Handwriting Remediation: A Comparison of Computer-Based and Traditional Approaches

GWENYTH I. ROBERTS
MARILYN T. SAMUELS
University of Calgary

ABSTRACT This study compared the effectiveness of computer-based handwriting exercises (Lally & Macleod, 1982) with traditional instruction in the remediation of handwriting difficulties. Thirty-six students in Grades 4 to 6 with poor handwriting received one of three different instructional methods. In Method 1, students performed computer-based handwriting exercises using the Apple Graphics Tablet, an electronic pen, and the computer monitor to track visible and invisible letters. In Method 2, conventional instruction was provided using pencil, paper, plastic overlays, and felt pens to copy and trace letter forms. In Method 3, conventional instruction using tracing and copying was provided through the computer using the Touch Window and a stylus pen. Several measures were used to assess improvement in performance. The results indicated that the traditional group using pen and paper demonstrated significant improvements from pretest to posttest on five measures, and the computer groups on two measures. The findings suggest that traditional instruction using pen and paper is the more effective treatment method.

Handwriting offers an important means of communication and self-expression. Learning to write is a complex process, requiring formal instruction in school. For many, proficiency in handwriting skill is elusive and, despite regular instruction, deficits may persist. Children with handwriting difficulties are easily identified in the classroom setting. They are usually reluctant to write and try to avoid written activities. The students are generally identified by others when they present problems with legibility or speed in their written work. Failure to achieve the basic skills of handwriting may have far-reaching effects on a student’s motivation, self-image, and employment prospects.

The development of legible handwriting involves a number of skills, including refinement of motor movements and precision control, efficiency in attending to visual stimuli, and refinement in attending to salient features of a stimulus (Alston & Taylor, 1987; Boehme, 1988; Keogh & Sugden, 1985). According to Schneck (1991), once the nature and the mechanics of the operation of handwriting are learned, the movements become automatic and visual monitoring is reduced. Automatic script is directly related to the speed and level of skill in handwriting (Rubin & Henderson, 1982).

Proficiency in handwriting is the goal of remediation. Several instructional techniques that have been identified include: control of the writing space, clustering of the letters, modeling and noting critical attributes, physical prompts and cues, tracing and copying, and writing from memory; repetition, self-evaluation, self-instruction, relaxation, individualization, and corrective feedback and reinforcement.

Few studies have been reported on the development of new handwriting instruments and writing surfaces (Peck, Askov, & Fairchild, 1980). Methods to improve student motivation, provide immediate corrective feedback and elicit the perceptual aspects of handwriting skills have been suggested (Furner, 1985; Lally, 1982). With the increasing emphasis on technology and computers in our society, instructional software programs on the microcomputer are increasingly available. Well-designed computer software provides the student with individualized attention and continuous feedback and is based on positive reinforcement practices. Students maintain high levels of motivation for computer use (Becker, 1986).

According to Furner (1985), a comparison of the capabilities of computer-based instruction with the instructional techniques shown to be important in learning handwriting suggests that computer-assisted instruction (CAI) has the potential to facilitate learning in this basic skill area. The importance of using the computer for the remediation of handwriting skill is that CAI provides ac-
curate, immediate feedback for refined motor learning and precise letter formation, as well as enhanced motivation to learn this skill.

Macleod, Lally (1981) and colleagues in Australia developed computer-based handwriting exercises that they reported enable students to be both active and accurate learners. The program provides remediation with the aid of computer feedback. The computer-based system used in several studies (Lally, 1981, 1982; Macleod & Lally, 1981; Macleod & Procter, 1979) involved a PDP-11/20 computer and a DIGIVUE display screen. The display screen consisted of 512 by 512 neon-orange light points that could be lit or extinguished individually and used in conjunction with a digitizer pen. Writing was created by drawing a lighted track under the tip of the pen as it was pressed down and moved around the screen. A small cursor box on the display screen continuously indicated the calculated pen position. Thin guidelines were presented for each stroke and, as students tracked this line, it changed into a thicker path. A blinking cursor provided immediate feedback regarding the acceptability of the pen’s movements within the preprogrammed limits. The track ceased when the movement deviated from the acceptable standard or when the pen was lifted. The required accuracy of the tracking was adjusted by changing the cursor box size. The effectiveness of this program was investigated with various populations of students experiencing handwriting difficulties.

