Relationship Between Handwriting and Keyboarding Performance Among Fast and Slow Adult Keyboarders

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KEY WORDS
- computers
- eye movements
- handwriting
- kinesthesia
- motor skills
- proprioception

OBJECTIVE. We examined the relationship between handwriting and keyboarding performance and between these writing modes and underlying performance skills.

METHOD. Sixty-three young, healthy adults who used the computer daily were recruited for this study by means of a convenience sample (mean = 25.3, standard deviation = 3.0); 15 were slow keyboarders and 17 were fast keyboarders. Participants were administered handwriting and keyboarding assessments, as well as measures of finger function, kinesthetic processing, and eye movement.

RESULTS. Although handwriting and keyboarding speed were moderately correlated, these activities did not share underlying performance skills. In addition, different correlation patterns between written communication modes and performance skills were found among slow and fast keyboarders.

CONCLUSION. Results suggest that occupational therapists and educators should consider a variety of factors before recommending keyboarding as an alternative written communication method for people with handwriting difficulties. Moreover, different recommendations appear to be warranted for slow and fast keyboarders.


Writing is an important tool, enabling opportunities for both intra- and interpersonal communication (Yinon & Weintraub, 2000). As early as the first year of school, children are taught to write; they use writing to summarize information taught in class, to complete assignments, to take tests, and to interact with others for noneducational purposes. The acquisition of writing skills is a complex process, demanding both intensive and extensive time and practice (Graham & Weintraub, 1996).

Proficient writing is defined as fluent sequences of strokes that are executed without high levels of effort and with reasonable speed and whose output is readable (Yinon & Weintraub, 2000). Despite the fact that most students achieve proficient writing, 12% to 21% of students are classified as having writing difficulties (Rogers & Case-Smith, 2002). Children with writing difficulties often display poor letter formation or poor organization and planning during writing (Handley-More, Deitz, Billingsley, & Coggins, 2003; MacArthur, 2000). As a result, their writing may be illegible or slow and inefficient (MacArthur, 2000). These difficulties are likely to affect children’s self-efficacy, negatively affecting their motivation to write and to express themselves using this medium (Graham, Schwartz, & MacArthur, 1993).

Children with writing difficulties are often referred to an occupational therapist (Cornhill & Case-Smith, 1996). In general, intervention is based largely on a remedial model, in which the focus of therapy is on improving performance skills and...
assisting students with their writing (Amundson & Weil, 1996). However, there are circumstances in which, even after intervention, students’ writing is not proficient enough to support their studies and communication. In such cases, other strategies and compensatory intervention models, such as using a computer (i.e., keyboarding) to support writing, are considered (Freeman, MacKinnon, & Miller, 2005).

In recent years, researchers have sought to identify the skills necessary for proficient handwriting. By contrast, little work has been done examining the skills necessary for proficient keyboarding. To determine the relative advantages of keyboarding versus handwriting and whether the former could serve as a viable alternative for the latter, it is necessary to compare these activities in terms of performance and what they entail.

**Relationship Between Handwriting and Keyboarding**

The literature on the relationship between handwriting and keyboarding is scant. Moreover, it is difficult to compare the studies because of the different number of hours spent on keyboarding, the testing methods, and the operational definitions of speed and accuracy. In examining these two activities, it appears that they share some common requirements. First, the linguistic processes required for writing by means of handwriting and keyboarding—such as planning, generating words, and retrieving knowledge from long-term memory—are similar (Berninger, Abbott, Whitaker, Sylvester, & Nolen, 1995). Thus, it is not surprising that these two writing modes share common underlying linguistic processes, such as orthographic coding and rapid automated naming (RAN; Berninger et al., 2006).

