Perceptual-Motor Function of School-Age Children With Slow Handwriting Speed

Mei Hui Tseng, Susanna M. K. Chow

Key Words: Gross and fine motor skills • psychomotor performance

Objectives. This study investigated differences in perceptual-motor measures and sustained attention between children with slow and normal handwriting speed and the relationship between these factors.

Method. Thirty-four slow handwriters and 35 normal speed handwriters (7 to 11 years of age) attending elementary schools in Taiwan were given three perceptual-motor tests and a vigilance task to assess sustained attention. Performances on these measures were analyzed using multivariate analysis of variance and regression analyses.

Results. A significant difference was found between slow and normal handwriters in upper-limb coordination, visual memory, spatial relation, form constancy, visual sequential memory, figure ground, visual-motor integration, and sustained attention. The three significant predictors of handwriting speed for the slow handwriters were age, visual sequential memory, and visual-motor integration. For the normal speed handwriters, age and upper-limb speed and dexterity were the only two significant predictors.

Conclusions. Slow and normal speed handwriters responded to handwriting demands through different perceptual-motor systems. Whereas upper-limb speed and dexterity seems to play an important role in normal speed handwriters, slow handwriters seem to rely more on visually directed processes, including sequence memory and visual-motor integration.


Proficiency in handwriting is essential if students are to accomplish an acceptable amount of work in the classroom and meet the standards of the teacher and the curriculum. Elementary school children typically spend up to 50% of the school day engaged in paper-and-pencil tasks (McHale & Cermak, 1992). Many of these tasks, including most tests and examination papers, are performed under time constraints (Amundson & Weil, 1996). Unfortunately, although a traditional instructional approach is sufficient for many children to become competent handwriters by 6 or 7 years of age, handwriting difficulties are common among children in both regular and special education classrooms (Bergman & McLaugh-lin, 1988). As a result, remediation of handwriting difficulties is one of the most important areas of school occupational therapy.

Handwriting, however, is a complex skill. It follows that before more systematic ways of teaching children to write can be developed, the constellation of skills that are necessary for efficient writing will need to be better understood. Competent handwriting depends on the maturation and integration of cognitive, visual-perceptual, and fine motor skills (Maeland, 1992; Rubin & Henderson, 1982; Sovik,
Handwriting requires finely graded manipulation of pencils to produce letter forms, in a fluent and ballistical manner, with a specific orientation and size, in a specific serial order, and in specific positions on a writing surface (van Galen, 1993). Further, according to Sovik and Arntzen (1991), fluent writing is produced by an integrated pattern of coordinated movements subject to visual monitoring and sensorimotor feedback. In support of this range of requirements, visual-motor integration was found to be the best predictor of legibility for both American and Norwegian children (Sovik, 1975) and for a group of Chinese school-age children (Tseng, Murray, 1994). Visual-perceptual skills, including visual-spatial perception, visual size discrimination, visual retrieval and left–right orientation, enable children to distinguish visually among graphic forms and to judge their correctness (Sovik, 1975; Thomassen & Teulings, 1983). Fine motor skills are also essential because accurately formed letters can only be produced by the proper timing and force control of coordinated arm, hand, and finger movements (Alston & Taylor, 1987; Thomassen & Teulings, 1983).

Much can also be inferred from the various ways in which handwriters do not achieve functional competence. Handwriting can be deficient either in terms of legibility or in terms of speed. Common handwriting problems such as incorrect letter formation, poor alignment, reversals, uneven size of letters, irregular spacing between letters and words, and slow motor speed (Alston & Taylor, 1987; Johnson & Carlisle, 1996) do not necessarily arise from identical underlying mechanisms. Most studies to date, however, have focused primarily on the relationship between illegibility and various visual-perception skills, fine motor skills, and visual–motor integration (Alston & Taylor, 1987; Carlson & Cunningham, 1990; Cornhill & Case-Smith, 1996; Johnson & Carlisle, 1996; Maeland, 1992; Tseng & Murray, 1994). Illegible handwriting also has been investigated in connection with other functional deficiencies. For example, Levine, Oberklaid, and Meltzer (1981) not only found that 72% of 26 children with “developmental output failure” (low academic work output) had difficulty with fine motor tasks, they further postulated that these children’s uncoordinated finger movements and diminished pencil control accounted for their “illegible and/or laborious, hesitant, and slow” (p. 20) handwriting.