Macleod and Procter (1979) used the program with three teenaged mentally handicapped students who were initially unable to write their names in script, despite extensive instruction with traditional methods. They found that with one or two 15 min sessions per week, all subjects were able to acceptably write their signatures using pen and paper within 3 months.

A second study (Macleod & Lally, 1981) examined teaching of manuscript lower case letters to 18 mildly handicapped students with handwriting difficulties. Two matched groups of 9 students were assigned according to their pretest samples of the 26 letters. The experimental group received 3 half-hour individual computer-based exercise sessions per week for 5 weeks. The comparison group received an equivalent amount of traditional instruction. Teacher rankings of letters following instruction suggested that more subjects in the experimental group than in the comparison group showed improvement. The authors outlined several advantages that the computer-based handwriting exercises had over traditional approaches. These advantages included enhanced motivation and attention, minimization of errors, transfer of control of movement from visual feedback to kinesthetic feedback, and the requirement for active decisions in letter formation.

In another study by Lally (1982), mentally handicapped children between 9 and 16 years of age made the greatest improvement in handwriting performance when a reducing-size cursor box was used. The author suggested that this group improved the most because of the gradual shaping of finer and finer hand/finger movements. As well, the degree of external cues was reduced and the students had to rely more on internal memory of the forms to predict the sequence of strokes.

In the above studies, the transfer of control of handwriting from conscious visual feedback to unconscious muscular control was a problem as students experienced difficulty attending to anything other than the visual feedback. The writing was larger than normal because the equipment necessitated characters that were 3 cm high. In a study by Lally (1981), the relationship between visual and nonvisual feedback was made more distinct, with the aim of making children attend to kinesthetic feedback processes. The movements of the pen on the lower half of the screen were separated from the actual production of the tracking display, which was at the top half of the screen. The children could be taught regular-sized writing (0.7 cm) while being presented with a magnified presentation of the pen movements (3 cm) on the top of the screen. In the training, the size of the cursor box was gradually decreased from 15 mm to 5 mm in steps of 1 mm.

Raters ranked the posttest handwriting samples to be better than the pretest samples for all subjects. Observations made in this study were that (a) students used finer finger movements to guide the pen along the track, (b) students’ writing following the training program was smaller than before, and (c) the physical separation of visual and kinesthetic feedback made it easier for the learner to direct attention to those control functions that are required for fluent handwriting.

These four studies suggest that this computer-based handwriting exercise program provides several advantages in the remediation of handwriting skill. Furner (1985) reported that the approach facilitates perceptual learning and provides individualization in both the task demand and the nature of the feedback. Increased student motivation was presented as a definite advantage when using this medium. Changes in skill had been demonstrated when using the computer-based handwriting exercises with both the handicapped population and with those students in regular classes who presented with handwriting difficulties (Lally, 1981). Lally and Macleod (1982) suggested implementing the handwriting exercises on an Apple microcomputer and graphics tablet so that the program would be more accessible to the regular classroom setting. A major difference between the implementation on the Apple computer and the equipment used in their studies is the displacement of the visual feedback on the computer screen. No published research studies have been found in which use of this equipment is discussed.

The present study investigated the effectiveness of the computer-based handwriting exercises using the Apple
computer (Lally & Macleod, 1982) with mainstream students in Grades 4 to 6 who were experiencing handwriting difficulties. The major objective of this research was to compare this new computer-based program with more traditional instruction in the remediation of handwriting difficulties. The study compares three methods of cursive handwriting remediation. In Method 1, the students used computer-based handwriting exercises (Lally & Macleod, 1982). Students used the Apple computer, the Apple Graphics Tablet, and an electronic pen to track programmed visible and invisible letters. In Method 2, conventional instruction was provided using pencils, paper, plastic overlays, and felt pens to copy and trace letter forms. In Method 3, conventional instruction using tracing and copying was provided through the Apple computer using the Touch Window (Personal Touch Corporation) and a stylus pen. This latter method was used to control for motivational effects of the computer in treatment. Based on the Australian studies, we hypothesized that students participating in the computer-based handwriting exercises group would demonstrate a greater improvement in pretest to posttest scores than the two groups using more conventional handwriting instruction.

