Effectiveness of an Integrated Handwriting Program for First-Grade Students: A Pilot Study

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We developed and piloted a program for first-grade students to promote development of legible handwriting and writing fluency. The Write Start program uses a coteaching model in which occupational therapists and teachers collaborate to develop and implement a handwriting–writing program. The small-group format with embedded individualized supports allows the therapist to guide and monitor student performance and provide immediate feedback. The 12-wk program was implemented with 1 class of 19 students. We administered the Evaluation of Children's Handwriting Test, Minnesota Handwriting Assessment, and Woodcock–Johnson Fluency and Writing Samples test at baseline, immediately after the Write Start program, and at the end of the school year. Students made large, significant gains in handwriting legibility and speed and in writing fluency that were maintained at 6-mo follow-up. The Write Start program appears to promote handwriting and writing skills in first-grade students and is ready for further study in controlled trials.


Handwriting is a critical life skill for elementary school students (Cahill, 2009). It is also a complex skill that requires the integration of lower-level perceptual–motor skills (e.g., visual–motor coordination) and higher-level cognitive skills (e.g., language, executive function; Graham & Weintraub, 1996; Weintraub, Yinon, Hirsch, & Parush, 2009). Although some children appear to learn handwriting automatically, most children must be taught handwriting to achieve writing fluency. Unfortunately, with the increasing emphasis on reading and math in the United States, handwriting instruction appears to be decreasing (Berninger et al., 2006). Too often in public schools, fundamental handwriting skills are not explicitly taught, and students who struggle with these skills are not identified until the demands for written production increase.

Graham et al. (2008) completed a survey of first- through third-grade teachers’ perceptions of teaching handwriting. Only 39% of the teachers surveyed indicated that their students’ handwriting was adequate, and only 46% indicated that their students’ handwriting speed was sufficient to keep up with classroom demands. The teachers reported that almost 25% of students experienced difficulty with handwriting (Graham et al., 2008). Although the teachers agreed that handwriting had important consequences for students, they also reported that they had not been adequately prepared to teach handwriting.

Students Who Struggle With Handwriting

Poor handwriting in young students can have several detrimental consequences. Students may focus on how to form the letters rather than on the words they are writing. They are also likely to lose some of their ideas given the extra effort and
time that it takes for them to write. Teachers may not appreciate and reinforce students’ efforts in written work if their words are not legible. In their survey of teachers, Graham et al. (2008) found that although teachers provided struggling students with extra encouragement and extra time to complete writing assignments, they did not provide adapted strategies to help students resolve the underlying problems affecting handwriting or use specific techniques to promote their handwriting skills. In a similar survey, Graham and Harris (2005) found that teachers tend to adapt writing assignments for struggling students by allowing them to give verbal answers or requiring fewer written responses. These compensatory strategies do not help students improve their handwriting legibility.

Children who have difficulty with handwriting struggle when asked to compose stories. Baker, Gersten, and Graham (2003) found that handwriting is a predictive factor in determining the length and quality of composition. Students who struggle to form letters often have difficulty switching their attention between the motor planning for letter formation and the concept or idea that they are trying to express (Cahill, 2009). In a study of 600 children in Grades 1–6, Graham, Berninger, Abbott, Abbott, and Whitaker (1997) found that handwriting fluency contributed directly to writing fluency. When students do not need to think about their handwriting, they can focus their cognitive resources on their ideas and their knowledge of the subject (Berninger et al., 2006). Thus, handwriting legibility and speed can affect students’ grades across all academic subjects (Cahill, 2009).

Handwriting Interventions

Handwriting intervention programs for typical students (Graham, Harris, & Fink, 2000), at-risk students (Berninger et al., 1997; Peterson & Nelson, 2003; Weintraub et al., 2009), and students with disabilities (Jongmans, Linthorst-Bakker, Westenberg, & Smits-Engelsman, 2003) have been researched. In a seminal study using at-risk first-grade students (N = 144), Berninger et al. (1997) demonstrated that neurodevelopmental training helped students improve the accuracy and legibility of letter formation. This study used a tutorial group (24 biweekly sessions) that included experimental warm-up activities followed by handwriting instruction. Five different warm-up interventions were applied: (1) motor imitation, in which participants imitated someone writing letters; (2) visual cueing, in which the participants copied a model that had arrows indicating the direction of drawing; (3) memory retrieval; (4) visual cues and memory retrieval; and (5) copying from a model without any cueing. The intervention associated with the best performance applied visual cues and memory retrieval; children who received this intervention improved on 7 of 10 outcome variables, including legibility and fluency scores. Berninger et al. hypothesized that visual cues and memory were most effective because the visual cueing facilitated automaticity and writing from memory created an efficient retrieval routine. They concluded that handwriting is not just a motor process; it requires developing memory representation and memory retrieval so that writing can become automatic.