Although slow handwriting speed often affects functional performance because it prevents students from meeting the time constraints involved in schoolwork (Amundson & Weil, 1996; Cermak, 1991; Levine et al., 1981; Oliver, 1990), few investigators have focused on this form of handwriting deficiency. Previous studies include that of Berninger and Rutberg (1992), who contended that finger function is the best predictor of handwriting dysfunction in that fine motor skill accounted for 52.5% of the variance in handwriting speed. Sovik, Arntzen, and Teulings (1982) found that poor coordination in the form of poor dissociation (e.g., exaggerated wrist and thumb movement) was inversely correlated with writing speed. Curiously, although Hamstra-Bletz and Blote (1993) found no relationship between slow handwriting and dysgraphia, children with dyslexia were found to write more slowly than children without reading disabilities (Martlew, 1992). This suggests that visual-perception or cognitive skills might also affect handwriting speed.

In this article, we attempt to identify more clearly the factors associated with slow handwriting in the hope that this may help to elucidate the underlying mechanisms. Because inadequate attention span also has been clinically observed to impair handwriting proficiency (cf. Levine et al., 1981, who found that 60% of their 26 low-productivity subjects also had serious difficulty concentrating), a vigilance test was included in the present study. We hypothesized that children with slow handwriting would obtain lower scores on a series of standard visual-perception, motor, visual-motor integration, and attention tests than did children with normal handwriting speeds.

**Method**

**Participants**

Teachers at two elementary schools in the greater Taipei area nominated 110 children from Grade 2 to Grade 6 to participate in the study. On the basis of between 6 and 18 months of classroom observations, the teachers evaluated 71 children as slow handwriters and the other 39 as having normal handwriting speed.

To ensure the accuracy of these groupings, the 110 referrals were each given the Chinese Handwriting Speed Test (CHAST; Tseng & Hsueh, 1997). In this test, children copy a text in pencil from a previously studied Chinese textbook, and handwriting speed is expressed as the number of Chinese characters written per minute. Incompletely written characters (three or more strokes omitted) are not counted. Characters with added strokes are counted. The intraclass correlation coefficient (ICC) for retest reliability was .98 with a 1-week interval. In this study, the ICC for interrater reliability was .95.

Using one standard deviation below the norm as the cutoff point, the children who scored below the cutoff point for the CHAST were assigned to the slow handwriter group (n = 34), and the children who scored above the cutoff point were assigned to the normal speed handwriting group (n = 35). Children whose teachers’ evaluations of handwriting speed and CHAST scores were inconsistent (n = 41) did not take further part in the study.

All participants had been receiving handwriting instruction in Chinese characters since Grade 1 and had normal intellectual function according to their school reports. The age and handwriting speed of the two groups of children are shown in Table 1.
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Table 1

Demographic Data of Slow Handwriters and Normal Speed Handwriters

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Mean Age (SD)</th>
<th>Mean Writing Speed (SD)</th>
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<td>Slow handwriting</td>
<td></td>
<td></td>
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<tr>
<td>Grade 2</td>
<td>4</td>
<td>88.4 (3.1)</td>
<td>3.6 (0.4)</td>
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<tr>
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<td>8</td>
<td>101.3 (8.6)</td>
<td>4.5 (1.0)</td>
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<td>Grade 4</td>
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<td>109.1 (2.3)</td>
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<td>Grade 5</td>
<td>5</td>
<td>125.4 (4.2)</td>
<td>9.0 (1.7)</td>
</tr>
<tr>
<td>Grade 6</td>
<td>5</td>
<td>135.6 (6.2)</td>
<td>9.3 (2.8)</td>
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<tr>
<td>Normal speed handwriting</td>
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<td></td>
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<td>Grade 2</td>
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<td>87.4 (3.1)</td>
<td>7.6 (2.4)</td>
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<tr>
<td>Grade 3</td>
<td>9</td>
<td>103.9 (6.6)</td>
<td>13.3 (2.8)</td>
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<tr>
<td>Grade 4</td>
<td>8</td>
<td>113.6 (3.8)</td>
<td>15.2 (2.2)</td>
</tr>
<tr>
<td>Grade 5</td>
<td>5</td>
<td>120.4 (4.6)</td>
<td>18.7 (2.8)</td>
</tr>
<tr>
<td>Grade 6</td>
<td>6</td>
<td>133.2 (7.1)</td>
<td>22.0 (2.8)</td>
</tr>
</tbody>
</table>

Note. N = 69, where n = 34 for the slow handwriting group and n = 35 for the normal speed handwriting group.