Method

Subjects

The subjects were elementary school students between the ages of 9 and 12, with (a) no history of severe language difficulties, (b) no history of severe attendance or behavioral problems, (c) normal or corrected normal vision, (d) no diagnosed neuromotor disability such as cerebral palsy or muscular dystrophy, and (e) instruction in manuscript and cursive writing in the previous elementary grades. The students were selected by teachers or occupational therapists on the basis of poor handwriting. Both normally achieving students and students previously diagnosed with learning disabilities who had poor handwriting were included in the study. Poor handwriting was defined as handwriting that interfered with the readability of the student's work or that was too slow to allow completion of written assignments.

Following referral to the study, the students were screened to determine whether they met more specific inclusion criteria of poor handwriting ability. Seventy-six students were referred to the project for initial screening. These referrals were received from a provincial children's hospital and from local school systems. Forty students were not included in the project for the following reasons: 29 students did not meet one or more of the specific inclusion requirements; 2 students did not receive parental consent to participate; 1 student moved away from the area; 1 student displayed unacceptable behavior at the time of the screening; and 7 students presented difficulty in the area of handwriting speed only. These latter students met the inclusion criteria but were not included in the study in order to achieve a more homogeneous grouping.

Participants in the study consisted of 36 students—12 subjects in each of the three treatment groups. A random-block technique was used to ensure greater homogeneity among the groups. We attempted to match age, sex, and diagnostic category of the subjects. The composition of the final three treatment groups is summarized in Table 1.

In each group, there were 2 students who had mild learning disabilities and 10 regularly achieving students. Each group was comprised of 10 boys and 2 girls. The average age of the participating students was 10.77 years.

Instruments

Screening Tools/Sample Handwriting Tasks

We used two handwriting samples to screen subjects for poor handwriting—a composition task and handwriting speed trials. We used these two tasks and two additional tasks—copying a paragraph and dictated phrases as pretest and posttest measures.

In the composition task, the students composed a short story based on the picture stimulus of the Story Test from the Test of Written Language (Hammill & Larsen, 1983). Handwriting speed trials were completed, based on a model outlined by Sovik (1975). The students memorized the sentence "A quick brown fox jumped over the lazy dog." They were then asked to write the phrase over and over at their normal speed during a 2-min time period. The copying of a paragraph task and the dictated phrases task were selected from the Slingerland Screening Tests (Slingerland, 1974).

The four handwriting samples were evaluated using the Handwriting Evaluation Scale developed by Malloy-Miller (1985). The scale involves a direct analysis of handwriting and Learning Ability

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment A (Computer-based exercises)</th>
<th>Treatment B (Traditional, using the computer)</th>
<th>Treatment C (Traditional instruction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of subjects in each group</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Learning ability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L.D.</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>non-L.D.</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Age (in months)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>128.83</td>
<td>129.92</td>
<td>129.08</td>
</tr>
<tr>
<td>SD</td>
<td>10.62</td>
<td>13.94</td>
<td>9.89</td>
</tr>
</tbody>
</table>
writing errors, using a correct/incorrect procedure based on written criteria. Malloy-Miller found that eight handwriting error categories were significant in discriminating good handwriters from poor handwriters. These categories included: size relations (within words), size relations (between words), spacing of letters, spacing of words, line quality, baseline orientation, closure, and speed. These eight categories were identified in the four handwriting samples and evaluated using the correct/incorrect procedure.