The two activities are also similar in the acquisition processes they require. Initially, people rely mostly on visual feedback to guide the motor movements required for handwriting or keyboarding. As they become more proficient, there is greater use of proprioception and kinesthesia to form the letters or press the keys (Benbow, Hanft, & Marsh, 1992; Sormunen, 1993). The similarities in these activities may explain the results of various studies showing low to high correlations between keyboarding and handwriting speed as early as first and third grades (Berninger et al., 2006) and upper elementary school (e.g., Connelley, Gee, & Walsh, 2007; Preminger, Weiss, & Weintraub, 2004; Rogers & Case-Smith, 2002). These results indicate that handwriting and keyboarding speed not only share common processes but also draw on unique processes. In addition, although no significant correlations between handwriting and keyboarding accuracy were attained (Preminger et al., 2004), a low but significant correlation was found between keyboarding speed and handwriting legibility (Rogers & Case-Smith, 2002).

**Performance Skills Related to Handwriting and Keyboarding**

Because of the similarities in the linguistic process of handwriting and keyboarding, in the current study we focused instead on the various sensory–motor skills underlying handwriting and keyboarding that may be different. In examining the relationship between handwriting or keyboarding and underlying performance skills, it is evident that, unlike handwriting, only a few empirical studies have investigated the sensory–motor demands of keyboarding, and even fewer studies have compared the underlying skills of these two writing modes (for a review, see Freeman et al., 2005).

**Finger Functions**

Various studies have shown that both handwriting and keyboarding require fine motor finger functions. For example, in-hand manipulation was correlated with handwriting legibility (e.g., Cornhill & Case-Smith, 1996; Feder & Majnemer, 2007). In addition, Berninger and Rutberg (1992), Premerger et al. (2004), and Weintraub and Graham (2000) reported that finger functions (i.e., finger succession, finger dexterity tests) were related to handwriting performance. Similarly, finger dexterity was found to be correlated with keyboarding (e.g., Gennier, 1987; McClurg & Kercher, 1989; Preminger et al., 2004). Yet, Berninger et al. (2006) did not find that finger succession significantly correlated with keyboarding speed among elementary school students.

**Kinesthetic Processing**

In analyzing handwriting and keyboarding, it is clear that both communication modes entail constant feedback through the proprioception and kinesthesia systems as well as visual monitoring (Chwirka, Gurney, & Burtner, 2002). However, most studies did not find a correlation between kinesthetic processing and handwriting (e.g., Preminger et al., 2004; Sudsawad, Trombly, Henderson, & Tickle-Degner, 2002) or keyboarding performance (Preminger et al., 2004).

**Eye Movement**

Reading and writing rely on eye function (Berninger et al., 2006). A few studies have shown that oculomotor movement is an important factor in reading (DeLuca, Di Pace, Judica, Spinelli, & Zoccolotti, 1999; Pirozzolo & Rayner, 1978) and speed of handwriting and keyboarding (DeLuca et al., 1999; Preminger et al., 2004). Therefore, it appears that this relationship needs to be further explored.
The studies described previously related to school-age children, and their results are equivocal; it is not clear whether adults show similar patterns. Moreover, many of the studies relating to keyboarding were performed on children who learned *touch typing*—a typing system in which the individual’s fingers are trained to hit particular keys (WordNet Search—3.0, 2008)—as part of the study, thus limiting the automaticity of their keyboarding. It is, therefore, difficult to make reliable conclusions regarding the relationship between keyboarding and individual performance skills. There is a need for more studies in this area and, specifically, in relation to adults.

This study examined the relationship between speed and accuracy of handwriting and keyboarding among young healthy adults. In addition, because of the lack of sufficient knowledge as to the commonalities between handwriting and keyboarding performance, we examined the relationship among performance skills, handwriting, and keyboarding. Specifically, we focused on finger functions, kinesthetic processing, and eye movement. These questions were raised in relation to the general population of the study, as well as the differences between fast and slow keyboarders.

The population selected for this study included those who regularly use a computer in their everyday lives so that skills of those with previous experience and expertise could be investigated. This choice of population was based on the assumption that by gaining an understanding of the skills of proficient keyboarders, it would be possible to understand the individual factors that contribute to skilled keyboarding. Consequently, this could enable one to understand possible correlations between handwriting and keyboarding. The results of this study may assist in a more in-depth understanding as to which people would benefit from keyboarding as an alternative means of written communication.

