Factors That Relate to Good and Poor Handwriting

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Objective: This study investigated the relationships between specific performance components, eye-hand coordination, visuomotor integration, in-hand manipulation, and handwriting skill.

Method: A sample of 48 typical first grade students were identified as good and poor handwriters by their teachers. Each child completed the Motor Accuracy Test; the Developmental Test of Visual-Motor Integration (VMI); two tests of in-hand manipulation, including a rotation and a translation task; and the Minnesota Handwriting Test (MHT).

Results: All test scores for the subjects with good handwriting were significantly higher than those of the subjects with poor handwriting. Each performance component test was significantly correlated to MHT scores. Translation, VMI, and rotation scores were significant predictors of MHT scores, accounting for almost 73% of variance. A discriminant analysis using the performance components correctly classified 98% of the students as good or poor handwriters.

Conclusion: In-hand manipulation has significant association to handwriting skill.

The importance of handwriting to performance in school has been well documented. Because handwriting is required in testing situations for most academic subjects, the legibility of a child's handwriting is critical to demonstrating what he or she has learned about that subject. When a child with poor handwriting is given a writing assignment, he or she may produce an incomplete response or one that the teacher cannot read (Tseng & Cermak, 1993). Handwriting performance is emphasized in the elementary grades, and students with difficulty may have lowered self-esteem and frustration because they are unable to fully express their knowledge in written form (Kaminsky & Powers, 1981; Rubin & Henderson, 1982). By the end of the elementary grades, handwriting skill becomes more important as the frequency of note taking, composition, and essay tests increases (Reisman, 1993).

Students with handwriting problems are often referred to an occupational therapist (Benbow, 1995; Oliver, 1990; Reisman, 1993). Typically, the occupational therapist analyzes handwriting difficulty into its sensorimotor and perceptual components to identify the foundational skills that seem to be associated with the handwriting difficulty. The therapist then designs activities to improve...
the performance components that appear delayed and seem to be interfering with handwriting skill. As performance components improve, the therapist helps the child generalize the new skills to handwriting performance. A number of correlational studies have identified the performance components that are associated with handwriting (Tseng & Cermak, 1993; Tseng & Murray, 1994; Weil & Cunningham Amundson, 1994). Kinesthesia, motor planning, eye-hand coordination, visuomotor integration, and in-hand manipulation are among the variables that have evidence of this association.

Kinesthesia

Kinesthesia is awareness of weight of an object (and of a limb) and the directionality of joint and limb movement. Accuracy in kinesthetic perception is assumed to be important to handwriting performance. It appears to influence the amount of pressure the child applies to the writing implement and to provide information about directionality during letter formation (Benbow, 1995; Cunningham Amundson, 1992). Benbow (1995) emphasized the critical role of kinesthetic perception to handwriting skill and proposed that “efficient writing depends on kinesthetic input” (p. 265). Because the somatosensory systems provide immediate and highly specific information about movement, their feedback may be more important than visual input in detecting movement error and in guiding precision movement. On the basis of this conceptualization of kinesthetic function, Benbow (1990) designed a writing program to enhance kinesthetic input and provide a progression of sensory activities for children with handwriting problems.

Kinesthetic function is difficult to measure, creating problems in valid study of its relationship to handwriting. Levine (1987) suggested that children with impaired kinesthetic function demonstrated awkward and inefficient pencil grip. He also hypothesized that limitations in kinesthetic function would result in slow writing that would not become automatic. The inference that children with awkward grip have problems in kinesthetic feedback was supported by Schneck (1991) who found that children with immature grasping patterns and poor handwriting had associated limitations in kinesthetic function.

Other research has supported the relationship of kinesthetic function to handwriting. Ziviani, Hayes, and Chant (1990) found that kinesthesia, as measured by the tactile subtests of the Southern California Sensory Integration Test (SCSIT) (Ayres, 1972b), was related to letter formation and alignment in children with myelomeningocele. In a study of the relationship of perceptual-motor measures to handwriting of Chinese children in grades 3 through 5, Tseng and Murray (1994) found the opposite: Kinesthesia, as measured by the SCSIT, did not emerge as a significant contributor to handwriting legibility and was not significantly different between children with good and poor handwriting.