Transfer Tasks

Five tasks were used as pre- and posttest measures to determine if changes occurred in areas related to handwriting. These tasks included tracing a line (Ayres, 1980), copying geometric forms (Beery & Buktenica, 1967), individual letter formulation, and two computer tasks. One of the computer tasks used the Touch Window (Personal Touch Corporation) and the students were asked to copy geometric forms (Bruiniks, 1978) with a stylus pen. The other computer task used the Apple Graphics Tablet (Apple Computer, Inc.) and involved one item from the computer-based handwriting exercises (Lally & Macleod, 1982). The raw scores from these tasks were tabulated.

Instructional Tools

Computer-based handwriting exercises (Lally & Macleod, 1982). This method uses an Apple Graphics Tablet (Apple Computer Inc., 1979) as the writing surface. The Apple Graphics Tablet has an 11-in. × 11-in. surface that can be activated when the user touches the surface with an electronic pen. The writing surface and pen are positioned below and in front of the monitor. The pen is attached to the tablet and is used on the tablet to control a cursor on the computer monitor. The pen does not leave any marks on the tablet. The pen/cursor is used to track visible or preprogrammed letters that appear on the monitor. As the students move the pen and cursor to trace the presented letter, the track on the monitor thickens in appearance. A high beep occurs when a directional change in the letter form is to be made. If the pen/cursor leaves the track, a low beeping noise occurs to indicate an error. The thickening of the track is interrupted at this point and resumes when the cursor is returned to the appropriate spot on the model letter track. Small writing on the graphics tablet is magnified in appearance on the computer screen. As accuracy improves, the size of the cursor is decreased from 15 mm to 5 mm. The computer records both accuracy and speed. The students’ actual pen movements may be displayed following completion of the exercise, if desired, but there is no model present.

Conventional handwriting instruction using the computer. This method uses a Touch Window (Personal Touch Corporation, 1985) as a graphics tablet/writing surface and a stylus pen and paper. The Touch Window is a transparent, touch sensitive surface. Paper with the model letters or words is placed under the Touch Window. The students trace or copy the letter forms seen on the paper onto the Touch Window and the letter forms appear on the computer screen. The letters practiced are large and small. The letters are evaluated by the instructor and student for form and accuracy. Small-letter formation is also practiced on paper alone.

Conventional handwriting instruction. This method uses paper, pencil, and felt pens to trace and copy the various letter forms. Both large and small letters are used in instruction. The letters are judged by the instructor and student for accuracy and form.

Procedure

Phase 1: Screening

Two sample handwriting tasks of speed and composition were used to evaluate eligibility for participation in the study. These tasks were marked according to predetermined criteria of legibility and speed. The students were either assigned to groups or eliminated from the study at the end of this phase.

Phase 2: Pretest

During the pretest session, the student performed two additional handwriting tasks and five transfer tasks. For all handwriting samples, the students were required to produce cursive writing only. Following the pretest, the handwriting samples were examined, noting specific difficulties with closure, baseline, space, size, line quality, letter formation, or slant. These observations were written on the individual students’ records, and problem letters were identified. A description of the students’ performance while writing was also taken.

Phase 3: Treatment

Several procedures were similar in each of the three treatment groups: Seven lessons lasting 40 min each were provided; the lessons were arranged by letter groupings according to the similarity of strokes involved in the formational sequence (the upstroke, the overcurve and the downcurve); letters of the alphabet were practiced individually, with more emphasis on problem letters that had been identified during the pretest; instruction was included for positioning and pencil grip; the letters were demonstrated, noting the critical attributes; a verbal description of the stroke sequence was provided by the instructor as the demonstration was presented and self-verbalizations of the students were encouraged but not required; physical prompts and cues were provided as necessary as the students formed the letters; in the targeted letters, some form of tracing/copying was provided, as well as writing from memory; the procedures were repetitive; self-correction was encouraged; and positive feedback on performance and encouragement was received.
from the instructor. Speed of the handwriting skill was not addressed formally in the remediation programs. The main focus of the remediation was appropriate formation, size, and alignment of the letters.

