SENSITIVITY OF THE PRINT TOOL: DISCRIMINATING CHILDREN WITH AND WITHOUT HANDWRITING DIFFICULTIES

A THESIS

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BY

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To the Dean of the Graduate School:

I am submitting herewith a thesis written by Susan L. Chrisman entitled "Sensitivity of The Print Tool: Discriminating Children With and Without Handwriting Difficulties." I have examined this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts with a major in Occupational Therapy.

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We have read this thesis and recommend its acceptance:

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ABSTRACT

SUSAN L. CHRISMAN

SENSITIVITY OF THE PRINT TOOL: DISCRIMINATING CHILDREN WITH AND WITHOUT HANDWRITING DIFFICULTIES

DECEMBER 2009

The purpose of this study was to determine the sensitivity of *The Print Tool*™ for discrimination between children with and without handwriting difficulties (HWD). Overall means of a convenience sample of 38 first, second, and third grade children with HWD were compared with a control group of 38 aged-matched children by grade and domain components. Findings revealed that the control group was significantly different than the HWD group, supporting the claim that *The Print Tool*™ discriminates between different groups. Ancillary to this, *The Print Tool*™ showed a discriminatory ability in both groups at all three grade levels. Domain components of placement and size also had significant differences across grade and group. Based on calculations, *The Print Tool*™ showed higher sensitivity than specificity meaning that it may be best to use the tool to evaluate children with existing HWD to further guide treatment and remediation rather than as a diagnostic tool.

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CHAPTER I

INTRODUCTION

Handwriting is an important occupation and skill that all children need to acquire in order to meet the common demands of classroom work in primary school (Weintraub & Graham, 1998). Children spend 31% to 60% of each academic day on fine motor tasks including handwriting (McHale & Cermak, 1992), therefore providing the means for elementary school students to communicate and demonstrate their knowledge in all academics. McHale and Cermak (1992) also state that, 90% of all children with learning disabilities also have fine motor or handwriting difficulties (HWD). Children who write well perform better in school, enjoy their classes more, and feel proud of their work (Briggs, 1980; Markham, 1976; Olsen, 2003; Sloan & McGinnis, 1982; Tseng & Cermak, 1993).

Proficient handwriting has also been considered a prerequisite for later academic success (Graham, Berninger, Abott, Abott, & Whitaker, 1997; Graham, Harris, & Fink, 2000). In order to determine if a child's handwriting is proficient, school-based occupational therapy practitioners often use standardized assessments designed specifically to evaluate handwriting performance. On the other hand, teachers may rely more on subjective data such as the daily work samples of children and their readability to determine handwriting legibility. Although standardized testing can be used to determine if there is progress in a student's handwriting performance (Unsworth, 2000),

this type of measurement may not discern whether the teacher in the classroom sees the actual progress. There is a need for teachers and occupational therapy practitioners to agree on which aspects or components of handwriting that they want their students to achieve (Hammerschmidt & Sudsawad, 2004). This agreement can be accomplished by using a handwriting assessment, like *The Print Tool*™, that integrates both professions' evaluation techniques to ensure student progress and the effectiveness of services in the schools. The purpose of this study is to further determine the psychometric properties of *The Print Tool*™ by examining the sensitivity of the tool to determine if it can effectively discriminate between children with and without HWD.

CHAPTER II

REVIEW OF LITERATURE

Children with Handwriting Difficulties

Handwriting is a complex motor task that is accomplished after a child achieves and integrates underlying perceptual-motor performance components (Cornhill & Case-Smith, 1996). Due to the complexity of handwriting, there is a high prevalence rate of HWD in elementary school children, with the disorder more commonly observed in boys. Children with HWD are estimated to range between 5% and 27% of school aged children, depending on grade, selection criteria, and instruments used (Hammerschmidt & Sudsawad, 2004; Hamstra-Bletz & Blote, 1993; Karlsdottir & Stefansson, 2002; Maeland, 1992; Mojet, 1991; Smits-Engetsman & Van Galen, 1997).

Past studies showed that children with HWD often have accompanying problems in the following performance components—kinesthesia, motor planning, eye-hand coordination, visual-motor integration, and in-hand manipulation (Cornhill & Case-Smith, 1996; Tseng & Cermak, 1993; Tseng & Murray, 1994; Weil & Amundson, 1994; Volman, van Schendel, & Jongmans, 2006). The majority of these factors were identified through the use of standardized tests developed mostly by occupational therapists such as, the Southern California Sensory integration Test (SCSIT; Ayres, 1972b), the Test of Motor Impairment (TMI; Stott, Moyes, & Handerson, 1985), The Motor Accuracy Test (MAC; Ayres, 1980), the Developmental Test of Visual Perception (VMI; Beery, 1989),

The Minnesota Handwriting Test (MHT; Reisman, 1993, 1995), and the Evaluation Tool of Children's handwriting (ETCH; Amundson, 1995).

In a more recent study, Hammerschmidt and Sudsawad (2004) surveyed teachers about factors relating to HWD and found that global legibility and readability are the best indicators of handwriting ability. It was determined that teachers do not use standardized assessment tools, but rather assess their students' handwriting subjectively, through visual analysis (Daniel & Froude, 1998; Graham, 1986). The study also revealed that even though teachers tend to look at handwriting globally, they also considered problems with letter formation, spacing, letter placement on a line, and sizing of letters as important contributors to HWD. The combination of problem factors and the prevalence rate have made handwriting the most common referral for occupational therapy services in the public schools (Benbow, 1995; Chandler, 1994; Clark-Wentz, 1997; Oliver, 1990; Reisman, 1993; Vreeland, 1999).