Motor Planning

Forming individual letters and writing detailed and complex sequences of letters appears to require ongoing motor planning. Cunningham Amundson (1992) explained that motor planning influences the child's ability to plan, sequence, and execute letter forms and the ordering of letters in words. Because motor planning is needed to execute unfamiliar movements, it would logically be important when a child is first learning to write. Most often, the motor planning aspect of writing is described as a component related to kinesthesia. When children have limited awareness of movement (i.e., decreased kinesthesia), they often have limited ability to plan and direct sequences of hand movement (Ayres, 1972a; Benbow, 1990; Cunningham Amundson, 1992).

Tseng and Murray (1994) found that a test of finger praxis was the best predictor of legibility sorting scores for the poor handwriters. Motor planning explained 10% of the variance in legibility and was the best and only predictor of legibility in the poor handwriters. Rubin and Henderson (1982) investigated the relationship between the Test of Motor Impairment (TMI) (Stott, Moyes, & Henderson, 1985) and handwriting performance as evidenced by the relationship between fine motor control and handwriting. Children with poor handwriting did not necessarily have poor fine motor skill but showed greater variability across the TMI's five subtests. The authors indicated that the TMI did not appear to be sensitive to differences in fine motor control between good and poor handwriters.

Eye-Hand Coordination

Skillful use of the hand under visual guidance is an integral part of handwriting. The extent of the eye's guidance differentiates spontaneous scribble from skilled imitation of symbols (Kellogg, 1969). Scribbles can occur without the eye guiding the hand. “In manuscript writing the hand's output depends almost entirely upon the input and ongoing guidance of the visual system” (Benbow, 1995, p. 260). For example, alignment of letters within the well-defined parameters of the writing lines requires the guidance of the visual system.

The Motor Accuracy Test (MAC) is a tracing task that measures a child's accuracy in tracing a curved black
Visuomotor Integration

Visuomotor integration seems to be an important variable to a child's handwriting skill, particularly when copying or transposing from printing material to cursive or manuscript writing. In copying, the child must visualize the letter form and shape, assign a meaning to the form, and then manipulate a writing tool to reproduce the same letter. A number of studies have examined the relationship between visuomotor integration and handwriting. Sovik (1981) found that visuomotor integration was the most significant predictor of handwriting performance in 180 American and Norwegian children ages 7 to 11 years. Rubin and Henderson (1982) compared handwriting scores with scores on the Bender Visual Motor Gestalt Test (Bender, 1946), a measure of visuomotor integration, and found that scores of the children with poor handwriting were significantly lower than those of children with good handwriting. In a more recent study of 59 fourth grade students categorized as (a) clumsy, (b) nonclumsy and dysgraphic, and (c) typically developing, visuomotor integration, as measured by the Developmental Test of Visual–Motor Integration (VMI), was a significant predictor of handwriting performance (Maeland, 1992). Beery (1989) recommended that instruction in writing (i.e., printing) be postponed until the student correctly copies the oblique cross form on the VMI (the eighth test item). The oblique cross requires the child to cross the midline with visual and manual diagonal strokes, as used in several manuscript letters (Benbow, 1995).

In a recent study of kindergarten children, performance on the VMI was moderately correlated to writing legibility as measured by the Scale of Children's Readiness In PrinTing (SCRIPT) (Weil & Cunningham Amundson, 1994). Kindergarten children who accurately copied the first eight forms of the VMI were significantly better performers on the SCRIPT than those who did not. The resulting correlation \( r = .47 \) was remarkably similar to the moderate correlations between the VMI and handwriting in the studies by Sovik (1975, 1981) \( r = .42 \) and Maeland (1992) \( r = .43 \). The similarity of these correlations is striking because different handwriting measures were used. In Maeland's study, the VMI was the only significant predictor of handwriting performance. These results were also supported by Tseng and Murray's (1994) findings that indicated that the VMI was the best predictor of legibility, accounting for 30.5% of the variance when good and poor handwriters were combined.