Instruments

Four measures, including three perceptual or motor tests and a vigilance test, were used in the present study. The Upper Limb Speed and Dexterity (ULSD) subtest of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP; Bruininks, 1978) was used to measure fine motor function. The BOTMP has been standardized on children ranging from 4.5 to 14.5 years of age. The ULSD subtest consists of eight items that involve placing pennies, sorting cards, stringing beads, displacing pegs, drawing vertical lines, and making dots. The test–retest reliability of the ULSD subtest was .89 for Grade 2 and .86 for Grade 6, with an interval of 7 to 12 days. The test–retest reliability ranged from .86 to .89, and the interrater reliability ranged from .79 to .97.

The Test of Visual-Perceptual Skills—Non-Motor (TVPS; Gardner, 1982), which measures nonmotor visual perception in children ranging from 4 years of age to 12 years, 11 months of age, was selected for the study because it covers a wide age range and examines various aspects of visual perception, including discrimination, memory, spatial relationships, form constancy, sequential memory, figure ground, and figure closure. It is also relatively easy to administer and score. The child is shown the test plates and is asked to point to the correct response from a series of choices. The TVPS has satisfactory internal consistency, with Cronbach’s alpha ranging from .66 (visual discrimination) to .97 (visual closure).

The Developmental Test of Visual-Motor Integration (VMI; Beery, 1989), which consists of 24 geometric forms to be copied in sequence from a test booklet, was designed for children ranging from 2 to 15 years of age. The geometric forms become progressively more complex, and the points for each successive, correctly copied form are added to the child’s score. Scores continue to accumulate either until all 24 forms have been copied or until three consecutive forms are copied incorrectly. The interrater reliability ranged from .58 to .99, and the test–retest reliability was .63 for an interval of 7 months and .92 for an interval of 2 weeks.

The Vigilance Task of the Gordon Diagnostic System (Gordon, 1991) was used to test the participant’s ability to focus and maintain attention over time and in the absence of feedback. The task presents a series of digits at a rate of one per second. The child is told to press the response button whenever a “9” follows a “1.” For the purpose of this study, the number of correct responses was totaled. Norms have been established on youngsters without hyperactivity who are 4 to 16 years of age (n = 1,300). Test–retest reliability was .68 to .85 with a 3-week interval.

Procedure

All children were tested one at a time in a separate, quiet room in the child’s own school. The perceptual or motor tests and the Vigilance Task (Gordon, 1991) were administered consecutively, with a 3-min break between each. Testing took approximately 40 min to 50 min for each child.

Data Analysis

Because many of the tests or subtests used in the current study have not been normed on Chinese children, raw scores were used for analysis. A multivariate analysis of variance (MANOVA) was performed to compare the scores of the slow and normal speed handwriting groups using the perceptual or motor measures and the Vigilance Task, and Pearson product-moment correlation was used to analyze the overall correlations. Stepwise regression analyses were performed to identify the best set of predictors, with handwriting speed entered as the dependent variable and the perceptual or motor measures and the Vigilance Task as predictor variables. Because the participants were drawn from Grade 2 to Grade 6, age was also entered as a predictor in the regression analyses.

Results

Group Differences

The normal speed handwriting group (n = 35) scored higher than the slow handwriting group (n = 34) on all measures (see Table 2). MANOVA revealed a significant difference between the two groups on all measures using Wilk’s lambda [.59905, F(10, 58) = 3.88193, p < .001]. Except on the Visual Closure and Visual Discrimination subtests, all of the univariate F test values were significant at the .05 level.

Correlation Among Handwriting Speed, Age, and Test Results

Tables 3 and 4 present the overall correlation matrices for the slow and normal speed handwriting groups, respectively. Age, the ULSD, visual memory, and visual sequential memory were the only four measures that correlated significantly with handwriting speed for both groups of handwriters.

Regression Analysis

Stepwise regression was used to identify the strongest pre-
dictors of handwriting speed for each handwriting group. Handwriting speed was selected as the criterion variable; age, the ULSD, the seven visual-perceptual subtests, VMI, and the Vigilance Task were the predictor variables. Given the small number of participants (n = 34 in the slow handwriting group; n = 35 in the normal speed handwriting group) relative to the number of predictor variables (n = 11), predictors with negligible correlations (r < .20) with handwriting speed were not included in the stepwise regression analysis.