Development of Standardized Assessments for Handwriting

Handwriting assessments have been evolving over the last 20 years. Currently, there are several commercially available assessments and each one varies greatly from others in their measurement approach (Graham, 1986). This discrepancy is largely due to the inherent subjectivity of discriminating good vs. poor handwriting legibility. Legibility is defined as the ease with which a letter, work, or number can be identified and read in isolation (Amundson, 1995; Graham, Boyer-Shick, & Tippets, 1989). It can be measured globally by comparing a child's writing samples to samples in the assessment manual or specifically by looking at particular handwriting components (e.g.

spacing, placement on a line, letter size). Each practitioner also brings a different historical experience regarding letter, number, and work formation and recognition (Diekema, Deitz, & Amundson, 1998) which influences how legibility may be scored.

In order to select an appropriate handwriting assessment, occupational therapy practitioners must consider the child's area of handwriting difficulty as well as the psychometric properties of the instrument (Feder & Majnemer, 2003). In a past study by Kaminsky and Powers (1981), a handwriting assessment was considered a good measure if it included classroom observations of writing tasks, far-point copying, near-point copying, dictation, and paragraph writing. Today, most practitioners continue to use standardized assessments in combination with contextual/classroom data gathering techniques to evaluate a child's proficiency because most standardized handwriting assessments have limitations. Limitations vary and include limited test domains, cumbersome administration and scoring, low test-retest reliability and validity, and the lack of normative data (Feder & Majnemer, 2003; Koziatek & Powell, 2002).

In a recent study, Feder and Majnemer (2003), critiqued five commonly used children's handwriting evaluation tools for manuscript writing. Each tool was described and its characteristics (e.g. test domains, scores obtained, psychometric properties) were analyzed. Results revealed limitations in at least one of the above characteristics for each tool. Most handwriting assessments lacked normative data except for the Minnesota Handwriting Test (MHT). The test-retest reliability of each test was lower than desirable for test development, but consistent across all of the assessments (Diekema, Deitz, & Admunson, 1998). The authors hypothesized that the low reliability was mostly due to

the variability in measures of legibility and performance. They recommended additional reliability and validity studies be conducted to further the test development of each assessment and to strengthen their psychometric properties.

In theory, it is vital that teachers and occupational therapy practitioners have a common understanding of what constitutes proficient handwriting. In practice, such agreement is not always the case. In a recent investigation, Danile and Froude (1998) found that the percentage of agreement of handwriting evaluation results between the two professions ranged only from 21% to 36%. Based on these results it seems that teachers and occupational therapy practitioners use different criteria to determine proficiency and that teacher assessments may also be different from the standardized measurement tools used by occupational therapy practitioners to evaluate handwriting performance. Another study comparing teachers' judgments of legible handwriting with children's scores on the ETCH found very small to insignificant correlations between the two ratings (Sudsawad, Trombly, Henderson, & Tickly-Degnen, 2001). These results further support the idea that teachers may use different criteria to determine handwriting legibility. In 2006, a new handwriting evaluation tool was developed with the specific aims of aligning aspects of handwriting evaluation and areas of focus for improvement that both teachers and occupational therapy practitioners consider important as well as providing relevant remediation strategies to children with HWD in the classroom. It is called *The Print Tool*™.

The Print Tool

The Print Tool™ (Olsen & Knapton, 2006) was designed to help elementary school teachers and occupational therapy practitioners facilitate children's success with printing. The purpose of *The Print Tool*™ is to pinpoint the causes of HWD in students six years and older using the evaluation section and plan the best way to help individual children using the remediation section. This evaluation tool measures eight handwriting components using samples of the child's writing in three domains--capital letters, lowercase letters, and numbers. The components analyzed are memory—remembering and writing dictated letters, orientation—facing letters in the correct direction, placement—putting letters correctly on the baseline, size—how big or small a child chooses to write, start—where each letter begins, sequence—order and stroke direction of the letter parts, control—neatness and proportion of the letter parts, and spacing—amount of space/distance between letters in words, and words in sentences.

During *The Print Tool*™ evaluation process, a child completes three different writing tasks. First, the child prints all their capital letters after they are dictated by the evaluator. Second, the child prints dictated words and sentences using capital and lowercase letters where specified. Third, the child prints their numbers 1 to 9 as dictated by the evaluator. *The Print Tool*™ takes ten to fifteen minutes to administer and 30 minutes to score. A transparent measuring tool is used to assist in accurate scoring of size, placement, and spacing, control.

Currently, *The Print Tool*™ is not standardized and there is no evidence that it can discriminate between individuals who are known to have HWD and those who do

not. Thus, the purpose of this study was to determine the sensitivity of *The Print Tool*™ by comparing scores of a sample of first grade, second grade, and third grade students with identified HWD on *The Print Tool*™ to a control group of aged-matched children. The following research questions were addressed, 1) will children without HWD score higher on *The Print Tool*™ than children with HWD, 2) are there any differences in means by grade level, 3) is there a difference between the HWD and control group on any domain component, 4) how sensitive is this instrument?

CHAPTER III

METHOD

Participants

A total of 76 children were recruited for this study (38 control and 38 with HWD). Children in the control group were recruited as a convenience from various schools within Albuquerque Public Schools, schools in Bloomfield, NM, a rural area, afterschool programs, and acquaintances. The sample of children with identified HWD were recruited for a previous research study from 10 elementary schools within Albuquerque Public Schools, Grants, NM, a rural area, and two agencies in the community that serve children with handwriting and sensory needs. To determine the number of participants for this study a power analysis was conducted. Because there are no studies currently available that have used *The Print Tool*™, power analysis was based on studies using a visual test with the same population of children. The power analysis based on the Beery VMI standard deviation data indicated that the sample size of thirty-eight per group was adequate to detect a group difference of 9.8 in standard scores with 80% power and an alpha = 0.05.

Inclusion criteria for the control group were children who 1) were enrolled in a regular education first, second, or third class, 2) had cognition considered within normal limits, and 3) spoke English as their primary language at school and home. Children were excluded if they 1) received Special Education, Title I, OT, SLP, PT, Resource,

ESL, or any other educational service, 2) had orthopedic or neurological impairments, and 3) had visual impairments not corrected by glasses.