**Method**

**Participants**

The study population included 63 volunteers (26 men, 37 women), ages 20 to 30 years (mean $M = 25.3$, standard deviation $SD = 3.0$), who were recruited by means of a convenience sample. Their main written language was Hebrew, and all had attended school in Israel since at least the second grade. The mean years of education was 14.0 ($SD = 1.9$). Forty-five participants (71.4%) were university students, and the rest worked in various professions, such as education, engineering, and allied health professions. Participants reported that they had never experienced any upper limb, neck, or back problems (including pain, inflammation, or fractures).

The study inclusion criteria also required that all participants had been typing for at least 3 hr per week for $>1$ year. The mean amount of keyboarding time per week ranged from 3 to 60 hr ($M = 9.17$, $SD = 10.36$). Fifty-six (88.9%) participants used two hands during typing, whereas 7 (11.1%) used only one hand. Only 2 participants typed using touch typing; the others relied on vision when typing. Fifty-four participants (85.7%) were right-hand dominant.

The participants were divided into two groups according to their keyboarding speed. The mean typing speed of the fast keyboarding group (top quartile, $n = 168$ characters per minute ($SD = 32.6$). The mean typing speed of the slow group (the bottom quartile, $n = 15$) was 86.2 characters per minute ($SD = 12.8$). The other participants were not included in the analyses of group differences. Table 1 describes the group’s demographic characteristics. Analysis indicated that the groups did not significantly differ in terms of gender, occupation, age, or education. However, the fast keyboarders did spend significantly more hours on the computer compared with the slow keyboarders ($t(45) = -2.21$, $p = .04$).

**Instruments**

**Participant Questionnaire.** The participant questionnaire developed for this study related to the following topics: (1) demographic information (e.g., name, gender, age, and education), (2) items relating to the general study criteria (e.g., past and present keyboarding and writing experience), and (3) questions identifying possible writing difficulties and general level of writing and keyboarding.

**Handwriting and Keyboarding Assessment.** The handwriting and keyboarding assessment (Gilmour & Weintraub,
2005) consisted of four subtests, each lasting 3 min: (1) copying a written paragraph in writing, (2) copying a paragraph in typing, (3) writing a dictated paragraph, and (4) typing a dictated paragraph. The texts chosen for all subtests were taken from the same journal for adults, so that the writing style and reading level of the paragraphs were the same and were suitable in terms of language and level to the population being tested. In this study, we focused only on the copying task because of the high correlation between copying and dictation performance \( (r = .82, p = .00) \). Writing tests were completed on a pad of lined paper, which is commonly used by students; pens were provided by the researchers. In the keyboarding tests, participants were required to type using the standard QWERTY keyboard layout (i.e., the standard keyboard arrangement) placed on a table at a height of 74 cm (30 in.) from the floor directly in front of the screen.

**Speed of writing-keyboarding** was calculated as the mean number of characters (letters, punctuation marks, and spaces) per minute (the sum of letters written or typed within 3 min divided by 3). **Accuracy of writing-keyboarding** was measured as a percentage of errors, that is, total characters written or typed minus errors (e.g., additions, omissions, incorrect letters), divided by the total number of letters written or typed, multiplied by 100. This formula was used in a previous study (Preminger et al., 2004). **Handwriting legibility** was scored on a 7-point scale with 1 being very legible writing and 7 being very illegible writing. Evaluation of legibility was based on the criteria of the Handwriting Assessment for Middle School (Weintraub, Drory-Asayag, Dekel, Jakobovits, & Parush, 2007).

