined the degree of coexistence of young boys diagnosed with ADHD and compared to a control group to measure fine motor abilities. This study covered boys ages 8-12 years of age and used the Motor Function Neurological Assessment to identify deficits in motor function. While this study looked at all motor functions, it found that boys between 11-13 years old experienced impaired coordination in thumb movements, which can be extrapolated to affect handwriting. Stray et al. (2009) concluded further research is needed to confirm these findings. Additionally, the participants in the study affected by thumb movements was a parallel to this author's participants.

This line of inquiry was expanded upon with a study involving 8 to 9-year-old children (predominantly male) diagnosed with ADHD. These participants' handwriting was then compared to typically developed children (Shen, Lee, & Chen, 2012). The authors of this study looked at handwriting performance, motor and perceptual abilities, and the relationships of these abilities on handwriting legibility and speed. Using the Tseng Handwriting Problem Checklist and the Basic Reading and Writing Test, Shen et al. (2012) found that the students diagnosed with ADHD performed significantly lower than those of the control group in both visual-motor integration, which translated to handwriting legibility and motor skill ability which then correlated to writing speed. Here the study looked at handwriting directly as it is evidenced in children with ADHD although the participants were not as closely related to those in this research.

Additional research has also pointed to a correlation of handwriting abilities of children diagnosed with ADHD (Borella, Chicherio, Re, Sensini, & Cornoldi, 2011). A study conducted by Langmaid et al. (2014) looked at a group of boys ages 7-12 diagnosed with ADHD against a control group of same age boys to determine if a correlation of poor handwriting skills existed in children with ADHD (Langmaid, Papadopoulos, Johnson, Phillips, & Rinehart, 2014).

Using the MovAlyzeRx software, the students' handwriting was analyzed for consistency and efficiency. The results were that students diagnosed with ADHD had higher scores in both consistency (less consistent letter formation and size) and ballisticity/efficiency (faster but more inaccurate letter formation.) The research also indicated that the degree to which the students' handwriting scores reflected impaired handwriting ability correlated directly to the degree of the severity of the ADHD diagnosis. Langmaid et al. (2014) concluded that additional research was merited to further understand the link between ADHD and handwriting differences. Additionally, this study matched most closely this author's research participants.

Handwriting and Mathematical Achievement

Of all of the core domains in education, mathematics is the subject which is least affected by classroom computer technology and thus, is most affected by a student's ability to write clearly and legibly. In 2010, Ziegler and Stoeger concluded that fine motor skills (handwriting in school-aged students) was linked to the ability to identify high achieving children, and that underachievers were more likely to have lower fine motor skills. This study consisted of 788 fourth grade students (373 boys and 415 girls from predominately upper-middle class families) and how they performed on cognitive tests with high fine motor ability demands versus low fine motor ability demands. The students' handwriting abilities were tested by replicating the letters of the Greek alphabet as accurately and as quickly as possible in three minutes. The students were then tested cognitively using the Culture Fair Intelligence Test (low levels of fine motor skills) and the Testing System for Scholastic and Educational Counseling Grades 4-6, PSB (high levels of fine motor skills.) Both tests correlated to mathematical ability and success. The study tested six hypotheses with hypothesis #2 being the predictive ability of mathematical achievement, separate from intelligence, absent fine motor skills (handwriting) abilities. The research confirmed their hypothesis that the lack of fine motor skills and poorer math performance were correlated. The population studied in this research did not correlate well to the proposed research population in two ways: the population in Ziegler's study is more than 50% girls and the demographics was predominantly upper middle class, whereas the research population for the author's study was predominantly lower middle to upper lower class.

Later research provided additional evidence that mathematical abilities and handwriting were linked (Pieters, Dosoete, Herbert, Vanderswalmen, & Van Waelvelde, 2012) Their research looked at the performance of 39 purposefully selected students (age 7 to 9 years old) with mathematical learning disabilities (MLD) compared to a control group of 106 typically developed children obtained through a convenience sample. The Pieters et al. (2012) study looked into four relationships, of which one questioned: are visual perception, motor skills and integration related to scores in mathematics? Students were assessed for motor skills and integration using the Beery-Buktenica Developmental Test of Visual-Motor Integration (VMI). The students were assessed for mathematical achievement using two tests: the Krotrijk Arithmetic Test Revision and the Arithmetic Number Fact Test to test in the domains of procedural calculation and number fact retrieval. Pieters et al. (2012) found that there is a correlation in the VMI scores and the mathematic scores in both domains tested. The researchers did acknowledge that the findings may not correlate to older children, as (visual) perceptual skills have a greater influence at earlier ages. This author's study participants were on average 3 to 4 years older; thus, expanding on the authors' work.

The evidence of this research was apparent to both teachers and students as shown in the study conducted by Oche in 2014. He randomly sampled 150 secondary school students and 200 secondary school teachers using simple random sampling. The participants were given a 5-point questionnaire with responses ranging from strongly agree to strongly disagree and included the option of a neutral response. Of the five research questions asked of the participants, it is research question 1: "How does poor handwriting affect student's achievement in school mathematics?" (Oche, 2014, p. 6) that was of interest. For all seven questions asked of both students and teachers, the results demonstrated that the perception of both sets of participants recognize the negative impact of poor handwriting on mathematical achievement. As Oche recommended, handwriting abilities should be emphasized more in school, but before that can be accomplished, additional research verifying the connections of handwriting ability and academic achievement need to be made.