The demographic details of the participant samples can be found in Table 1. The control group had 12 students in first grade, 13 students in second grade, and 13 students in third grade. The mean age for first grade was 6.7 years for males and 6.7 years for females. In second grade, the mean age for males was 7.9 years and for females was 8.1 years. The mean age for students in third grade was 9.0 years for males and 8.5 years for females. Overall, there were more males (n=27) than females (n=11). Seventeen children were Anglo, 17 were Hispanic, and 3 were identified as Other. The majority of students were right-hand dominant (n=33). The demographics of the HWD group in closely matched the control group by size in grade level within 1 or 2 participants, age within 6 months (except for females in first grade within 11 months), gender within one (except females in third grade within 3), ethnicity within one for Anglo, and right and left hand dominance numbers were exactly the same per group.

Table 1

Demographic Information for Control and HWD Groups

	N	Mean Age	Age Range	Ethnicity			RH	LH
				Anglo	Hispanic	Other		
Grade 1--Control								
Male	10	6.7	6.2-7.4	2	7	1	9	1
Female	2	6.7	6.8-6.9	1	0	1	2	0
Grade 1--HWD								
Male	11	7.1	6.4-8.1	5	5	1	9	2
Female	2	7.6	7.7-7.8	0	2	0	2	0
Grade 2--Control								
Male	8	7.9	7.7-8.7	4	3	0	6	2
Female	5	8.1	7.3-8.7	2	3	0	4	1
Grade 2--HWD								
Male	8	8.0	7.5-8.5	6	1	1	6	2
Female	6	8.1	7.10-8.6	4	2	0	6	0
Grade 3--Control								
Male	9	9.0	8.1-10.0	5	3	1	8	1
Female	4	8.5	8.5-9.1	3	1	0	4	0
Grade 3--HWD								
Male	10	8.9	7.10-9.6	2	7	1	10	1
Female	1	8.10	-	1	0	0	0	0

Note. Demographic Information: RH = right handed; LH = left handed.

Inclusion criteria for the HWD group were children who 1) were currently receiving occupational therapy services, 2) had handwriting goals on their Individualized Education program (IEP), and 3) spoke English as their primary language at school and home. Children were excluded if they had mental retardation, autism, and/or a motor impairment (i.e. cerebral palsy). Table 2 describes the IDEA eligibility of the HWD group for occupational therapy services as a related service. The most common eligibility categories were Developmental Delay (n=18) and Speech Language Impairment (n=10). Ten children in the sample were on prescription medications for diagnosed conditions such as attention deficit disorder, attention deficit hyperactive disorder, asthma, bipolar disorder, and/or seizure disorder. Six participants wore glasses for vision correction.

Table 2

IDEA Eligibility for Occupational Therapy Services for the HWD Group

	N	Eligibility Criteria					
		DD	Gifted	OI	OHI	SLD	SLI
Grade 1							
Male	11	7	0	0	0	0	4
Female	2	1	0	0	0	0	1
Grade 2							
Male	8	4	0	0	0	4	0
Female	6	1	0	1	1	1	2
Grade 3							
Male	10	5	1	0	2	0	2
Female	1	0	0	0	0	0	1

Note. Eligibility Criteria: DD = Developmental Delay; OI = Orthopedic Impairment; OHI = Other Health Impaired; SLD = Specific Learning Disability; SLI = Speech Language Impairment.

Instrument

The instrument used in both sample groups was *The Print Tool*™ (Olsen & Knapton, 2006). The purpose of *The Print Tool*™, as outlined by the authors, is to identify specific areas in which students are or are not experiencing HWD by scoring three domain areas (capitals, lowercase, and numbers) on the eight domain components of successful handwriting (memory, orientation, placement, size, start, sequence, control, and spacing). For the purposes of the study only the six most objective and measurable components for each domain were included (the domain components of control and spacing were not used). Refer to Table 3 for the complete definitions and descriptions of the domain components of *The Print Tool* ™ chosen for the study.

Table 3

Definitions and Descriptions of Domain Components of the Print Tool™

Domain Component	Definition and Description
Memory	Remembering and writing dictated letters and numbers. Error scored if letter is omitted, unidentifiable in context, or incorrect case is used.
Orientation	Facing letters and numbers in the correct direction. Error scored if letter is reversed.
Placement	Putting letters and numbers on the baseline. Error scored if letter is placed 1/16" above or below baseline for 1st grade and beyond.
Size	How big or small a child chooses to write. Error scored if letter goes outside measurement box on scoring transparency. Varies by grade. 1st grade: 9/16" for "tall" letters, i.e. "b, h", 4/16" for "short" letters; 2nd/3rd grade: 6/16" for tall letters, 3/16" for short letters.
Start	Where each letter or number begins. Error scored if letter does not begin at the starting point according to criteria in manual.
Sequence	Order and stroke direction of the letter or number parts. Error scored for Orientation and Start errors, or if sequence is different from criteria in manual.

To score the tool, percentages are calculated by grade for each domain and component, as well as a total overall score. Since normative data has not been established for *The Print Tool*™, scores of the participants were compared to suggested handwriting expectations in tables within the *User's Manual*. The tables provide suggested target/cutoff scores by age level for children ages six through eight or older. If children perform at or above the suggested target/cutoff scores, they are considered not to have HWD. If they perform below the target/cutoff scores, then specific domain components are identified and prioritized to implement effective interventions and remediation.