Graham et al. (2000) also examined the effects of supplementary handwriting instruction on the writing performance of first-grade students who demonstrated difficulty in handwriting. Their sample consisted of 36 first-grade children from 12 classrooms, 14 of whom had a disability. Half were assigned to handwriting instruction, and half were assigned to a phonological awareness program. The handwriting instruction consisted of 27 lessons in which all the letters were taught. Alphabet practice and copying sentences quickly were emphasized. The students in handwriting instruction improved more than did the control group on alphabet production, number of correct letters, and composition fluency. The gains were maintained at 6-mo follow-up testing. The Graham et al. study is important in that it demonstrated the relationship between learning handwriting and learning to write. Students who received handwriting instruction, including those with disabilities, were able to write more fluently.

Occupational therapy scholars have also examined the effects of handwriting interventions on students with handwriting problems. Jongmans et al. (2003) studied an approach using the principles of motor learning that included students applying handwriting in a meaningful context (e.g., writing a story) and self-evaluating their legibility. In a trial with children with and without poor handwriting, the intervention group significantly improved in handwriting quality compared with a control group, with a strong effect (d = 1.14) for the children with poor handwriting. In a randomized experimental design, Peterson and Nelson (2003) examined the effects of a handwriting program on first graders in a school for economically disadvantaged children. The intervention included a 5-min warm-up session of sensorimotor “heavy work” activities, a 20-min session of activities to improve motor planning and letter formation, and 5 min of handwriting practice. The students who received intervention improved in legibility more than did the control group, achieving moderate to strong effects (d = 0.67).
Denton, Cope, and Moser (2006) compared sensorimotor intervention to motor learning (practice) intervention using a sample of 6- to 11-yr-old children \((N = 38)\) who had difficulty with handwriting but did not receive special education. The interventions were provided 4 times per week for 5 weeks to small groups of 2–3 children. The children who received the therapeutic practice intervention improved significantly more in legibility than did the children who received sensorimotor interventions.

In a study that partially replicated Graham et al. (2000), Zwicker and Hadwin (2009) compared the effects of a cognitive intervention, a multisensory intervention, and a control group in a randomized trial. Seventy-two students in first and second grade participated and were assigned to one of the intervention groups or a control group. After 10 weeks of intervention, 30 min/wk, the groups did not demonstrate any significant differences from pretest to posttest. Both intervention groups demonstrated a medium effect \((d = 0.48–0.51)\) when compared with the control group. The intervention may not have been of sufficient intensity to show a strong effect.

In a randomized controlled trial, Weintraub et al. (2009) compared an intervention emphasizing executive functions with one emphasizing sensorimotor activities. Children in general education were assigned to a sensorimotor group, a task-oriented (executive functions) group, or a control group. Both groups used mnemonics to help the children remember letter formation, self-evaluate their work, and transfer learning through writing practice in the classroom. Both the sensorimotor and the task-oriented intervention groups had better overall legibility than the control group, and both groups improved significantly in legibility and letter formation.

On the basis of these studies, what handwriting intervention is most beneficial and which children benefit from handwriting programs are not clear. Most of the interventions were applied to small groups of children outside the classroom. Interventions outside the classroom may lack alignment with the curriculum, and students may not transfer newly learned skills into classroom activities. Classroom-embedded occupational therapy programs have been developed. Bazyk et al. (2009) evaluated the fine motor and emergent literacy outcomes of integrated occupational therapy services for kindergartners with and without disabilities. This model follows the current emphasis on inclusive services and may be a more efficacious model for handwriting interventions (e.g., Graham et al., 2000). Inclusive models allow the occupational therapist to align services with the curriculum, teachers’ philosophies, and classroom rules. Another advantage of providing occupational therapy services in the classroom is that the occupational therapist can model for the classroom is that the occupational therapist can model for the students, suggest interventions that are practical and realistic, and more easily provide services to students at risk but not in special education.