For the slow handwriting group, the best predictors of handwriting speed were age, which accounted for 42.4% variance; visual sequential memory, accounting for 13.1%; and the VMI, accounting for 6.5% [F(3, 30) = 16.2997, p < .0001]. For the normal speed handwriting group, only age and the ULSD were found to be significant predictors. Age accounted for 64.4% of the variance, and the ULSD accounted for 9.95% of the variance in handwriting speed [F(2, 32) = 46.296, p < .0001].

Discussion

In this study, we found that, as a group, the slow handwriters performed less well than the normal speed handwriters on all measures (see Table 2). For the visual discrimination test and the visual closure test, however, the difference between the groups was not significant. Perhaps the familiarity of the written text to participants—it contained characters that the children had already learned—taxed less heavily the basic visual processing abilities of discrimination and closure. Task familiarity has been found to significantly influence handwriting speed (Dixon, Kurzman, & Friesen, 1993). Therefore, visual discrimination and visual closure may play a less important role in copying familiar texts.

Poor coordination or inadequate fine motor skills have often been invoked to explain slow handwriting speeds (Berninger & Rutberg, 1992; Levine et al., 1981; Lindsey & Beck, 1984; Sovik & Arntzen, 1991; Sovik et al., 1982). In this study as well, fine motor skill as measured by the ULSD was strongly correlated with handwriting speed in both groups (see Tables 3 and 4). However, the regression analysis showed that fine motor skill was only an important predictor of handwriting speed for the normal speed handwriting group and not for the slow handwriting group. This suggests that two different mechanisms might underlie the handwriting performance of the two groups, with the slow handwriters relying more heavily on visual processing, especially sequential memory and visual-motor integration, and the normal speed handwriters’ performance more related to upper-limb coordination.

The fact that visual sequential memory was the second best predictor for slow handwriters also might suggest that when intervention is required for slow handwriters, occupational therapy should be directed toward enhancing the memory for visual form and sequence. Although the present study examined Chinese handwriting, the importance of visual memory is similar to that reported in two studies on English written language in children with handwriting difficulties. Whereas Myklebust (1973) found these children had difficulties in mentally visualizing letters and words, Levine et al. (1981) noted their impairment in memory retrieval for visual patterns and sequences. Although it is possible to speculate on the differences between the processing of Chinese (a logographic script) and English (an alphabetic script), Tseng, Hung, Chen, Wu, and Hsi (1986) found overwhelming support from both a literature review and their own neurological studies of patients with brain damage that there are more similarities than differences in the processing of the two scripts. Both of the two scripts, for example, are processed in the left brain hemisphere on the basis of their phonological characteristics.

The finding that handwriting speed was strongly correlated with age for both slow and normal speed handwriters is consistent with previous studies (Hamnstra-Bletz & Blote, 1990; Sovik, 1975; Tseng & Hsueh, 1997; Ziviani & Elkins, 1984). Increased handwriting speed follows naturally from the empirically observed fact that coordinated handwriting movements improve with age and schooling (Meulenbroek & van Galen, 1986; Sovik, 1993).

The finding that the slow handwriters performed more
poorly in a laboratory measure of attention than the normal speed handwriters supports clinical observations of a strong relationship between slow handwriting and teachers’ ratings of inattention. This finding also suggests that a possible component of slow handwriting stems from difficulties with maintaining vigilance under unstimulating conditions. Helping parents and teachers to promote an optimal arousal level in order to facilitate attention span deserves occupational therapists’ serious consideration when working with children with slow graphomotor output.

**Conclusion**

This study was not an attempt to examine the relationship of quality or speed to handwriting performance. Quality and speed are important, and both should be addressed as valid and independent indicators of handwriting performance. This study is perhaps one of the few that examined slow handwriters and found that these children, as a group, were poorer than children with normal speed handwriting in graphomotor output, in level of perceptual-motor skills and proficiencies, and in attention.

Results of regression analyses showed that the slow handwriting group was not just slower than the normal speed handwriting group: They were qualitatively different in the way they processed written information. The performance of the slow handwriters seemed to heavily depend on visual processing, whereas that of the normal speed handwriters was motor based. Findings of this study suggest that intervention for slow handwriters should focus on facilitating visual processing, including memory and visual-motor integration, rather than the fine motor training so often emphasized in occupational therapy programs.

**Acknowledgments**

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**References**


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**Table 3**

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Note: n = 34.

*aVariables with r > .2 were tested as predictor variables in the regression analysis.

* p < .05, ** p < .01, *** p < .001.

**Table 4**

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Note: n = 35.

*aVariables with r > .2 were tested as predictor variables in the regression analysis.

* p < .05, ** p < .01, *** p < .001.
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