Inter-rater reliability correlation coefficients of *The Print Tool*™, between research team members, were determined for each convenience sample because data was collected for each group at different times. For the HWD group, inter-rater reliability was established using samples from 18 children by two experienced occupational therapy practitioners and one student. Intraclass Correlation Coefficient (ICC) scores were run and the ICC for the total overall *Print Tool* scores (for all components in the domains--capitals, lowercase, and numbers) was .96. ICCs for overall domain scores were: capitals .90, lowercase .95, and numbers .97 and ICCs on the different components of the tool ranged from .64 to .99. (unpublished data, Jan. 2008). For the control group, inter-rater reliability was calculated as the percentage of agreement with percentages ranging from.67 to .92 with the overall score percentage of agreement being .80. It was established by one experienced occupational therapist, two students, and two blind

occupational therapists, living out-of-state and certified in the administration and scoring of *The Print Tool*™.

Intraclass correlation coefficients for *The Print Tool*™ were also calculated to determine its test-retest reliability using the total domain scores and the overall scores on the tool. The ICC and confidence limits for total overall scores was .54 (0.33, 0.73) and ICCs and confidence limits for overall domains were: 41 for capitals (0.20, 0.66), .47 for lowercase (0.25, 0.69), and .61 for numbers (0.42, 0.78). The significance or p value for all test-retest ICCs was $p < .01$.

Procedure

The procedure closely replicated that used in May 2007 for the collection of data for HWD group. Prior to beginning data collection, Institutional Review Board (IRB) approval was obtained. One certified occupational therapist and two occupational therapy students served as data collectors and scored case study examples of *The Print Tool*™ to gain experience in administration and scoring. The data collectors contacted schools, teachers, afterschool programs and/or parents to determine eligible participants. After informed consent was obtained, one of the data collectors administered *The Print Tool*™ in a quiet area at the child's school, home or afterschool program. When testing was completed, each *Print Tool*™ evaluation score sheet was scored by one of the data collectors and/or two additional occupational therapists that were certified to score *The Print Tool*™ to control for scoring bias that may have occurred. Each score sheet was coded and kept confidential in a locked file cabinet where only the study's data collectors had access to the information. Data collection was completed in June 2009.

Data Analysis

To analyze the sensitivity of the *Print Tool*™ the known groups method was used to predict how the different groups were expected to behave. The statistical difference between the two groups was analyzed with a significance level set at $p < .05$. A 2 X 3 ANOVA was conducted to compare the means by group and grade. Independent samples *t* tests were conducted on overall group means as well as post hoc analyses of means by group, grade, and domain components. Other measures of sensitivity, specificity, and predictive value were analyzed.

CHAPTER IV

RESULTS

Data was analyzed comparing means of the control and HWD groups by group and grade (see Figure 1 for means). A 2 X 3 group by grade ANOVA was done to determine significance. There was a significant difference for both group (F (1) = 13.66, $p < .001$) and grade (F (2) = 12.65, $p < .001$). There was no significant interaction for group and grade. Independent samples t tests comparing the participants' overall scores on *The Print Tool*™ were conducted on the control and HWD groups to determine if there was a significant difference between the groups. Results revealed significant differences between the control and HWD group. The mean [M] and standard deviation [SD] for the control group and HWD group were (M = 88.41, SD = 7.88) and (M = 76.26, SD = 10.55), t = -5.74 (75), p = .001.

Post hoc independent sample t-tests were conducted to determine the differences in means for overall scores by grade. In cases where there was unequal variance the more conservative scores were used. For grade 1 the means for the control and HWD groups were (M= 84.08, SD = 9.52) and (M = 71.77, SD = 11.14) respectively, t = -2.96 (23), p = < .001. For grade 2 the means for the control and HWD groups were (M = 87.08, SD = 7.15) and (M = 73.79, SD = 8.22) respectively, t = -4.47 (25), p = .001. For grade 3 the means for the control and HWD groups were (M = 93.62, SD = 3.50) and (M = 84.73, SD = 7.82) respectively, t = -3.69 (22), p = .001.

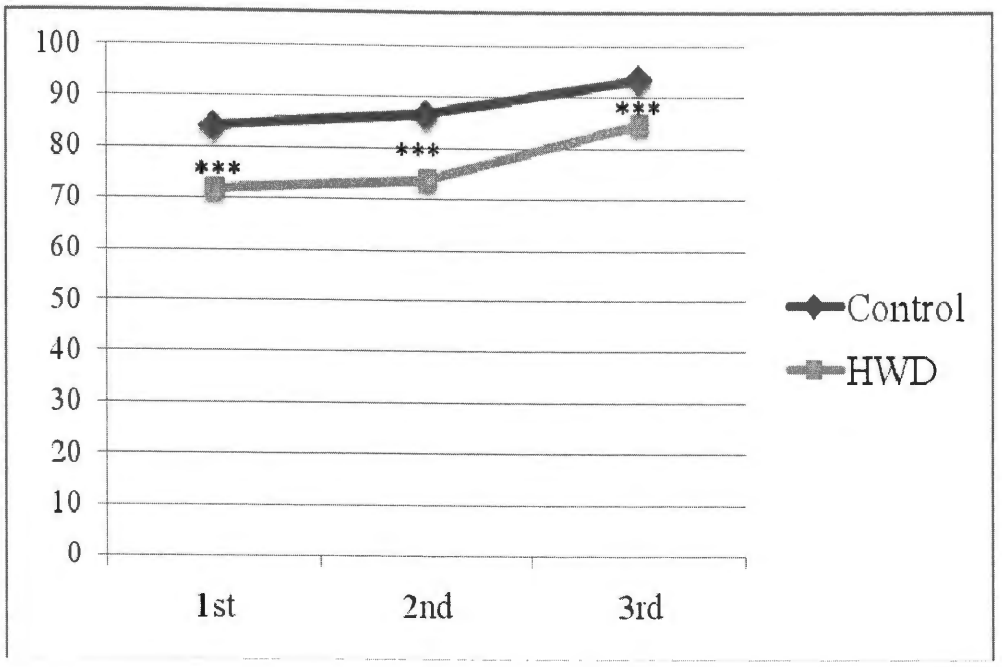

Figure 1. Total mean scores on *The Print Tool* ™ for the control group and HWD group for 1st, 2nd, and 3rd grades. ***$p \leq .001$ between control and HWD for grade.