In-Hand Manipulation

Writing requires precise and rapid manipulation of the writing tool. Writing appears to be accomplished by the action of intrinsic muscles and simultaneous proximal stability that allow for sequential fixation and release of elbow and wrist. Both precision and speed are needed in achievement of functional and legible handwriting (Benbow, 1995). Movement of the pencil on the paper requires the ability to isolate and grade individual finger and thumb movements.

The relationship between the intrinsic muscle action and handwriting skill has not been well researched. Benbow (1987) described a relationship between tripod pencil grasp with an open web space and the production of good handwriting. In grasp with an open web space, the thumb is in opposition, and the pencil is controlled between the thumb pad and distal fingers.

According to Exner's (1992) terminology for in-hand manipulation, shifting, or moving the pencil across the fingers, occurs frequently during handwriting. Benbow (1995) referred to the movement of the pencil through the fingers (pushing the fingers toward or away from the pencil's point) as translation (also a term used by Exner, 1992). Complex rotation of the pencil is used when the child inverts the pencil to erase and then returns it to point-down for writing (Exner, 1995). According to our clinical observation, children with dynamic grasping patterns may use simple rotation (rolling in the finger tips) to form certain letters.

During the actual writing task, minute radial finger movements guide the pencil to form letters. Appropriate use of force on the pencil and the paper may be assumed to rely on precise somatosensory information. Although the tactile and kinesthetic feedback of holding and man-
Manipulating a pencil appears to be quite different from the feedback received when moving objects in and out of the hand, both skills are hypothesized to be highly associated with kinesthetic and tactile input (Benbow, 1995; Case-Smith, 1991; Jennerod, Michel, & Prablanc, 1984; Levine, 1987; Stifwell & Cermak, 1995). These authors and others (Humphry, Jewell, & Rosenberger, 1995; Pehoski, 1995) have suggested that the development of in hand manipulation and manipulation of a pencil is highly associated with concurrent development of somatosensory perception in the hands.

The relationships between in-hand manipulation and writing have been explored but not conclusively determined. Humphry and colleagues (1995) found a strong relationship between in-hand manipulation and coloring accuracy in a sample of typical children between 2 years and 7 years of age ($n = 180, r = .52$). Case-Smith (1995) found a significant relationship between in-hand manipulation and scores on the MAC in preschool children with motor delays ($n = 30, r = -.53$).

The variables that influence handwriting and, in particular, relate to difficulties have not yet been clearly identified. Disparate results among researchers may be created by different definitions of handwriting legibility and different measures of handwriting skills. Identification of the variables that have significant effects on handwriting remains an important research question. The information that results will help occupational therapists determine relevant performance components to evaluate and define appropriate emphases in intervention for students with handwriting problems.

The purpose of this study was to investigate the differences between children with good and poor handwriting as identified by teacher report and the Minnesota Handwriting Test (MHT) (Reisman, 1993, 1995) on certain performance components identified in the literature as influential to handwriting legibility: eye–hand coordination, visuomotor integration, and in-hand manipulation. A second purpose was to investigate whether the scores on tests of these performance components can predict scores on handwriting performance as measured by the MHT.

**Method**

**Subjects**

A convenience sample consisting of 49 typically developing first grade children attending schools in one county of central Ohio was used in this study. Children with documented learning disabilities, developmental delays, or sensory impairments were excluded. The subjects were judged to be either good or poor handwriters by their teachers. The teachers were asked to use the following criteria to judge penmanship: (a) alignment of letters within writing lines, (b) legibility, (c) spacing between letters and words, (d) uniformity of letter size, and (e) accuracy of letter formation. With these criteria, the teachers identified 26 children with good handwriting and 23 children with poor handwriting.

A second criterion, as established by Reisman (personal communication, March 1995), was applied to categorize the subjects into good handwriting and poor handwriting groups. Each subject completed the MHT as an assessment of handwriting legibility. Subjects who scored 166 of the total possible 170 were included in the good handwriting group. The poor handwriting group included children who scored 150 or below. On the basis of these sampling criteria, one subject who did not fall into his teacher-assigned group was eliminated; therefore, 48 subjects were used in the data analysis. Of the subjects in the poor handwriting group, 9 were girls and 14 were boys; of the subjects in the good handwriting group, 19 were girls and 6 were boys. Thirty-nine subjects used their right hands for writing and nine used their left. The mean age was 7.3 years. Forty-five subjects were Caucasian, and three were African-American.