**Coteaching Models**

One model of inclusive services is the coteaching model. Coteaching evolved from models of collaborative teaching designed to promote full inclusion of children with disabilities. It was originally developed as an instructional approach in which a general educator and a special educator share the teaching responsibility (Cook & Friend, 1995). In coteaching, the related service provider (e.g., occupational therapist) models strategies for the regular education teacher, allowing the teacher to learn methods for adapting and modifying instruction for the children with special needs. Typically, in coteaching the related service provider is responsible for modifying the instruction and monitoring student progress, and the general education teacher is responsible for the content of the instruction (Weiss & Brigham, 2000). Cook and Friend (1995) defined five variations of coteaching: (1) one teaching and one assisting, (2) station teaching, (3) parallel teaching, (4) alternative teaching, and (5) team teaching. Our program used station teaching, in which the class is divided into groups and students move through stations, each led by an occupational therapist or a teacher. We also used team teaching, in which the occupational therapist led the handwriting instruction and the teacher led the writing applications, and all adults supported individual student performance.

Key elements of coteaching include a common planning time, defined roles and responsibilities, high-level communication skills, and administrative support (Arguelles, Hughes, & Schumm, 2000). In a synthesis of qualitative research studies, Scruggs, Mastropieri, and McDuffie (2007) identified attributes and resources that special education and general education teachers need to succeed in coteaching. One common theme from the studies was that teachers need administrative support, planning time, and training. In particular, planning together is essential to coordinating teaching styles and goals. Although coteaching may seem to require more time, the benefits to students can outweigh the cost. Students generally receive more individualized attention and benefit from having the input of two teachers. In addition, teachers learn new skills from the occupational therapists (Scruggs et al., 2007). Flexibility and
adaptability of the teacher and occupational therapist are important.

Coteaching models have not yet been extensively researched. Murawski and Swanson (2001) completed a meta-analysis in which they synthesized six studies of coteaching. Most effect sizes were moderate (mean $M = 0.40$). These authors and others (e.g., Kloo & Zigmond, 2008; Volonino & Zigmond, 2007) concluded that additional studies of coteaching are needed.

Given that both occupational therapists and teachers have expertise in handwriting and writing, with an emphasis on different aspects of the skills, coteaching a handwriting intervention program may be an effective way to enhance students' handwriting and writing skills. Using the skills of an occupational therapist to provide a handwriting program that is integrated into the classroom may provide benefits to students who struggle with handwriting but are not eligible for direct occupational therapy services. A coteaching model involving occupational therapists and teachers can provide comprehensive instruction, allow emphasis on handwriting within the writing curriculum, and enable students to link handwriting skills to writing and composition.

Purpose

The purpose of this study was to develop and pilot test an integrated handwriting program, Write Start, for first-grade students. Specific research questions were

1. Can a cotaught, classroom-embedded handwriting program be implemented for 12 wk with high fidelity?
2. What effect does the program have on students' legibility and writing fluency?
3. Are the handwriting and writing skills developed during the Write Start program maintained at 6-mo follow-up?

Method

Research Design

We used a single-group pretest–posttest design with time as the independent variable. The participants were measured before and after intervention and at 6-mo follow-up. The study protocol was approved by the appropriate institutional review board of the Ohio State University Office of Responsible Research Practices.

Participant Selection

One first-grade class in a Midwest suburban school participated in the study. Inclusion criteria were that the class have ≥2 students with an individualized education pro-
taught in Session 1, and the students copied a sentence as a writing sample, rotated through two small-group activities, and then spent 20–30 min writing stories or writing an assignment. This final period of Session 2 was called the “writing workshop.” The teacher emphasized good handwriting during the writing workshop using the consistent terms introduced to the students during the handwriting instruction. A manual was developed for the program, including core principles, session and intervention descriptions, and activity instructions.

**Measures**

A fidelity measure developed from the core principles defined expected therapist and teacher behaviors and child responses. The fidelity instrument was trialed in three sessions and then revised. Using the finalized measure, authors Case-Smith and Bishop independently rated intervention fidelity for the same five sessions with 90% agreement. After this reliability check, Bishop or Case-Smith rated fidelity during the sessions 16 times (6 times for Session 1 and 10 times for Session 2).