For further analysis, means for the domain components were analyzed. Independent samples *t*-tests were conducted for an even closer look at the performance of the groups by grade and the following domain components: memory [M], orientation [O], placement [PL], size [S], start [ST], and sequence [SQ]. Table 4 shows the comparison of means and standard deviations as well as the *t* values, degrees of freedom (*df*) for the groups by grade and domain component.

Table 4

Comparison of Group Means and Standard Deviations for Grades and Domain Components on the Print Tool™

Domain Component	Control		HWD			
	M	*SD*	*M*	*SD*	*df*	*t*
Memory						
Grade 1	96.0	5.66	86.2	12.00	23	- 2.59*
Grade 2	99.2	0.83	90.9	8.08	13.30	- 3.82***
Grade 3	97.2	3.16	95.7	4.36	22	- 0.93
Orientation						
Grade 1	91.3	8.17	93.0	6.83	23	0.56
Grade 2	97.5	5.14	93.1	95.20	25	- 2.17*
Grade 3	97.8	3.67	96.3	4.34	22	- 0.96
Placement						
Grade 1	75.1	15.32	54.5	24.42	20.38	- 2.55*
Grade 2	84.4	10.01	54.7	19.93	25	- 4.83***
Grade 3	96.3	3.54	82.6	11.18	11.70	- 3.89***
Size						
Grade 1	96.8	6.77	58.8	35.24	23	- 3.80***
Grade 2	70.4	29.87	45.3	30.14	25	- 2.17*
Grade 3	98.8	1.83	79.7	23.69	10.10	- 2.66*
Start						
Grade 1	76.7	18.87	90.2	10.30	23	2.26*
Grade 2	90.2	6.93	88.9	8.26	25	- 0.47
Grade 3	90.1	7.84	86.3	12.86	22	- 0.89
Sequence						
Grade 1	68.6	21.30	80.0	11.07	23	1.70
Grade 2	81.6	10.71	82.9	7.66	25	0.37
Grade 3	85.0	9.30	82.5	13.47	22	- 0.53

Note. *$p < .05$, ***$p < .001$.

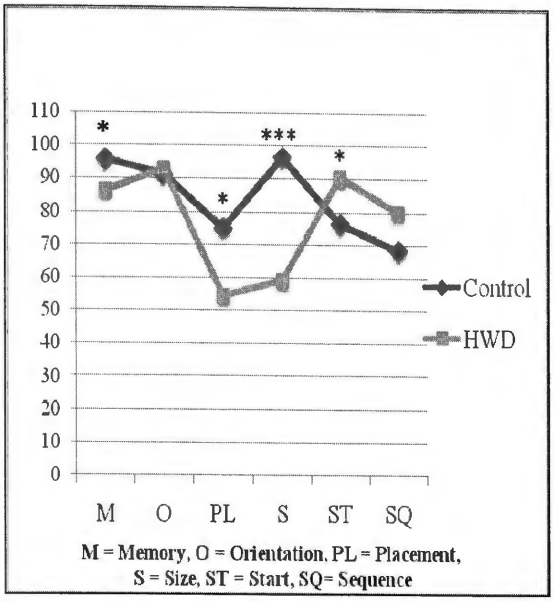

Figure 2. Comparison of group means and domain components on the Print Tool™ for grade 1,
*$p < .05$, ***$p < .001$.

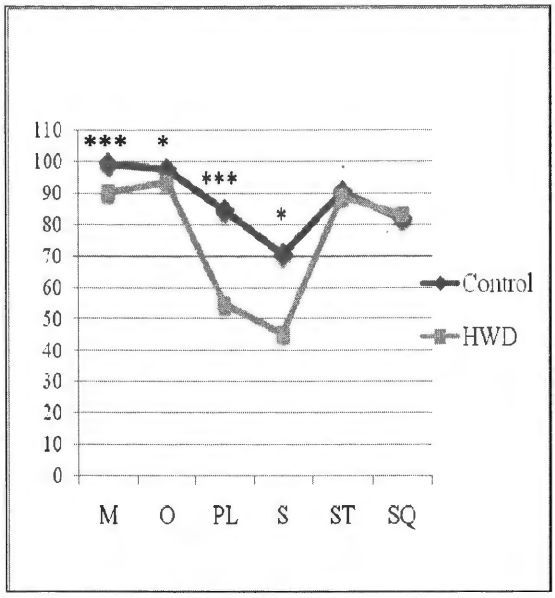

Figure 3. Comparison of group means and domain components on the Print Tool™ for grade 2,
*$p < .05$, ***$p < .001$.

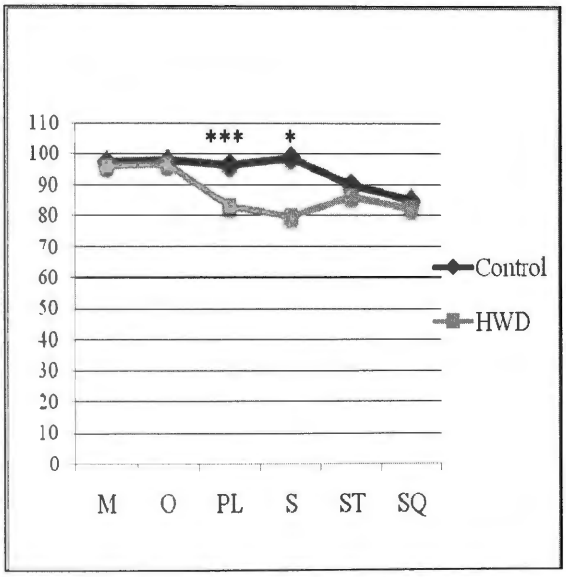

Figure 4. Comparison of group means and domain components on the Print Tool™ for grade 3,
*$p < .05$, ***$p < .001$.