Students Diagnosed with ADHD and Academic Success in Mathematics

Mathematics is a domain that requires focused attention during both instruction as well as practice in order to be successful. This is especially true as a student progresses from elementary school to middle school, and the concepts taught move from concrete using manipulatives to the abstract realms. This becomes critically problematic for students diagnosed with ADHD. A study published in 2010 revealed a genetic link to many cases of ADHD and reading and mathematical performance (Hart et al., 2010). Two hundred seventy-one pairs of twins, approximately 10 years of age were assessed for the degree of ADHD symptoms using the Strength and Weakness of ADHD-Symptoms and Normal Behavior (SWAN) to identify two specific facets of ADHD: attention to task and hyperactivity. The Woodcock-Johnson III achievement test was the instrument used to assess the children's mathematical performance. Using covariance modeling, Hart et al. concluded that there is a genetic correlation between ADHD and achievement in mathematics. They discussed that the behavioral components of ADHD may also be an influencing factor in low achievement scores in mathematics as well as a genetic factor.

Specifically, for a child to receive maximum benefit from direct instruction, that child needed to master the ability to sit quietly and remain focused, both behaviors that are identified as difficult for a child with ADHD. Hart recommended further research into the relationship of mathematical achievement of students with ADHD and their environmental factors.

A similar study in Great Britain looked at a larger sample size (N = 6121) to verify the findings of Hart's previous research and to expand on the effects of environmental factors. (Greven, Kovas, Willcutt, Petrill, & Plomin, 2014). The participants were 1,895 male twin pairs, 2,291 female twin pairs, and 1,935 opposite sex twin pairs, ages 8-10 years old. The children were rated for ADHD symptoms using the DSM-IV scales from the Connors' Parent Rating Scale-Revised. The traits of hyperactivity-impulsivity and inattentiveness were isolated. Measures of mathematical abilities were conducted through the administration of three web-based assessments completed by each child. These tests were based on the National Foundation for Educational Research 5-14 Mathematical Series, which is closely aligned with the national standards for curriculum in Great Britain. The results of this study revealed not only a correlation between mathematical abilities and ADHD but identified a statistically significant stronger correlation with inattentiveness as opposed to hyperactivity-impulsivity. Further, the research also showed that the greater the score in inattentiveness, the lower the score in mathematical abilities. Even after considering environmental factors, correlation was still evident, more modestly so, but still incredibly significant. Interestingly, hyperactivity-impulsivity even when controlling for inattentiveness, was not a correlating factor in math abilities. Greven et al. (2014) concluded that mathematical abilities were inversely related to the levels of inattentiveness in children with ADHD. Again, the discussion regarding whether the ability measures were due to a deficit in mathematical abilities, or a lack of attention while receiving direct instruction which results in unmastered mathematical content needs to be addressed. Greven et al. (2014) concluded that further study was warranted into non-genetic environmental relationships between children with ADHD and mathematical achievement.

This question had also been looked at in order to tease apart the neurocognitive effects of ADHD from the inattentive aspects of the disorder (Antonini et al., 2016). The study included 147 children ages 7 to 11 years old, of which 102 were diagnosed with ADHD. The children diagnosed with ADHD were further classified as inattentive (ADHD-I) or inattentive with hyperactivity/impulsivity (ADHD-C) based on parent responses to the Diagnostic Interview Schedule for Children-Parent Version and the Vanderbilt Teacher Rating Scale. Math achievement for all students was determined by administering the WIAT-II NO subtest (for mathematics). Productivity and accuracy were also calculated by assessing their production on a worksheet based on their skill level for 20 minutes. Productivity was measured by the number of problems completed and accuracy was measured by the percentage of problems correct. The ADHD-I and ADHD-C groups had similar on task measurements. Both groups scored significantly lower on the WIAT-II NO as well as on productivity. Interestingly, all three groups (ADHD-I, ADHD-C, and control group) scored similarly on accuracy. While this study did have some limitations such as such as small sampling size, and method of sampling (convenience), and the worksheets were administered in a laboratory and not in a classroom where inattentiveness may have additional impact, it also verified a link between ADHD and math underachievement. Antonini et al. (2016) summarized the findings by stating that their findings appear to be the first in regard to identifying students based on ADHD accommodating requirements and math achievement, and hence, needs expansion and replication. In all three of these studies, the participants were younger (by 2 to 4 years) as well of both genders, but these studies did provide a basis for this author's study.

Summary

There was a growing consensus in current research that students with ADHD have demonstrated lowered mathematic achievement, as Hart et al. (2010) concluded. Their study was expanded and verified when Greven et al. (2014) replicated this study using a larger population. In an effort to directly tie lack of math abilities to ADHD, Antonini et al. (2016) further identified their participants by hyperactivity and inattentiveness and determined that inattentiveness could not be ruled out as a factor for poor math achievement. Further, the research supported that students with ADHD also demonstrated poorer fine motor skills as found by Stray et al. (2009). Shen et al. (2012) reached a more pointed conclusion relating ADHD is correlated to lack of handwriting abilities, when Langmaid et al. (2014) refined this finding to consistency and fluidity, which in turn, can result in lower overall academic success.

CHAPTER 3

METHODOLOGY

As the number of students from special education are included in the general education classroom increases, their academic performance is assessed and scrutinized with more detail. Further, the percentage of these included students diagnosed with ADHD is continually increasing (Attention Deficit/Hyperactivity Disorder: Data and Statistics, 2017). This quantitative study looked at students' handwriting abilities and determined if there were patterns of handwriting abilities and the correlating math abilities of these boys.