Handwriting legibility and speed were assessed using the Evaluation Tool of Children’s Handwriting–Manuscript (ETCH–M; Amundson, 1995) and the Minnesota Handwriting Assessment (MHA; Reisman, 1993, 1999). The following ETCH–M sections were administered: lowercase alphabet writing, near-point copying, far-point copying, and dictation. We computed percentage scores on the basis of number of legible letters or numbers. Speed scores from the letters were used in the analysis. The ETCH–M demonstrated fair test–retest reliability for letter legibility ($r = .77$) and word legibility ($r = .71$) when first- and second-grade students were tested 1 wk apart (Diekema, Deitz, & Amundson, 1998). Feder, Majnemer, Bourbonnais, Blayney, and Morin (2007) examined the validity of the ETCH–M and found that teachers’ rating of handwriting correlated with ETCH–M scores. The MHA measures legibility and speed on the basis of a single sample in which students write a sentence that contains all letters of the alphabet. The maximum score is 34, and the rate is computed as the number of letters completed in 2.5 min. Test–retest reliability in a sample of 69 first-grade children was .72 for legibility and .50 for rate (speed). No validity studies of the MHA have been published (Feder & Majnemer, 2003).

We measured writing performance using the Writing Fluency and Writing Samples subtests from the Woodcock–Johnson Tests of Achievement, 3rd edition (WJIII; Woodcock, McGrew, & Mather, 2007). The WJIII is a well-used, well-developed test of academic achievement that was recently reformed on a sample of 8,782 participants. Reliability for the Writing Fluency and Writing Samples subtests was .89 in a sample of 6-yr-olds.

In the Writing Fluency subtest, students were instructed to compose sentences from three words written beside a picture. The test requires minimal idea generation but requires the child to link words in a complete sentence under a time constraint. Students who did not produce three grammatical sentences within 2 min were told to stop. Those who produced three grammatical sentences were allowed to continue for 7 min. One point was awarded for each grammatical sentence using all the written words without modification. In the Writing Samples subtest, the student wrote a meaningful sentence for a given purpose (a picture). The test requires retrieval of word meaning and syntactic information. We used raw scores in the analysis.

The students were evaluated 3 times: (1) at baseline, (2) the week after the program ended, and (3) 6 mo after the program ended. Author Bishop evaluated them individually in a quiet space. The tests were scored with the evaluator blinded to whether they were pretests or posttests; all of the follow-up tests were scored at a later time.

**Data Analysis**

We calculated summary scores, percentage scores, or both for each subtest of the ETCH–M, MHA, and WJIII measures and entered them into the SPSS version 18.0 database (SPSS, Inc., Chicago). Means and standard deviations were computed. We used a general linear model to investigate within-subject effects for the three measurement times and calculated post hoc t tests to examine differences in the measures for each time period. Bonferroni corrections were used to estimate significance in paired differences for the three measurement times; therefore, the a priori $\alpha$ level was $p \leq .017$. Effect sizes were calculated to estimate the program effect using pretest and follow-up measures.

**Results**

Nineteen students (8 girls and 11 boys; $M$ age = 77.5 mo, standard deviation [SD] = 6.0, range = 68–86 mo) completed the program. Two of the students received special education services; 1 received occupational therapy and speech–language pathology services. One student was on a response-to-intervention program in which she received intervention specialist services. One student received free lunch. Students were African-American ($n = 1$), Asian ($n = 3$), and White ($n = 12$). Two students missed one of the testing sessions (1 girl’s dominant hand was casted at the time of the pretest, and 1 boy was absent for posttesting); therefore, although all 19 participated, we obtained complete
data on 17 students. Attendance was recorded, and 85%–100% of the students were present at each session.

**Fidelity Measure**

The fidelity of the program was high, supporting the Write Start program’s feasibility. Therapists and teachers demonstrated from 93% to 94% fidelity (M% = 93.5, SD = 10) for individual sessions, meaning that they correctly and consistently followed the principles and procedures almost 94% of the time. The students’ engagement and responsiveness were also measured as a complementary component of treatment fidelity. Students responded to the instruction and were engaged in handwriting or writing tasks 83%–93% of the time (M% = 88, SD = 9.5) across the 16 fidelity measures.

**Handwriting and Writing Performance**

The Ms and SDs for assessments at the three measurement times are presented in Table 1. The general linear model indicated that both a linear and a quadratic model were highly significant (suggesting that progress leveled after the program ended). The linear significance and t-test results are given in Table 2 with estimated effect sizes for pretest-to-follow-up testing. We used Bonferroni correction to determine significance between testing times. The students made significant gains in handwriting legibility and speed and in writing fluency and samples from pretest to posttest. Handwriting legibility and speed scores were maintained, and writing fluency scores continued to improve 6 mo after the intervention ended.