**Instrument**

The subjects were tested individually by the first author in 20-min to 25-min sessions. The following tests were administered: the MAC (Ayres, 1980), the VMI (Beery, 1989), the rotation and translation tasks (Case-Smith, 1993, 1995; Pehoski, 1994), and the MHT (Reismann, 1995).

To complete the MAC, the subject traced a 15-in. black curved line on a standard protocol sheet taped to the table at the subject's midline. A red felt-tip marker was used so that the subject's line was easily distinguishable from the black line. An accuracy score was obtained with a map reader to measure the distance that the subject's red line deviated from the black line. The time-adjusted raw score for the preferred hand was calculated.

The VMI is a developmental sequence of 24 forms that the subject copied as a measure of visuomotor integration. Scores were calculated by adding the point values for the forms correctly copied until the subject failed to copy three consecutive forms. The raw point score was standardized on 3,824 subjects; has excellent psychometric properties (Beery, 1989); and is widely used by psychologists, educators, and therapists.

Two tasks, translation and rotation, that required manipulation of a small peg within the fingers were used.
to test in-hand manipulation. In both tasks, the subject was instructed to use his or her preferred hand, that is, the one used to write his or her name. In the translation task, the subject was presented with a pegboard with two 1-in. pegs placed in the center. The examiner instructed the subject to pick up and hide the pegs one at a time in his or her hand and then replace them in the pegboard. The time for task completion with three, four, and five pegs was recorded, and the sum of the times was calculated for the data analysis.

In the rotation task, the examiner presented each subject with a pegboard with five pegs in place in the row closest to the subject. He or she was instructed to prehend each peg, turn it over, and place it in its original hole. Each subject completed four trials of five pegs each, and the examiner recorded the time for each trial. The sum of times was used in data analysis.

The MHT was used to evaluate each subject's handwriting. Interrater reliability of 98% on 30 handwriting samples was achieved between the first author and Reisman. The handwriting test was administered at the end of the testing session to prevent the examiner from viewing the subject's handwriting before testing. The subject was asked to copy a sentence from a near-point sample preprinted at the top of the paper. The following mixed order sentence that contains every letter of the alphabet was presented: "the brown jumped lazy fox quick dogs over." Mixed order was used to eliminate the advantage that copying a complete and logical sentence would give to children with good memory and reading skill (Reisman, 1993). The MHT testing sheets and scoring system for standard manuscript and D'Nealian style of print were used, depending on the style that the subjects had been taught. Each letter of the sample was scored for legibility (e.g., recognizable, complete, no reversals), form (e.g., absence of gaps and overlaps), alignment (e.g., on the line), size (e.g., relationship of letter parts), and spacing (e.g., between letters in words) (Reisman, 1993). Most of the scoring was based on 1/16 in. error allowance.

Certain psychometric properties of the MHT have been investigated (Reisman, 1993). Interrater reliability of the MHT based on two raters' scores of 30 samples was .97 for the alignment category and .86 for the legibility and form categories (Lilly, 1987). In a sample of 99 subjects, test-retest reliability for handwriting samples 5 to 7 days apart was .72 (Reisman, 1993).

Data Analysis

Statistical analyses included t tests to compare the two groups on each of the performance measures and correlations. Stepwise multiple regression was used to determine whether the performance component measures predicted the subjects' scores on the MHT. Discriminant analysis was used to assess whether the combination of performance measures correctly classified the subjects as good or poor handwriters.

Results

Comparison of Performance Component Scores Between Good and Poor Handwriters

Scores for all of the performance component tests were compared for the good and poor handwriting groups. Means, standard deviations, and the results of a one-way t test are shown in Table 1. For each test, the subjects in the good handwriting group scored significantly higher than those in the poor handwriting group.

Relationship of Performance Components to Handwriting Scores

Pearson correlation coefficients were computed to estimate the relationships among the variables (see Table 2). Scores for each of the performance components correlated with the scores on the MHT. A stepwise multiple regression analysis, with the MHT scores as the criterion variable and the performance measures as predictor variables, demonstrated that translation, VMI, and rotation were significant predictors of MHT scores. Translation entered first and accounted for 63.7% of the variance; the VMI explained an additional 5.9% of the variance; and rotation entered last, accounting for an additional 3.3% of the variance in MHT scores (see Table 3).