Research Design

This study employed a quantitative design to examine the relationship of boys with ADHD and their handwriting abilities as it relates to their math skills and comprehension. Specifically, it was an explanatory correlational design because the research sought to clarify the association between two variables, handwriting and math achievement, and what type of relationship existed.

A document analysis was used to look at the participants' handwriting for analysis of degree of legibility and consistency and looked for any patterns in handwriting abilities. Handwriting scores were created multiple times for each participant, and over multiple days of work sample provided. These handwriting legibility scores were found to be generally consistent with each participant, thus ensuring the handwriting legibility scores were valid. The assessment scores were based on a department rubric which all middle school teachers at the school site co-created to use for grading, providing interrater reliability. Interrater reliability (or concordance) is the measure of how much in agreement a particular score is reached among multiple reviewers of a piece of work (Hayes & Krippendorff, 2007). These teachers work together to score student work to ensure that each student's assessment would result in the same score regardless of which teacher scored it. For the purpose of this study, assignments were graded by each of the students' classroom teachers with random assessments selected for regrading by one of the other teachers to test for consistency in grading. The math scores were provided by the math teachers themselves, which as content experts, created score validity.

Data Collection

Both data variables were collected from the work samples (assessment samples) provided by each of the participants' teachers. The independent variable, handwriting clarity, was obtained from multiple work samples from each student. The dependent variable, math scores, was also located on each student's work sample, one score for each answer worked out.

Handwriting Samples

For confidentiality purposes, each participant was identified by number and this number was given to all teachers aiding in this study for data gathering. Several samples of each participants' handwriting were obtained from their teachers with the students' names were blacked out and replaced with a participant number instead. The handwriting samples provided were found on each the participants' mathematics assessments. These work samples were scored based on three factors to create a legibility score: spacing, height and shape clarity (see Appendix A). The spacing was be analyzed with lacunarity, which is a geometric measure of variance in spacing (Crespo, 2017). Height was measured using calipers that measure to 0.0001 inch and looked at how consistent the height and of the numerals were written. The shape clarity was measuring accuracy of the written numerals compared with generally accepted mathematical practices.

Measures of Math Achievement

The second set of data was obtained from the participants' assessment samples. The math scores used were from assessments samples where freeform handwriting is necessary to derive an answer, and not just calculation skills using a calculator. Each assessment question is given its own individual score, thus providing more opportunities for comparing a math score to handwriting clarity data points.

Study Location

The students attended a middle school in a suburb of Los Angeles, California. They were aged 12 to 15 years old, in grades 6, 7, and 8. The school was a Title I school in a lower middle-class neighborhood. The school's population was 42% Hispanic, 18% White, 17% Asian, and 8% African American. Fifty-eight percent of the student body qualifies for a free or reduced-price lunch; approximately 13% of the students are English Language learners (Office, n.d.)

Participant Selection

The research sample was purposeful and by convenience. The participants were identified as having been diagnosed with ADHD (either by qualifying for special education services or by qualifying for a 504 plan). The participants were selected from the middle school where the researcher currently teaches. Potential participants were originally identified by a search of the special education and 504 accommodation files identifying students diagnosed with ADHD. Parents were contacted via a letter describing the research and their child's possible participation in it. (see Appendix B). Once any questions were answered and parental permission was received, the student was contacted and given an abbreviated overview of the research and his permission was obtained (see Appendix C).

The participants were between the ages of 11 and 14, many for whom English was not their primary or original language spoken. A description of the participant breakdown can be found in Table 1: Demographics.

Table 1

Demographics

Grade

Sixth Grade	36%
Seventh Grade	27%
Eighth Grade	36%

Age

11 years	18%
12 years	27%
13 years	36%
14 years	18%

Race

African American	18%
Hispanic/Latino	54%
White	27%

Table Continued

Pacific Islander	9%

English Language Learners

Native English Speakers	45%
Emerging Fluent or Fluent	36%
High Intermediate	9%
Low Intermediate	9%