The major differences among the treatment methods were the instructional tools used. The traditional pen-and-paper method used plastic overlays and felt pens, whereas the traditional computer method used the computer with a Touch Window and a stylus pen. The computer-based exercises method used the computer with an Apple Graphics Tablet and an electronic pen. This latter method had a number of instructional features that were not present in the traditional groups as previously described.

**Phase 4: Posttest**

Posttest samples were taken within 1 month of the pretest. These involved the same tasks as the pretest, as well as the handwriting sample tasks of speed and composition.

**Phase 5: Parent-Teacher Rating**

The parents and teachers of the students who participated in the study received a sample of the students' handwriting from the pretest and from the posttest (copying a paragraph sample). The identifying information and time of testing was not provided. The parents and teachers were given a scoring guide (Hammill & Larsen, 1983) and were asked to place a number rating on the students' samples.

**Phase 6: Scoring**

All the writing samples (both pre- and posttest) were scored by two raters using seven error categories of The Handwriting Evaluation Scale, following training to establish interrater reliability. The raters included the first author and an occupational therapist experienced in the rating of handwriting legibility. A reliability estimate for each error category was calculated, based on percentage of agreement considering all possible agreements. An overall reliability of .93 was calculated from the raw percentage agreements. The raters then proceeded to independent scoring of 36 test packages each. Each of the seven error categories was marked independently and separately by the raters. The raters were blind as to the subject identification or the time of test. Tasks were scored in random order.

**Phase 7: Reporting/Conferencing**

The students' assessment and treatment results were discussed with (and/or a written report provided to) the parents or teachers of those who requested this service.

**Results**

Fifteen variables were measured including the Handwriting Evaluation Scale ratings on legibility and speed (8), the transfer task scores (5), and the parent-teacher ratings (2). The Handwriting Evaluation Scale measures were based on scores of the percentage of correct responses in each of eight categories. The transfer task measures used raw scores. The parent/teacher ratings measure used a number score from 0 to 10 based on a scoring guide. The data were collected on 36 subjects at pretest and at posttest. Pretest to posttest gain scores were calculated on 14 of these variables. The spacing of letter variables was eliminated from the analysis because few errors were observed in the pretest or posttest samples.

An analysis of the factors involved was performed to determine whether the number of variables could be reduced. In the analysis, we found that there were 10 common factors. Reduction in the number of variables from 14 to 10 was not considered useful because there was limited interpretation of the new factors. The number of variables was, therefore, left at 14.

Pretest to posttest scores improved for most of the 14 variables except speed, for which lower scoring was observed in the posttest. Minimal changes were observed in 5 variables. Correlated $t$ tests were calculated for pretest to posttest gain scores in the 14 variables for the three treatment groups. In the computer-based handwriting exercises group, significant differences in the pretest to posttest scores were noted in 2 variables: computer exercises, $t = -8.40, p < .001$ and teacher rating, $t = -3.10, p < .01$.

In the group receiving conventional handwriting instruction using the computer, significant differences in gain scores were noted in two variables: closure, $t = -4.49, p < .001$ and parent rating, $t = -6.27, p < .001$. In the group receiving conventional handwriting instruction using paper and pencil, significant differences in the pretest to posttest scores were noted in five variables: size relations—within words, $t = -3.65, p < .001$; baseline orientation, $t = -3.07, p < .01$; letter formation, $t = -4.55, p < .001$; parent rating, $t = -3.82, p < .001$, and teacher rating, $t = -5.07, p < .001$.

We used multivariate analysis of variance (MANOVA) to determine whether the pretest groups were similar on the 14 variables. On the basis of this test, we accepted the null hypothesis that the groups did not differ, $F(28) = .537, p = .955$. We then performed a MANOVA using the pretest to posttest gain scores of the 14 variables. This test was performed to assess whether the three treatment groups differed on these variables. On the basis of this test, we rejected the null hypothesis and accepted the alternative hypothesis that the groups differed, $F(28) = 2.397, p = .005$. We performed discriminant function analysis and calculated two discriminant functions. The discriminant functions were plotted using group centroids (means of discriminant scores). As shown in Figure 1, the first discriminant function discriminates the traditional group using pen and paper (G3) from the other two groups. The second function maximally separates the
computer-based exercises group (G1) from the traditional group using the computer (G2), with the traditional group using pen and paper (G3) falling between these two groups. For the first discriminant function, the primary predictors included the variables of letter formation and teacher rating. The traditional group using pencil and paper (G3) improved the most in these variables.