**Discussion**

We examined the feasibility of a cotaught classroom-embedded handwriting intervention. The occupational therapist–teacher team implemented the program with high fidelity (93% sampling for 16 of 24 sessions); this fidelity suggests that the procedures can be consistently implemented with first-grade students. In addition, the students were engaged, followed the instructions, demonstrated focused writing practice, and responded to the therapist’s and teachers’ feedback. The high fidelity of students’ responses (i.e., students demonstrated the expected response 88% of the time for the 16 sessions) is somewhat surprising because their initial handwriting skills varied widely. The handwriting instruction appeared to be sufficiently interesting and motivating to consistently engage most of the students.

The students made large gains in handwriting legibility that were maintained through the end of the school year. During the 12-wk period, the students’ legibility on the ETCH–M progressed from a mean of 62% to 87% (change score = 25%). The M score (87%) at the end of the Write Start program is considered to indicate legible handwriting that one can read without effort. This level of legibility was maintained 6 mo later. They also made substantial improvements in handwriting speed and reduced the time required to write the alphabet from >3.0 min to 1.5 min. This increase in handwriting speed suggests that students became much more efficient in handwriting. The writing fluency scores continued to increase throughout the year, and students made highly significant gains during the program that continued after its end.

Although inclusive models for intervention services are advocated, the research on cotaught, classroom-embedded interventions is minimal (Bayzk et al., 2009; Mastropieri et al., 2005; Scruggs et al., 2007; Volonino & Zigmond, 2007). The Write Start program is a preventative intervention in which an occupational therapist and teachers team to provide handwriting and writing

| Table 1. Means and Standard Deviations for Pretest, Posttest, and Follow-Up Measures (N = 17) |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Variable                                      | Pretest M (SD)                                 | Posttest M (SD)                                | Follow-Up M (SD)                              |
| ETCH–M                                        |                                               |                                               |                                               |
| Lowercase letters, % legible                  | 60.8 (25.0)                                   | 87.7 (11.5)                                   | 86.8 (11.2)                                   |
| Lowercase letters, s                          | 201.8 (94.6)                                  | 96.2 (34.0)                                   | 83.5 (35.8)                                   |
| Near copy, % legible                          | 83.9 (13.3)                                   | 94.1 (8.0)                                    | 94.8 (8.8)                                    |
| Far copy, % legible                           | 81.7 (14.8)                                   | 90.4 (9.1)                                    | 91.5 (9.1)                                    |
| Dictation, % legible                          | 52.4 (25.1)                                   | 79.4 (20.4)                                   | 80.0 (19.0)                                   |
| Total % legible                               | 65.5 (19.3)                                   | 87.1 (10.1)                                   | 88.0 (10.1)                                   |
| Minnesota Handwriting Assessment              |                                               |                                               |                                               |
| Rate, no. letters in 2.5 min                  | 22.2 (7.1)                                    | 32.0 (2.9)                                    | 33.2 (0.2)                                    |
| Legibility, no. legible letters               | 29.2 (4.3)                                    | 31.7 (2.2)                                    | 32.0 (2.3)                                    |
| Woodcock–Johnson Tests of Achievement         |                                               |                                               |                                               |
| Fluency                                       | 0.9 (0.8)                                     | 4.5 (4.5)                                     | 6.9 (5.5)                                     |
| Writing samples                               | 7.7 (2.7)                                     | 14.8 (4.6)                                    | 16.7 (3.8)                                    |

Note. ETCH–M = Evaluation Tool of Children’s Handwriting–Manuscript; M = mean; SD = standard deviation.
instruction. Writing activities and story composition followed the handwriting practice. By monitoring and reinforcing students in small groups, this team guided correct letter formation and emphasized the importance of good handwriting when composing stories or writing assignments.

The study’s findings offer some support to Berninger’s hypothesis that automatic, legible handwriting allows fluent writing and enables more advanced composition (Berninger et al., 1997). Although participants’ handwriting and writing skills improved significantly, a more rigorous study design with a control group and a larger sample are necessary to test how and to what degree these skills are linked.