Economically Disadvantaged*

Free lunch	27%
Reduced priced lunch	54%
Full priced lunch	18%

Note. As designated by qualifying for a free or reduced-price lunch

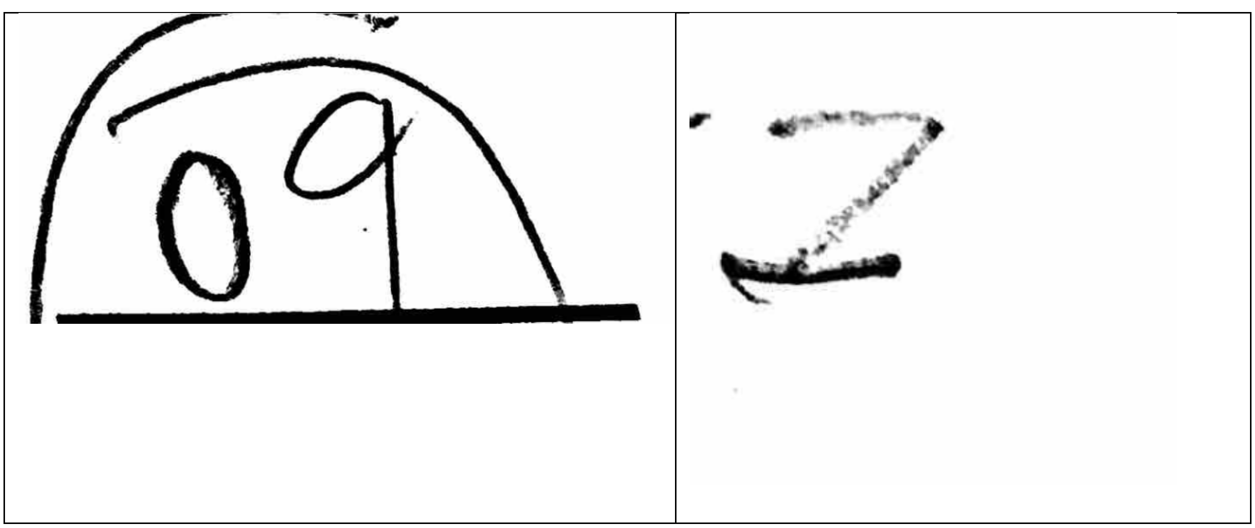
Data collection

The data was obtained from student work samples provided to the researcher by the participants' math teachers. Each work sample was then analyzed and coded for handwriting clarity using three measures: regularity of spacing between written characters, regularity in sizing of written characters, and generally accepted character shape.

For spacing of characters, the distance written between each numerical character was measured to determine if there was regularity of spacing of characters. A high score of 3 was given if the spacing between numerals was even and consistent more than seventy percent of the sample. A score of 2 was given if the spacing was consistent between thirty percent and seventy percent of the sample. A score of 1 was given if the spacing was inconsistent.

The regularity in character height was also scored based on the percent of consistency within the work sample. A score of 3 was given for highly consistent (more than seventy percent), a score of 2 for moderately consistent (even height between thirty percent and seventy percent). And a score of 1 for consistent height in less than thirty percent of the work sample.

The shaping of the characters was scored based on how the numerals were written in comparison to generally accepted mathematical standards. All of the participants received their elementary education in the United States; thus, all received handwriting education based on American standards for numerals and not the European standards. While this criterion is the least quantifiable of the scoring categories, the samples showed the most consistency in how the students shaped their numerals in generally accepted practices. While the majority of the work samples showed generally accepted written numerals, there were a few consistent deviations (see Figure 1)



Is this a 4 or a 9?

Is this a 1, a 2, or a 7?

Figure 1. Sample student work of handwritten numerals.

Data Analysis

For the purposes of this study, both descriptive statistics as well as inferential statistics were used. The scores were first analyzed for mean, mode, median, and range of both the handwriting scores and the students' math scores. The data was then analyzed using the Pearson Correlation Coefficient Calculator (online software program for Social Sciences) to calculate the correlation between each participant's handwriting scores and his math scores. Correlational analysis is a technique in statistics that measures whether two or more variables are related, what type of a relationship it is, and how strong that relation, if it exists is (Cresswell, 2008). For the purpose of this study, a Pearson's correlation coefficient was obtained which described the statistical relationships being questioned in order to determine if there was a relationship between the student's handwriting and their math scores. To test the significance of the statistical analysis, a p-value was calculated. The p-value score provides insight into the probability that the statistical finding is significant. In this explanatory research design, multiple samples were obtained from each participant, with the variable handwriting was associated with that participants math score for each sample problem scored.

CHAPTER 4

RESULTS

The data was analyzed using descriptive statistics in order to obtain a “picture” of the data. The mean, mode, median and standard deviation of both the handwriting clarity scores and the math scores were calculated using traditional statistical analysis (Larson & Farber, 2003), and provided different measures of central tendency. Further, the standard deviation provided a measure of how closely the data were “clumped” together. A correlation analysis was then performed on the pair sets of data points to look for the type and strength of the relationship between handwriting clarity and academic math grade.

Data Analysis

Once all coding was complete, the handwriting was analyzed for general trends or tendencies. First, the written characters were analyzed for consistency in height, with a minimum score of 1 (most inconstant heights in characters) to a maximum of 3 (completely consistent heights of characters.) The mean score for consistency in heights was 2.61 indicating that the uniformity in character heights written by most students was high. The handwritten work was then analyzed for uniformity of spacing, with a score of 1 meaning least uniform to 3 signifying most consistent. The mean of the uniformity scores was 2.1 signifying a lower level of overall consistency in the spacing between the math characters. The third and final portion of the handwriting analysis was to look at the overall shaping of numerals compared to generally accepted practices. The mean of the shaping scores was 2.01. With a high score of 3 signifying the best written shapes and a 1 signifying the worst written shapes, this average score is the lowest of the three.

The mean of the overall handwriting clarity scores was 6.31 ($\mu = 67$) out of a possible score of 9 with a potential low score of 3 (range = 6). This indicated that the handwriting samples were moderately consistent in clarity. The median clarity score was 6 indicating that scores trended towards the middle of the clarity scale. The mode was 7, the most common level of clarity was on the clearer end of the scale. The standard deviation was calculated to be 1.54. This signified that the scores were not tightly clustered about the mean, and were more even spread out.

The math scores were also analyzed using descriptive statistics. The mean of the math scores was 2.57 out of possible 4 with a potential low score of 1 (range = 3). This indicated the students' average achievement was a low "C" average grade earned. The median was 2 with a mode of 4. The standard deviation was calculated to be 1.24. This score is closer to one and signifies that the math scores were more closely clustered than the writing scores.

The final analysis looked at the relationship between these two sets of data. Because there appeared to be a linear relationship of the two sets of data, a correlation needed to be calculated. Further, since both sets of data were continuous, a Pearson's correlation coefficient was obtained, as it is a measure of strength between the two data sets (Lane, n.d.).