Table 1
Means, Standard Deviations, and Results of t Tests on Performance Measures for Subjects With Poor and Good Handwriting

<table>
<thead>
<tr>
<th>Variable</th>
<th>Poor Handwriting</th>
<th>Good Handwriting</th>
<th>t*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Accuracy Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>137.4</td>
<td>153.6</td>
<td>6.22*</td>
</tr>
<tr>
<td>SD</td>
<td>10.0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>Visuomotor Integration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>15.0</td>
<td>23.6</td>
<td>5.02*</td>
</tr>
<tr>
<td>SD</td>
<td>5.2</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>Rotation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>50.7</td>
<td>32.8</td>
<td>-10.91*</td>
</tr>
<tr>
<td>SD</td>
<td>6.7</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Translation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>59.2</td>
<td>35.1</td>
<td>-8.86*</td>
</tr>
<tr>
<td>SD</td>
<td>12.1</td>
<td>5.0</td>
<td></td>
</tr>
</tbody>
</table>

* df = 46

An unequal variance t test was used for the translation task because of differences in group variance.

p < .001
The discriminant analysis correctly classified all 25 subjects in the good handwriting group and all but one of the 23 subjects in the poor handwriting. Ninety-eight percent of the subjects were correctly classified.

Discussion

Performance Component Differences Between Good and Poor Handwriters

The subjects in the good handwriting group seemed to be clearly distinguished from those in the poor handwriting group. First, the agreement between the MHT scores and the teachers’ categorization of the students with handwriting problems was remarkable. The almost perfect agreement suggests that the teachers accurately evaluated the subjects’ handwriting skills and that the MHT is a valid test of handwriting performance. In addition, the subjects with good handwriting scored significantly higher on all of the performance components. Individual results are discussed in the following sections.

Eye-hand coordination. The MAC required the subject to visually guide his or her hand on a preprinted curved line. Scores accounted for speed and accuracy. Benbow (1995) and Laszlo and Bairstow (1985) suggested that after writing is learned, it relies less on visual input and more on kinesthetic input. Although the completion of the MAC probably requires both sensory systems, the visual system appears to dominate. The tracing task differs from handwriting, which first graders usually accomplish by copying or dictation. In our results, the correlation between MAC and MHT scores was moderate ($r = .594$). Eye-hand coordination has not always demonstrated a strong relationship to writing performance (Ziviani, 1995); however, Tseng and Murray (1994) obtained similar results to ours. In their sample, MAC scores demonstrated a .47 correlation with handwriting and differed between good and poor handwriters. These combined results suggest that eye-hand coordination skill is a fundamental component of handwriting and should be evaluated when handwriting legibility is low. When a child’s scores support this relationship, specific practice of eye-hand coordination activities (e.g., cutting, lacing, stringing beads, completing finger mazes, assembling manipulatives) may lead to improvement in handwriting performance.

Visuomotor integration. VMI scores were significantly lower for the subjects with poor handwriting (15.0) than those for the subjects with good handwriting (23.6), $t = 5.02, \ p < .001$, and the VMI was a significant predictor of handwriting performance. These findings supported those of Weil and Cunningham Amundson (1994), Tseng and Murray (1994), and Sovik (1975). This consistency of findings is striking in that Weil and Cunningham Amundson’s sample consisted of children 5 to 6 years old, Tseng and Murray’s sample consisted of students in third through fifth grades, and our sample consisted of 7-year-old children in first grade. The correlation of the VMI and handwriting across studies indicates that the VMI is a strong predictor of handwriting skill at a variety of ages and that a child’s skill in copying forms has a strong relationship to handwriting. Routine evaluation of children with handwriting problems would determine whether visuomotor integration was a performance component to emphasize in intervention.