M = Memory
O = Orientation
PL = Placement
S = Size
ST = Start
SQ = Sequence

Figures 2, 3, and 4 also depict the significant difference of certain domain components by group and grade. They show a significant difference across all grades and groups for placement and size domain components on *The Print Tool*™. Uniquely, grade 1 revealed a significant difference in start, grade 2 showed significance in orientation; and grade 3 showed no additional significance.

Lastly, the sensitivity, specificity, and predictive value of *The Print Tool*™ were examined. Sensitivity is a statistical measure of the number of participants that were correctly identified as having HWD and specificity is a measure of the percentage of control participants correctly identified as not having HWD. A positive predictive value (PV+) estimates the likelihood that a HWD participant who tests positive for HWD actually has HWD. A negative predictive value (PV–) indicates the probability of a control participant who tests negative for HWD is actually without any HWD. For these analyses, the participants were divided into age levels rather than grades in order to match the suggested target scores of *The Print Tool*™, on page 66 of the *User's Manual*, which are based on age levels. The sensitivity, specificity, and predictive values of *The Print Tool*™ were calculated and summarized in Figure 3.

Status determined by the Print Tool	HWD Present	HWD not present	Total
HWD Present	A (True Positive) Participants of HWD score below the cutoff on the tool—HWD is present (Sensitivity) (32)	B (False Positive) Participants of Control group score below the cutoff on the tool (17)	A + B 49
HWD not Present	C (False Negative) Participants of the HWD group score above cutoff on the tool (6)	D (True Negative) Participants of Control group score above the cutoff on the tool—HWD not present (Specificity) (21)	C + D 27
Total	A + C 38	B + D 38	A + B + C + D 76

Sensitivity: A / (A + C): 32 / (32 + 6) = .84 or 84% detection rate
Specificity: D / (B + D): 21 / (17 + 21) = .55 or 55% specificity
Test accuracy: A + D / (A + B + C + D): 53/76 = .70 or 70% test accuracy
PV +: A / A + B: 32/ (32 + 17) = .65 or 65% positive for HWD
PV–: D / C + D: 21/ (6 + 21) = .78 or 78% negative for HWD

Figure 5. Demonstration of the concepts of sensitivity, specificity, and predictive values on the Print Tool™.

The balance between sensitivity and specificity was also examined using a graphic representation called a receiver operating characteristic (ROC) curve. Several cutoff points for the tool were set by age levels according to the suggested target scores for children ages 6 to 8 or older and sensitivity and specificity were calculated at each point. Then the ROC curve was created by plotting a point for each cutoff score that represented the proportion of participants correctly identified as having HWD on the Y-axis (true positives) against the proportion of participants incorrectly identified as having HWD (false positives) on the X-axis. The Y-axis represented sensitivity, and the X-axis represented one minus specificity (1-specificity).

Figure 6, 7, and 8 represent the ROC curves for participants ages 6 to 8 or older. Within each figure is an area value called the area under the ROC curve (AUC). The graph of the 6 year olds has an AUC of .95 which means that a clinician giving *The Print Tool*™ to 6 year olds would choose the correct diagnosis of HWD 95% of the time. For 7 year olds the AUC = .75, meaning that a clinician would choose the correct diagnosis of HWD 75% of the time, and for 8 or older the AUC = .77, meaning that a clinician would choose the correct diagnosis of HWD 77% of the time. Therefore, the AUC represents the ability of the tool to discriminate between children with and without HWD. Looking at the figures, it appears that *The Print Tool*™ is more sensitive for 6 year olds than for 7 year olds and up, but overall, the tool would be considered a moderately sensitive instrument.

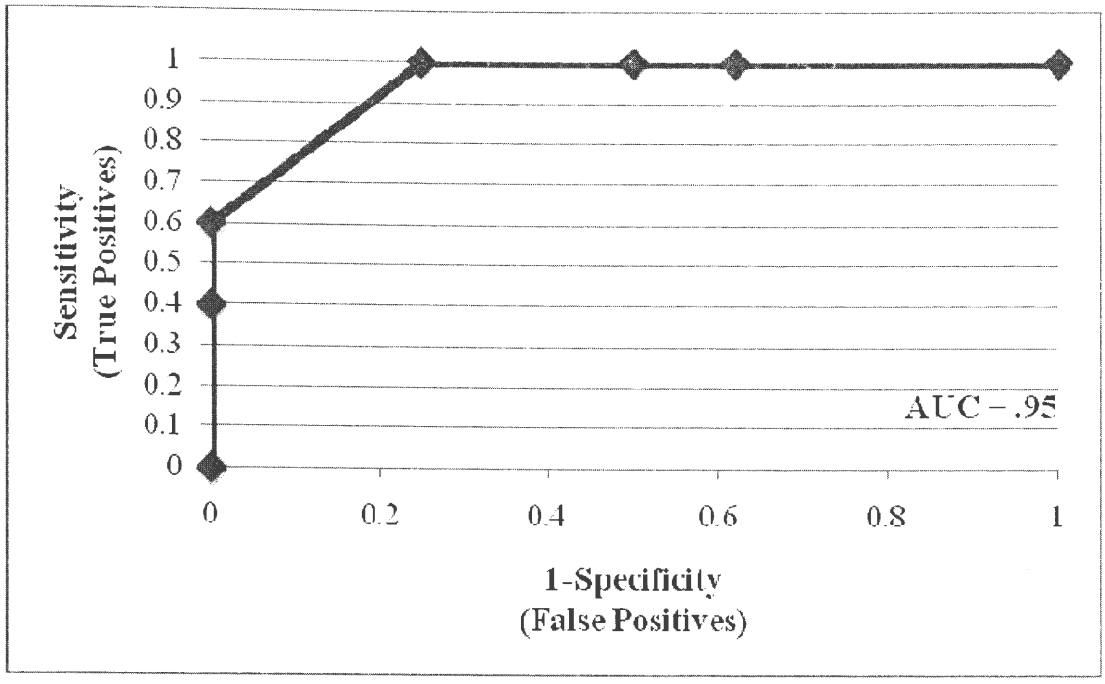

Figure 6. ROC curve for 6 year olds.