The gain scores for our participants were greater than those in comparable studies (e.g., Denton et al., 2006). For example, students who completed the Write Start program gained 25% on the ETCH–M compared with participants in the handwriting program researched by Zwicker and Hadwin (2009), who gained 15%–20% on the ETCH–M. The coteaching model, in which three adults with common goals contributed to instruction, monitoring, and reinforcement, may account for the success in handwriting.

**Limitations**

Because this was a pilot study, the sample was small and limited in diversity. In addition, a ceiling effect on the ETCH–M and the MHA may have limited the amount of gain in handwriting legibility that the students could demonstrate. Without a control group, only limited conclusions about the Write Start program effects can be made. Although the students made significant progress when pretest and posttest scores were compared, the degree to which maturation and the first-grade curriculum accounted for student progress is unknown.

**Conclusion**

Write Start is a classroom-embedded, cotaught handwriting program for first-grade students that can be implemented with high fidelity by a trained occupational therapist and teachers. Students who participated in the 12-wk program made highly significant gains in handwriting legibility and speed and writing fluency. Trials with a control group are needed to further investigate the effects of the Write Start program.

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**Table 2. General Linear Model With Post Hoc t-Test Results (N = 17)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Within-Subjects</th>
<th>Pretest to Posttest</th>
<th>Posttest to Follow-Up</th>
<th>Pretest to Follow-Up</th>
<th>Pretest to Follow-Up</th>
<th>Effect Size (Cohen’s d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pretest 2</td>
<td>Posttest 2</td>
<td></td>
<td>Posttest 2</td>
<td>Posttest 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(F, p)</td>
<td>(t, p)</td>
<td></td>
<td>(t, p)</td>
<td>(t, p)</td>
</tr>
<tr>
<td><strong>ETCH–M</strong></td>
<td></td>
<td>(F, p)</td>
<td>(t, p)</td>
<td></td>
<td>(t, p)</td>
<td>(t, p)</td>
</tr>
<tr>
<td>Lowercase letters, % legible</td>
<td>21.46 (&lt;.001)</td>
<td>-4.92 (&lt;.001)</td>
<td>0.52 (0.614)</td>
<td>-4.98 (&lt;.001)</td>
<td>1.40</td>
<td></td>
</tr>
<tr>
<td>Lowercase letters, s</td>
<td>26.00 (&lt;.001)</td>
<td>5.09 (&lt;.001)</td>
<td>1.90 (0.080)</td>
<td>5.24 (&lt;.001)</td>
<td>1.80</td>
<td></td>
</tr>
<tr>
<td>Near copy, % legible</td>
<td>13.00 (&lt;.001)</td>
<td>3.35 (.004)</td>
<td>-0.95 (0.355)</td>
<td>7.06 (&lt;.001)</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td>Far copy, % legible</td>
<td>8.70 (.001)</td>
<td>-3.33 (.004)</td>
<td>-0.58 (0.572)</td>
<td>-3.77 (.002)</td>
<td>0.82</td>
<td></td>
</tr>
<tr>
<td>Dictation, % legible</td>
<td>14.69 (&lt;.001)</td>
<td>-4.67 (&lt;.001)</td>
<td>0.00 (1.000)</td>
<td>-4.17 (.001)</td>
<td>1.25</td>
<td></td>
</tr>
<tr>
<td>Total % legible</td>
<td>32.23 (&lt;.001)</td>
<td>-5.48 (&lt;.001)</td>
<td>-0.76 (0.460)</td>
<td>-6.79 (&lt;.001)</td>
<td>1.53</td>
<td></td>
</tr>
</tbody>
</table>

**Minnesota Handwriting Assessment**

| Rate, no. letters in 2.5 min     | 32.07 (<.001)  | -4.40 (<.001)    | -1.46 (0.164)         | -5.73 (<.001)        | 2.37                   |
| Legibility, no. legible letters  | 6.37 (.005)    | -2.50 (.024)     | -0.59 (0.564)         | -3.67 (.002)         | 0.85                   |

**Woodcock–Johnson Tests of Achievement**

| Fluency                          | 13.95 (<.001)  | -3.53 (.003)     | -2.05 (0.059)         | -4.84 (<.001)        | 2.19                   |
| Writing samples                  | 82.44 (<.001)  | -10.35 (<.001)   | -2.40 (0.029)         | -13.63 (<.001)       | 2.86                   |

Note. ETCH–M = Evaluation Tool of Children’s Handwriting–Manuscript. For all F and t tests, df = 16. With Bonferroni correction applied, p < .017 is significant.
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References