Discussion

The results of this study indicate that the subjects did not benefit equally from the three treatment methods. The findings do not support the hypothesis that students participating in the computer-based handwriting exercises group would demonstrate a greater improvement in pretest to posttest scores than in the conventional handwriting instruction groups. The results also indicate that the traditional group using pen and paper displayed the greatest difference on a linear combination of the pretest to posttest variables, particularly demonstrated through the letter formation and teacher rating measures. The computer groups were the most similar in outcome, although the computer-based handwriting exercises group performed better on the computer-based exercises variable.

This study did not replicate the findings of Macleod and Lally (1981). They found that the computer-based handwriting exercises group was superior to a group receiving an equal amount of traditional instruction. Some of the factors that may have contributed to this difference include the equipment and the instructional features used in the computer-based groups, the type of instruction used in the traditional groups and the measures used.

The Equipment and Instructional Features of the Computer-Based Systems

The features of the computer-based exercise program used in the Macleod and Lally (1981) study were slightly different from the features advocated later by the Australian researchers (Lally & Macleod, 1982, 1983). The 1981 study involved use of the PDP system with a DIGIVUE screen and did not involve features of displacement and magnification of visual feedback. The use of the Apple Graphics Tablet was advocated by Lally and Macleod (1982), although studies comparing the effectiveness of this equipment with more traditional instruction were not performed. Lally and Macleod made assumptions that the benefits of the computer-based handwriting exercises using the PDP system are generalized to use of the Apple system. The results of this study suggest that this may not be the case.

Osguthorpe and Chang (1987) found that the Apple Graphics Tablet was not as dependable as a comparative tablet, largely due to the sensitive connection between the pen and the computer. In the present study, we found that the sensitive connection between the pen and the tablet interfered at times, creating errors during the handwriting exercises and causing the students to appear frustrated with the medium.

In several studies performed by the Australian researchers (Lally, 1982; Macleod & Lally, 1981) the track the students created was directly under the pen tip. Later investigations recommended separation of the visual and kinesthetic feedback. In the present study, the computer-based handwriting exercises involved displacement where the students performed the pen movements on the Apple Graphics Tablet on a desk surface with the tracking of the letters appearing on the computer screen. Clarification is needed in future studies to determine whether it is beneficial to separate visual and kinesthetic feedback. Many authors advocated the integration of the kinesthetic and visual processes rather than separation in learning (Ayres, 1973; Birch & Lefford, 1967; Jung, Kornhuber & DaFonseca, 1963). Held and Rekosh (1963) stressed that visual space perception can be upset seriously by disrupting the normal relation between self-produced movement and its concurrent sensory feedback. Whether the displacement of visual feedback from the kinesthetic feedback upsets the "normal relation" is not known. The separation of visual feedback from kinesthetic feedback may have had a negative effect on the subjects' motoric response in that this separation may interfere with performance on tasks that require automaticity. We speculated that in the computer-based handwriting exercises group, the displaced visual
feedback may have interrupted the students' perceptions rather than aided the kinesthetic component.

Another comment on the visual feedback in the computer-based handwriting exercises (Lally & Macleod, 1982) is that the students' attempts to approximate letter shapes while tracking causes the computer to draw well-formed model letter shapes on the display screen. The children see the desired product rather than their own possibly ill-formed attempts. Welford (1976) suggested that feedback should give information to the student that is clearly and simply related to the action and that indicates any discrepancies between what has been achieved and what was required. According to Ayres (1973), studies indicate that problems occur when there is disparity between visually perceived apparent motion and actual motion. Sovik's (1981) theory of psychomotor control, underlined the importance of the information that individuals receive from their own actions during the execution of a task. In the computer-based handwriting exercises, the students do not observe their path in comparison with the true path. It may, therefore, be difficult to perceive the deviation and to adjust for this in future performances. The feedback of the student's actual performance is delayed and may not be beneficial at that point. In the traditional treatment group using pen and paper, the students were more involved in deciding whether the letter was properly formed. This direct feedback may have contributed to their better performance in letter formation.