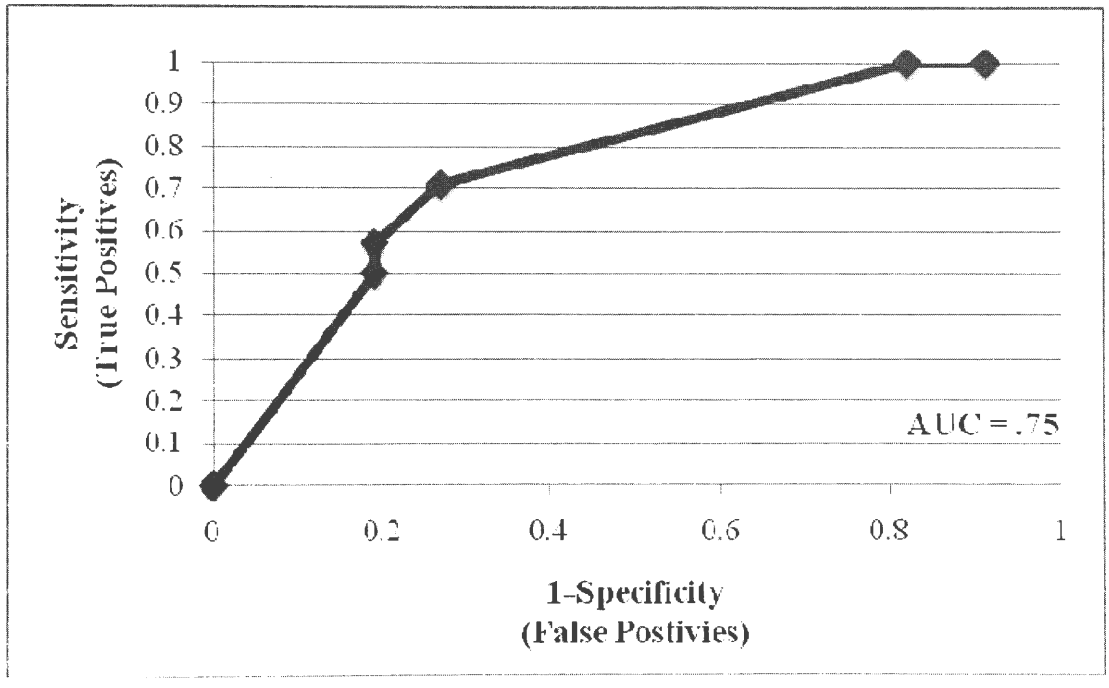

Figure 7. ROC curve for 7 year olds.

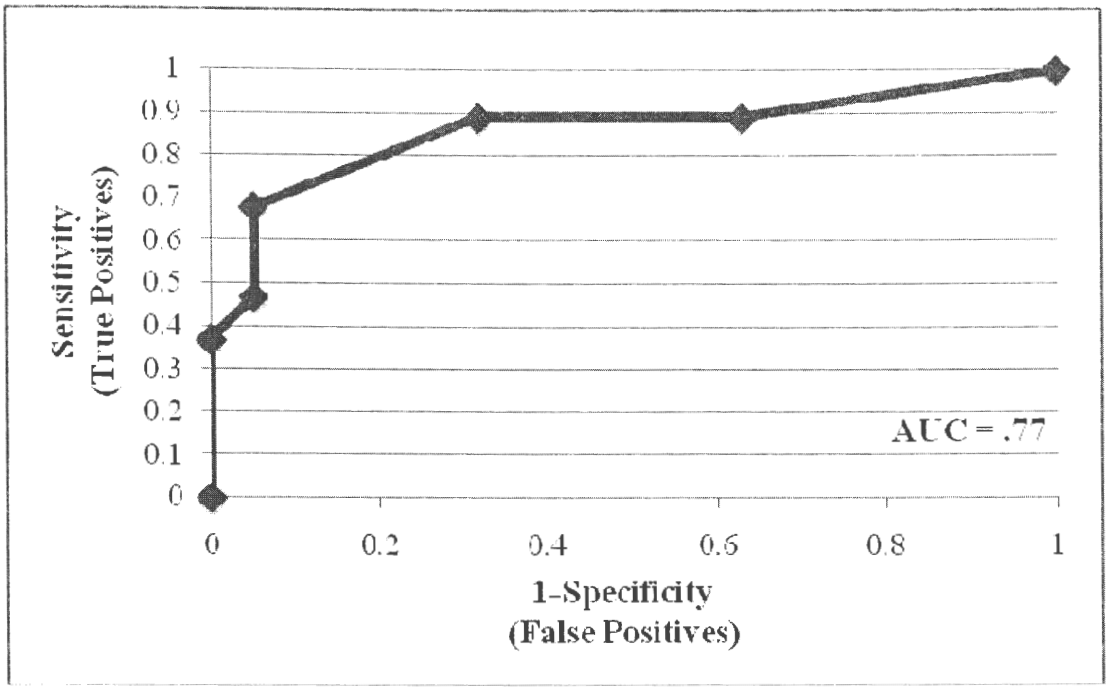

Figure 8. ROC curve for 8 year olds or older.

CHAPTER V

DISCUSSION

The most significant finding in the study was that the control group was significantly different from the HWD group on *The Print Tool*™. This supports the claim that the tool discriminates between different groups—a group with an identified HWD and one without. Ancillary to this, *The Print Tool*™ showed a discriminatory ability in both groups at all three grade levels. A secondary finding was that some domain components on the tool appeared to be better discriminators than others. Placement and size had significant differences between groups at every grade level. Also, as children advanced in grade there were fewer components showing significant differences.