The data values of handwriting clarity and academic score were analyzed using statistical regression with a correlation coefficient of: $r = 0.5953$.

This correlation coefficient indicated a moderate positive correlation as indicated in the graph (see Figure 2). As the values of the *x*-variable (handwriting scores) increased, the value of the *y*-variable also increased, thus creating a graph that slopes in a positive direction indication a positive correlation.

For the purpose of this study, a positive correlation indicates that a direct connection does exist between a student's ability to write clearly and the student's achievement in math.

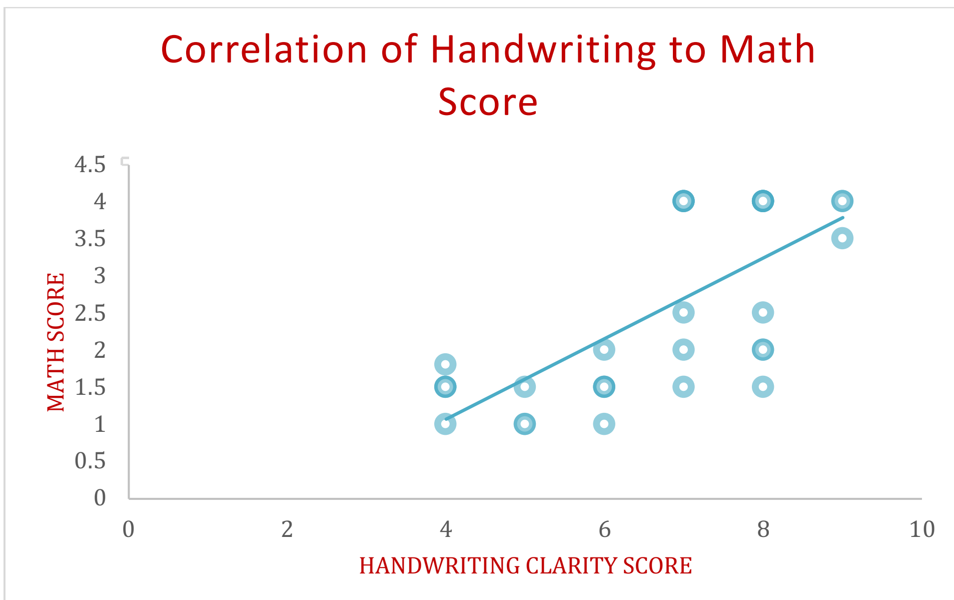


Figure 2. A correlation of handwriting to math score graph.

In addition to the Pearson's r-value, a p-test for statistical significance was calculated. In using a p-value test, the p-value is calculated to determine if the hypothesis of no correlation exists between handwriting clarity and math ability. In order to have a valid sample size for testing, each individual math problem was scored separately, thus providing between 4 and 6 data points for each student work sample. The resulting p-value ($p=0.00001$) indicates that the correlation is statistically significant (since $p < 0.05$) and the hypothesis that no correlation between handwriting and math ability exists is false.

Validity

While the population sample size was small, multiple work samples with multiple assessments questions were provided for each participant. These multiple samples provided approximately six to eight different pieces of student work product to evaluate and analyze.

Sample Data Procurement, Sorting, and Storage

The works samples, from which the data were collected was first sorted by assessment. As each assessment was different, comparing handwriting clarity on identical assessments lead to more consistent scoring. Each assessment provided two or three different academic scores, and thus two or three different handwriting samples to analyze. Each work sample then had its own scoring rubric for clarity, and the overall clarity score was assigned.

Although all identifying information regarding the participant information was deleted form the student work samples, the work samples were kept under lock in an office not on the campus where the students attend.

CHAPTER 5

DISCUSSION AND CONCLUSION

Schools and their students are under pressure to perform well in state mandated high stakes testing. As many of these students are special education populations included in the general education classroom, these students are also under those same pressures. With the growing number of students with ADHD as a percentage of the overall population, this subset of students is having a large impact on the overall scores of each school and for each teacher. What can be done to help these students succeed? Is their handwriting clarity hindering their success? By looking at this relationship, teachers may be able to provide supports for their students to improve their performance in math.

Summary of Findings

The analysis of the data reveals a moderately strong positive correlation between the clarity of the students' handwriting and their math achievement as measured by their attained math scores on assessment questions. In this particular study, the topics covered by the math teachers were very procedural; with multi-step problems that require attention to detail. In this case, the results show that if a student's handwriting is poor, there is an expectation that poor performance in math may follow. Taking this finding further, the degree to which a student's handwriting is poor may be a predictor to the degree to which that student will be struggling in mathematics. This leads to the inverse finding that if a student has clear handwriting for mathematics work, there is a strong probability that the student will be successful in mathematics. However, while the research in this thesis indicates that there is a direct correlation between poor handwriting and a poor performance in mathematics, the application of this research should be limited to a case by case evaluation.

Limitations

Threats to Validity

The population sample size was small. The sample was a convenience sample, and as such, was limited to the number of potential participants that were enrolled in a single small middle school campus. The total potential number of participants was only 15, and after contacting all parents/guardians for permission, only 11 subjects gave permission. When $n < 30$, sample data does not necessarily translate to the population at large (Larson & Farber, 2003).

Another possible threat to the validity of the results is the interpretive nature of one of the sub-scores used to create an overall handwriting clarity score. While the heights of the individual numerals as well as the spacing between them could be measured, the “acceptable shape” score has some subjectivity that is intrinsic to the researcher.