In the Macleod and Lally (1981) study, large writing was used on the PDP computer system with no magnification. In 1982, Lally and Macleod reported that the students' small hand movements resulted in larger visual movements on the display screen, with a goal of promoting nonvisual processes to control the handwriting skill. In the present study, the students in the computer-based exercises group produced small pen movements on the Apple Graphics Tablet (1.5 cm) and the magnified tracking of the letters (6 cm) appeared on the computer screen. In the traditional group using pen and paper, a large size of writing was used initially (6 cm), prior to engaging in standard size cursive writing. The computer-based handwriting exercises group did not experience the larger writing and perhaps, the accompanying kinesthetic feedback. The accuracy of letter formation may have been enhanced by the large size of writing used in the traditional group using pen and paper and in Macleod and Lally's (1981) study.

Auditory feedback is also incorporated as one of the features of the computer-based handwriting exercises. Each time the direction of the stroke is to be changed, a beep occurs to indicate this change. A different beep is heard every time the students leaves the specified track of the model letter. A record of the number of times the students leave the track is kept and "number of errors" is displayed at the end of each exercise, along with a value for speed. Lally and Macleod (1983) reported that most students were intensely interested in their performance in speed and accuracy, and this was also true in the present study. The effect of the negative feedback received if progression did not occur rapidly may have affected outcomes.

Tracking used in the computer-based group, was a combination of tracing and copying. The cursor in the computer-based handwriting exercises was initially large, providing more of a model to the students. As the skill of tracking improved, the cursor size was reduced and provided less of a lead in demonstrating the model formation of the letter. The students participating in the computer-based handwriting exercises experienced difficulty with the smallest cursor box size (5 mm), performing repeated "back tracking" movements of the pen.

The program does not allow for uniqueness in legibility, as the students must track model letters in order to perform correctly. Plattor and McQueen (1986) suggested that individual differences in handwriting should be accepted, provided that the writing is legible. This occurred in the traditional groups. In the computer-based handwriting exercises group, the students became concerned with the errors incurred in tracking rather than with the process of writing itself.

Instructional Methods in the Traditional Groups

The type of instruction used in the traditional comparison group in Macleod and Lally's (1981) study was not described. It is not specified whether the instruction was individual or group. In the present study, the traditional paper-and-pencil instruction involved individual sessions.

Measurements Utilized

In the present study, the instruments used to measure improvement in performance were specific and examined the components involved in the handwriting task. In Macleod and Lally's (1981) study, the results were based on a more global measure, that of teacher ranking. The differences in measurement technique may have affected outcomes.

Summary and Conclusions

The results of the present study concurred with previous findings that handwriting skill is composed of several component parts. The findings also indicated that when students are learning new aspects of the handwriting task that their speed of writing decreases. The implications of the study suggest that further investigation is needed in delineating the components of handwriting skill. Our findings also suggest that the individual features used in the instruction of handwriting must be studied separately, whether implemented through a computer-based system or when using a more traditional model. This particular study suggests that conventional instruction of handwriting using pen and paper is super-
ior to the computer-based handwriting system developed by Lally and Macleod (1982) using the Apple Graphics Tablet. The assessment procedures and the instructional features that we used in this study are proposed as critical variables in the outcomes. Further study is required to determine the most effective instructional features in handwriting remediaion and the use of these features in future computer-based handwriting programs. One should not conclude that all computer-based handwriting systems would be less effective than traditional instruction. Limitations to the present study are recognized by our use of small sample sizes and the reliability problems inherent with gain scores. The ability to generalize from these data is extremely limited, and the study should not be construed as a comparison of traditional and computer-directed handwriting remediation in any generic sense. Replication of the study is required using larger sample sizes.

REFERENCES