In-hand manipulation. A strong relationship between handwriting and in-hand manipulation has been hypothesized (Benbow, 1987, 1995; Exner, 1995; Myers, 1992) but not demonstrated in research findings. In our study, in-hand manipulation (i.e., translation and rotation skills) was significantly different between the subject

| Table 2: Pearson Correlation Coefficients Among Variables |
|----------------|----------------|----------------|----------------|----------------|----------------|
| Variable       | MAC      | VMI      | Rotation | Translation | MHT      |
| MAC            | 1.000    | 0.465    | -0.635   | -0.684       | 0.594    |
| Rotation       | -0.635   | -0.536   | 1.000    | 0.773        | -0.770   |
| Translation    | -0.484   | -0.497   | 0.733    | 1.000        | -0.798   |
| VMI            | 0.465    | 1.000    | -0.536   | -0.497       | 0.609    |
| MHT            | 0.594    | 0.609    | -0.770   | -0.798       | 1.000    |

Note. All correlations were significant at $p < .01$. MAC = Motor Accuracy Test, MHT = Minnesota Handwriting Test, VMI = Developmental Test of Visual-Motor Integration.
groups. Correlations between in-hand manipulation and handwriting scores were moderate to high, and both translation and rotation predicted handwriting performance. These results support the contention that precise control of fingers and thumb, such as that needed to move objects in and out of the hand, is highly associated with letter formation in handwriting. These findings were consistent with the conclusions of others (e.g., Case-Smith, 1995; Exner, 1992; Humphry et al., 1995) that poor in-hand manipulation is linked to poor performance of functional activities. These relationships suggest that efficient in-hand manipulation and legible handwriting may share common factors (e.g., control of intrinsic muscle function, accurate tactile and kinesthetic perception).

Benbow (1995) identified manipulative components that appear to be needed in both in-hand manipulation and handwriting (e.g., an open web space, isolated finger movements, thumb opposition, distal finger prehension, adequate palmar arch). Somatosensory processing may be an important variable that contributes to both types of hand skill. Accurate tactile and kinesthetic discrimination is inherent in precise and efficient use of force (Westling & Johanson, 1984). Precision handling of small objects and of a writing tool requires that the child have high levels of control of force (Eliasson, 1995; Stilwell & Cermak, 1995). Our results suggest that efficient production of letters is related to coordinated muscle action and accurate use of force, such as that observed in object manipulation within the hand.

Implications for Practice

Occupational therapists have become increasingly responsible for providing intervention to children experiencing difficulty with handwriting (Tseng & Cermak, 1993; Weil & Cunningham Amundson, 1994). An appreciation of the multiple factors that contribute to handwriting acquisition is important to providing effective remediation. Results of this study support findings of prior research that eye-hand coordination and visuomotor integration are significantly related to handwriting ability. Performance components should be evaluated when a child demonstrates handwriting problems. In addition, evidence of a strong association between in-hand manipulation and handwriting proficiency suggests that in-hand manipulation skill is important to examine when analyzing poor handwriting performance. It also suggests that enhancing a child's in-hand manipulation may contribute to improvement in handwriting. Manipulative activities during the toddler and preschool years, before the introduction of writing implements, may improve the child's intrinsic muscle function and decrease the probability of acquiring an inefficient pencil-grasp pattern.

Limitations

The study's design had several limitations. The sample was one of convenience, where all subjects were from one central Ohio school district. The examiner was not blind to the subject's handwriting classification during testing; however, most of the tests used objective scoring systems based on time measures or criterion-referenced scoring systems. The associations among variables found in this study were strong but cannot be interpreted as cause-and-effect relationships. In addition to the perceptual–motor variables investigated in this study, other variables can influence handwriting (e.g., auditory reception, cognition, visual perception). These should also be considered in any thorough evaluation of a handwriting problem and should be explored in future studies.

Conclusion

Handwriting is a complex skill that is accomplished after the child has achieved and integrated underlying perceptual–motor performance components. The occupational therapist uses skills in task analysis to identify which components seem most influential to a child's handwriting skill development. The findings suggest that when a student is identified as having handwriting problems, the performance components investigated in this study should be evaluated to gain understanding of the unique contributing factors to those problems.

The moderate correlations suggest that the relationships among variables are complex and that the contributing factors to handwriting performance vary among individual children. The study supported the hypothesis of other researchers and handwriting experts that in-hand manipulation has an important relationship to handwriting skill. ▲

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