Scoring Grades On 1-100% More Refined Data Points

The data collected at this site represented math scores using the CMAST method of grading mathematical mastery. This scoring rubric, using only 1-4 caused large “spacing gaps” between potential scores. In typical classrooms, scores are represented as a percentage, with grading scale in increments of one percentage point. With the CMAST grading scale, if a 4 is the equivalent and a 1 is the equivalent of 25%, then each point increment is the equivalent of a 25% spread. This leaves the question of whether the strength of the correlation would be greater if the grading scale was more refined. Further, in CMAST scoring, a question with no relevant answer or work shown is still scored with a "1."

Consider Homework

The data gathered was from summative assessments only. No homework was studied. No assumption can be made that this correlation can be inferred for student homework. The study originally intended to look at homework as part of the work samples provided by the participants; however, many of the participants did not complete or turn in any homework samples for analysis. Taking this into consideration, homework was not included in the study.

Types of ADHD

This study analyzed the work of students diagnosed with attention deficit disorder. There was no categorization of the type of ADHD each student had. The three types of ADHD are: inattention, hyperactivity-impulsivity, and mixed form (Dupuy, Barry, Clarke, Mccarthy, & Selikowitz, 2013). It is unknown what subtype each participant in the study had. Further research would look into whether there is a relationship with any specific type of ADHD and handwriting and math achievement.

Future Research

Girls

In future research, girls need to be included in the study. As the population available to the researcher was limited, the relationships in girls was not studied. Larger sample sizes should include girls. This is especially crucial societally, as girls are often overlooked in the STEM classes. With proper remediation, these often-overlooked girls can also be successful (Stoeger, Duan, Schirner, Greindl, & Ziegler, 2013)

Small Sample Size

The sample size for this study was small and a larger sample size needs to be studied for reliability.

Include High School and Possibly Elementary School Students

This study looked only at a narrow range of ages. Future research into this topic should include high school students. Also, elementary students should also be studied for any correlations; however, any findings in that demographic could be suspect. As this population is still in the learning stage of handwriting, the findings may not be valid.

Conclusion

This research resulted in three conclusions of student handwriting and the related math scores those students achieved. The first finding is that the students' handwriting is related to their achievement in math. The second conclusion is that the relationship between handwriting clarity and math achievement is a statistically positive one. The final takeaway is that this moderately strong relationship between handwriting and math success is also statistically significant.

The primary conclusion of this study was to determine if a relationship did indeed exist between handwriting ability (as measured by clarity) and the students' achievement in math (as measured by their attained math scores). After the data was analyzed, a relationship was found to exist.

Second, after the correlation was analyzed further, the relationship between handwriting and math achievement was determined to be a positive relationship. This translated to the finding that the "better" the student wrote, the higher the math score that student earned.

The final conclusion of the analysis was that the relationship between a student's handwriting and his math scores was moderately strong. This implied that the impact on a student's math score will be easily affected by a change in his handwriting.

This project was designed to look at three aspects already researched in special education: ADHD, handwriting, and mathematical achievement with the purpose of determining whether a relationship exists between all three factors. Current literature had paired two of these factors together in different combinations, leaving a gap of knowledge tying all three factors together. After identifying the study of 6th, 7th, and 8th grade boys diagnosed with ADHD, samples of their handwritten math work were analyzed and classified by legibility levels. These levels were then compared with the participants' level of academic achievement (score or grade) in their math class.

The potential implications for this study may find that if handwriting is related to academic success in math and that remedial handwriting instruction could become a simple remedy for poor performance in mathematics.

Implications

Teaching handwriting. Since a correlation was found between handwriting and math ability as measured by achievement scores, it leads to a conclusion that it would benefit the poorer performers in math to learn how to write more clearly at least in the course of written mathematical expressions and equations using numbers and math symbols.

Graphic organizers. Students who are challenged in writing clearly, especially with spacing issues, should be given type specific graphic organizers that allow the students to fill in the math equations or expressions in such a way as to "contain" each part of the math problem.

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REFERENCES

REFERENCES

37th Report to Congress on the Implementation of the Individuals with Disabilities Act, 2015. (2017, 2 26). Retrieved from Department of Education: https://www2.ed.gov/about/reports/annual/osep/2015/parts-b-c/37th-arc-for-idea.pdf

Antonini, T. N., Kingery, K. M., Narad, M. E., Langberg, J. M., Tamm, L., & Epstein, J. n. (2016). Neurocognitive and behavioral predictors of math performance in children with and without ADHD. *Journal of Attention Disorders*, 108-118.

Attention Deficit/Hyperactivity Disorder: Data and Statistics. (2017, February 19). Retrieved from CDC Center for Disease Control and Prevention: https://www.cdc.gov/ncbddd/adhd/data.html

Barkley, R. A., & Biederman, J. (1998). Definition of ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry, 37*(4), 344-345.

Borella, E., Chicherio, C., Re, A. M., Sensini, V., & Cornoldi, C. (2011). Increased intraindividual variability is a marker of ADHD but also of dyslexia: A study on handwriting. *Brain and Cognition*, 33-39.

Brossard-Racine, M., Majnemer, A., Shevell, M., & Snider, L. (2011). Handwriting capacity in children newly diagnosed with Attention Deficit Hyperactivity Disorder. *Research In Developmental Disabilities, 32*(6), 2927-2934.

Crespo, Y. S.-P.-M. (2017). Spatial analysis of handwritten texts as a marker of cognitive control. *Journal of Motor Behavior*, 1-10.