Additional findings revealed an overall moderate sensitivity (.84) and moderate to low specificity (.55) on *The Print Tool*™. This meant that there was an 84% chance of detecting HWD and only a 55% chance of determining that children do not have HWD when administering the tool. The predictive values of the tool also yielded moderate results with a 65% likelihood that a participant with HWD who tested positive actually had HWD and a 78% probability that a participant that tested negative on the tool actually had no HWD. The ROC curves also delineated which age levels of the tool were more sensitive. The 6 year olds had the highest sensitivity with only moderate sensitivity for the 7 year olds or older.

The importance of knowing the sensitivity, specificity, and predictive values of *The Print Tool*™ are vital to its validity as an assessment. Even though the tool obtained positive HWD cases 84% of the time, it was only able to obtain true negatives—no HWD present, 55% of the time. Since the test is more sensitive than specific, the tool will more readily identify children with HWD and it will be less likely that a child that scores negatively (higher) on the tool will have HWD, thus leading to a higher negative predictive value (PV– = 78%) than positive (PV+ = 65%). These findings support the claim that *The Print Tool*™ may be better at identifying children with HWD than identifying children without HWD. Therefore, it may be best to use the tool to evaluate children with existing HWD in order to help further guide treatment and remediation rather than using it as a diagnostic tool that stands alone due to its low specificity.

There are other possible explanations for the secondary findings. As expected the evidence showed there was a difference in the groups and participants were chosen correctly. More HWD were detected for 6 year olds than for 7 year olds or older. One might speculate that this is possible because 6 year olds have not yet mastered their printing abilities and 7 or 8 year olds may have acquired more skill with practice in school over time.

However, it is interesting to note that the 6 year old HWD group scored higher on start and sequence than the control group. This may have occurred because the participants in the HWD group were receiving occupational therapy services and these components might have already been addressed in their therapy. Perhaps the components

of start and sequence are slower developing skills. Even so, by second grade the control group caught up with the HWD group and scored slightly higher on those components.

A rationale for placement and size being significantly different between groups at each grade level might be that they were the only two components used in the study that were scored objectively using the transparent measuring tool. This may mean that these components were scored more accurately than the others. Another reason might be that these components are not as cognitive in nature as other components like memory, start, and sequence. Placement tends to use more visual motor abilities that require good fine motor coordination for success. Size also uses more visual perception skills as well as coordination. For children with HWD these skills tend to be very challenging, given their eligibility for services, such as developmental delay or orthopedic impairment, and may still be developing. Perhaps their significance means that placement and size are the two main discriminators of good handwriting abilities and have the biggest impact on overall legibility.

Lastly, when looking at mean comparisons of the domain components by grade level (see Figures 2a, 2b, and 2c), the findings revealed that the tool may be best used in first and second grades rather than third grade. This is because there were more significant differences in the components in first and second grade than in third grade where the scores of both groups seemed to have almost equalized, illustrating less significant difference.

Limitations

One limitation of this study was that the sample sizes were small which does not give the study much power. In future studies of this nature a larger study would yield greater effects. Another limitation was the low test retest reliability. Even though this is common in handwriting assessments, it makes the scores unstable due to the high variability of the performance of children in early elementary school years. Also only two geographic regions were used which only allowed the results to be generalized to children who have similar characteristics to those who participated in this study. Participant selection was a further limitation. They were selected out of convenience from places of employment, acquaintances, or friends, not representing a heterogeneous population of first, second, and third grade students, as a random sample would have. An additional limitation was that the data collectors in both groups were not blind to the participant's handwriting classification during testing; however objective scoring systems were used. One more limitation was that the study only looked at 6 of the 8 components of handwriting. The unexamined components (control and spacing) may influence the sensitivity of the tool and should be explored in future studies

Implications for Practice

When evaluating a student's handwriting, it is important to consider *The Print Tool*™ overall scores as only one aspect of a comprehensive evaluation. It is ok to use the tool but do not rely on it as a diagnostic tool due to its low specificity and test-retest reliability. The positive findings on sensitivity add to the understanding that *The Print Tool*™ can accurately detect children with HWD. The significance should also help

evidenced-based clinicians and educators feel more comfortable using this instrument to measure handwriting difficulties as well as build their confidence in the treatment/remediation decisions they make based on those scores. The use of *The Print Tool*™ along with other data gathering techniques may allow the educational team to obtain the most comprehensive picture of the student's handwriting abilities.

Directions for Future Research

Replication of this study with a larger sample would improve generalizability. Possibly another sensitivity and test-retest reliability study could address the other domain components (i.e., control and spacing) assessed by the tool. More studies examining other psychometric properties of *The Print Tool*™ are also needed to further establish support and strength for its use. Other studies exploring the sensitivity and test-retest reliability of other handwriting assessments would be useful in order to gain a broader perspective and may lead to improvements in test administration and scoring of the various handwriting assessments.

CHAPTER VI

CONCLUSION

Occupational therapy practitioners and teachers need sensitive assessments to perform evidence-based research on handwriting remediation programs, develop treatment plans, and make intervention decisions. The results from this study lend moderate support to the sensitivity of *The Print Tool*™ when comparing the groups by grade and domain components. It is difficult to find an assessment that is perfectly sensitive because young children have a high level of variability in performance and scoring handwriting can be very subjective and complex. Findings also suggest that the tool may be more effective at finding HWD in first and second grades than third and that best used as an assessment to guide treatment and remediation of children with HWD rather than a diagnostic tool. Perhaps one day *The Print Tool*™ will become standardized, but in the meantime, emulate best practices by using this tool in conjunction with another standardized handwriting assessment and/or other contextual data gathering techniques for the best hopes of determining HWD.

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