Cresswell, J. W. (2008). *Eduactional Research: Planning, Conducting and Evaluating*

Quantitative and Qualitative research. Saddle River: Pearson Education.

Dupuy, F. E., Barry, R. J., Clarke, A. R., Mccarthy, R., & Selikowitz, M. (2013, September). Sex differences between the combined and inattentivetypes of attention deficit hyperactivity disorder: An EEG perspective. *International Journal of Psychophysiology, 89*(3), 320-327.

Education, C. D. (2018). *Test Results for English Language Arts/Literacy and Mathematics*. Retrieved May 26, 2018, from California Department of Education: https://caaspp.cde.ca.gov/sb2017/ViewReport?ps=true&lstTestYear=2017&lstTestType=B&lstGroup=2&lstCounty=00&lstDistrict=00000&lstSchool=0000000

Fuchs, L., & Fuchs, D. (2005). Identifying appropriate test accommodations for students with learning disabilities. *Focus on Exceptional Children, 37*(6), 1-8.

Gardner, H. (1993). *Multiple intelligences: The theory in practice.* New York: Basic Books.

Gardner, H., & Hatch, T. (1989). Multiple intelligences go to school: Educational implications of the theory of multiple intelligences. *Educational Researcher, 18*(8), 4-10.

Ghanizadeh, A., & Haghighi, H. B. (2010). How do ADHD children perceive their cognitive, affective, and behavioral aspects of anger expression in school setting? *Child and Adolescent Psychiatry and Mental Health, 4*(1), 4.

Greven, C. U., Kovas, Y., Willcutt, E. G., Petrill, S. A., & Plomin, R. (2014). Evidence for shared genetic risk between ADHD symptoms and reduced mathematics ability: A twin study. *Journal of Child Psychology and Psychiatry*, 39-48.

Hart, S. A., Petrill, S. A., Willcutt, E., Thompson, L. A., Schatschneider, C., Deater-Deckard, K., & Cutting, L. E. (2010). Exploiting how symptoms of attention-deficit/hyperactivity disorder are related to reading and mathematics performance: General genes, general environment. *Psychological Science*, 1708-1715.

Hayes, A. F., & Krippendorff, K. (2007). Answering the call for a standard reliability measure for coding data. *Communication Methods and Measures*, 77-89.

Kemenetz, A. (2015). *The test: Why our schools are obsessed with standardized testing -- but you don't have to be* . New York: PublicAffairs.

Kirby, M. (2017). Implicit assumptions in special education policy: Promoting Full inclusion for students with learning disabilities. *Cild and Youth Care Forum*, 175-191.

Lange, K. W., Reichl, Lange, K., Tucha, L., & Tucha, O. (2010). The history of attention deficit/hyperactivity disorder. *Attention Deficit Hyperactivity Disorders, 36*(12), 241-255.

Langmaid, R. A., Papadapoulis, N., Johnson, B. P., Phillips, J. G., & Rinehart, N. J. (2014). Handwriting in children with ADHD. *Journal of Attention Disorders, 18*(10), 504-510.

Larson, R., & Farber, B. (2003). *Elementary Statistics: Picturing the World.* Upper Saddle River: Prentice-Hall.

No Child Left Behind. (2018, May 23). Retrieved from U. S. Department of Education: https://www2.ed.gov/policy/elsec/leg/esea02/index.html

Oche, E. (2014). The influence of poor handwriting on students' score reliability in mathematics. *Mathematics Education Trends and Research, 2014*, 1-15.

Office, D. R. (n.d.). *School Profile: Philip Magruder Middle*. Retrieved from California Department of Education: https://www.cde.ca.gov/sdprofile/details.aspx?cds=19650606023170

Pieters, S., Desoete, A., Van Waelvelde, H., Vanderswalmen, R., & Roeyers, H. (2012). Mathematical problems in children with developmental coordination disorder. *Research in Developmental Disabilities*, 1128-1135.

Pieters, S., Dosoete, A., Herbert, R., Vanderswalmen, R., & Van Waelvelde, H. (2012). Behind mathematical learning disabilities: What about visual perception and motor skills? *Learning and Individual Differences*, 498-504.

Shen, I.-H., Lee, T.-Y., & Chen, C.-L. (2012). Handwriting performance and underlying factors in children with Attention Deficit Hyperactivity Disorder. *Research in Developmental Disabilites, 33*(4), 1301-1309.

Stoeger, H., Duan, X., Schirner, S., Greindl, T., & Ziegler, A. (2013). The effectivenessof a one-year online mentoring program for girls in STEM. *Computers and Education, 69*, 408-418.

Stray, L. L., Stray, T., Iversen, S., Ruud, A., Ellersten, B., & Tonnessen, F. E. (2009). The Motor Function Neurological Assessment (MFNU) as an indicator of motor function problems in boys with ADHD. *Behavioral and Brain Functions, 5*(22).

Tosto, M. G., Momi, S. K., Asherson, P., & Malki, K. (2015). A systematic review of attention deficit hyperactivity disorder (ADHD) and mathematical ability; Current findings and future implications. *BMC Medicine, 13*(1), 1-14.

Van Hoorn, J. F., Maathuis, C. G., Peters, L. H., & Hadders-Algra, M. (2010). Handwriting, visuomotor integration, and neurological condition at school age. *Developmental Medicine and Child Neurology, 52*(10), 941-947.

Ziegler, A., & Stoeger, H. (2010). How fine motor skills influence the assessment of high abilities and underachievement in math. *Journal for the Education of the Gifted*, 195-219.

APPENDICES

APPENDIX A

SCORING OF OVERALL HANDWRITNG ABILITY

3 is most consistent, 1 is least consistent 9 is highest, 3 is lowest

Student #	Height (3 to 1)	Spacing (3 to 1)	Shape (3 to 1)	Overall Score (9 to 3)	Math score

APPENDIX B

IRB PARENT RELEASE FORM

FORM E
CSUDH Institutional Review Board (IRB)
Parental Permission for Child to Participate in Research

California State University, Dominguez Hills

Parental Permission/Informed Consent to Participate in Research

The Study of Handwriting and Academic Success of
Middle School Boys Diagnosed with ADHD

You are being asked to allow your child to participate in a research study. Before you give your permission, it is important that you read the following information and ask as many questions as necessary to be sure you understand what your child will be asked to do.

Investigators:
Primary researcher: Donna L DaVanzo, California State University Dominguez Hills
Teacher: Magruder Middle School
310-533-4527
University supervisor: Saili Kulkarni, PhD; California State University Dominguez Hills
College of Education
(310) 243-3914

Purpose of the Study: The purpose of this study is to see if there is a relationship between the handwriting skills of middle school age boys with ADHD and their success in math class. Your child has been identified as a potential participant for this study as he qualifies for services due to a diagnosis of ADHD.

Description of the Study:
The study will mean that your son's math teacher will give to me copies of your son's math work (homework, tests, quizzes.) Your son will not spend any time with me inside or outside of the classroom on this study. The study is expected to last approximately 4-6 months. There will be no experiments performed; the only experimental aspect of this study will be the gathering of data from your son's math work samples.

Risks or Discomforts:
Your son is not at risk during this study, but he may feel uncomfortable about being in this study if other students find out about it.

Benefits of the Study:
I cannot guarantee that you or your child will receive any benefits from this study. The results of this study may be shared with other teachers on campus if there is information learned that may improve teaching practices. Can I share the results with you too, if you are interested?

Confidentiality:
All records and copies of your son's work will be kept under lock and key. His name will also be blacked out to maintain confidentiality. Only myself and my university supervisor will have access to these copies.

Incentives to Participate:
Your son will receive no incentive to participate in this study.

Voluntary Nature of Participation: ***Participation in this study is voluntary. Your decision of whether or not to allow your child to participate will not influence your future relations with California State University, Dominguez Hills, and Magruder middle School.. If you decide to allow your child to participate, you are free to withdraw your consent and to discontinue his/her participation at any time without penalty or loss of any benefits to which you are otherwise entitled***.

Questions about the Study: **If you have questions regarding this study or your child's rights as a human subject and participant in this study, you may call the investigator, Mrs DaVanzo at 310-533-4527 or the Institutional Review Board for the Protection of Human Subjects at CSUDH, 310-243-3756. You may also write to the Office of Graduate Studies and Research, California State University, Dominguez Hills, 1000 E. Victoria Street, Carson, CA 9074**

Your signature below indicates that you have read the information in this document and have had a chance to ask any questions you may have about the study. Your signature also indicates that you agree to allow your child to be in the study and have been told that you can change your mind and withdraw your consent at any time. You have been given a copy of this consent form.

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Name of Participant (please print)

Signature of Parent or Guardian Date

Signature of Investigator Date

APPENDIX C

IRB STUDENT RELEASE FORM

FORM F
CSUDH Institutional Review Board (IRB)
Assent from Child

California State University, Dominguez Hills
Assent to participate in Research

The Achievement of Middle School Boys in Mathematics

Investigator:
As you know, I am going to college at night, and I am working on a project for my diploma.

Purpose and Description of the Study:
My project is about looking at the math work that boys do and how well they learn the math. To do that, I will need your math teacher to give me copies of your math work such as your homework, or quizzes.

Risks or Discomforts:
Since I am not looking at everyone's math work, you might feel weird about it. If you do, that's okay and I won't look at your work, or you can even ask me later to stop if you want.

Confidentiality:
I will have your name blacked out so no one will even know whose math work I am looking at.

Voluntary Nature of Participation:
I have already talked to your (mom/dad/etc) about this project and he/she said it was okay to do it, but it's okay if you don't want to. No one will be upset with you if you say no, and anything you do will not be bad for your math grade. You can also quit at any time, if you change your mind later.

Questions about the Study: Do you have any questions? What do you want to know? If you want to talk to your (mom/dad/etc) to make you more comfortable, that is all right.

Please mark one of the choices below to tell us what you want to do:

______No, I do not want to be in this project

______Yes, I do want to be in this project

Write your name here Date

Researcher's Signature Date

APPENDIX D

RAW DATA TABLE

Data Table

Handwriting Score	Math Score	Handwriting Score	Math Score
7	2.5	5	1.5
7	3	7	4
8	4	7	2.5
9	4	4	1.5
4	2	8	4
3	1	8	4
7	1	8	4
6	1	9	3.5
7	4	8	1.5
7	4	6	1.5
8	3	6	1
8	2	6	2
4	1	5	1
3	1	4	1.5
5	2.5	4	1.8
7	4	6	1.5
7	4	5	1
7	4	4	1.5
5	4	4	1
5	1	7	4
6	1	9	4
5	1	8	2
6	2	8	2.5
5	1.5	7	4
6	4	7	2
5	1	7	1.5
5	4	8	4
6	4	8	2
6	4	8	4
5	3.5	8	4
5	4	7	4
5	2	9	4
5	2	6	1.5
6	1.5		