In addition, an observation sheet of handwriting and keyboarding performance was completed while the participants were engaged in these tasks. The observation sheet was developed for this study on the basis of the Hebrew Handwriting Assessment (Erez & Parush, 1999). During the handwriting task, the observer monitored hand dominance, pencil grip, seating posture, handwriting fluency, and the like; however, during keyboarding, observation focused on the number of fingers used on each hand and the use of visual guidance. To determine interrater reliability, scores were allocated by two occupational therapists for 20 participants who were randomly selected. A strong positive and significant correlation was found \( (r = .743, p < .01) \).

**Functional Dexterity Test.** The Functional Dexterity Test (FDT; Aaron & Stegink Jansen, 2003) was used to evaluate participants’ ability to perform functional tasks with the fingers using a dynamic pencil grip over a short amount of time. The measure was developed for use with adults ages ≥20 years. The score is based on performance time. The interrater reliability of the FDT was very high \( (r = .99, p < .01) \) when all results were included.

**Finger Keyboarding Tapping Test.** The Finger Keyboarding Tapping Test (FKTT; Gilmour, 2005) was adapted for use in the current study on the basis of the original Finger Tapping Test (Spreen & Strauss, 1991) and assessed bilateral motor speed. This task mimicked the act of keyboarding while controlling for the linguistic aspect of writing. In the FKTT, participants placed the index fingers of each hand on a specific key of the keyboard. They were then requested to press each key in an alternating manner for 10 s as fast as they could. **Speed** was calculated by counting the number of letters that were typed. **Percentage of accuracy** was calculated as the total number of letters typed, minus the number of errors (incorrect letters), divided by the total number of letters, multiplied by 100.

**The Purdue Pegboard.** The Purdue Pegboard (Tiffin, 1960), developed for use among adults, measures speed and dexterity. The Purdue Pegboard consists of four subtests. In this study, we focused on three of the subtests: Dominant Hand, Both Hands, and Assembly. Separate scores are recorded for each subtest. The Purdue Pegboard test was found to have high interrater and test–retest reliability (\( .84 < r < .91 \)). In addition, the Purdue Pegboard was found to have high discriminant validity (i.e., differences between the typical population and those with poor motor skills because of brain injury, with the highest validity seen in the Assembly subtest \( (r = .76, p < .001) \); Lezak, 2004).

**Pediatric Examination of Educational Readiness at Middle Childhood.** The Pediatric Examination of Educational Readiness at Middle Childhood (Levine, 1984) is a neurodevelopmental assessment that has been shown to be related to handwriting (Sandler et al., 1992) and keyboarding skills (Preminger et al., 2004). In this study, we used only the Pencil Excursion subtest, which measures kinesthetic skills during a graphomotor task. Although the test is designed for children ages 9 to 15, it was used here because we found no other relevant measures of kinesthetic processing for adults. To ensure the suitability of this test, we first administered the test to seven adults and found no ceiling effects. The final score was calculated by adding the three scores on the score sheet.

**Developmental Eye Movement.** The purpose of the Developmental Eye Movement (DEM; Garzia, Richman, Nicholson, & Gaines, 1990) is to assess deficiencies of eye function. The DEM includes two tasks. In the first task (Horizontal), participants are required to read 80 numbers aloud, as fast as possible, from left to right and line by line without using their finger. For this task, a horizontal adjusted time (in seconds) score is calculated using the following formula: time it took participant to read numbers \( \times 80 \) (numbers)/\( 80 – \) omission errors + addition errors. In the second task (Vertical), participants are required to read 80 additional
numbers from top to bottom arranged in four columns. The score for this task is determined by the performance time (reading the numbers). The authors stated that the score of this task does not take errors into consideration because they are very rare. In addition, a ratio score is calculated as the relation between the horizontal adjusted time and the vertical time. Construct validity was demonstrated by means of a correlation between the DEM test and the reading test of the Wide Range Achievement Test: \( r = - .79 \) for the Horizontal task and \( r = -.55 \) for the Vertical task (Garzia et al., 1990). In this study, we reported the Horizontal score, which reflects the act of reading and the ratio score.

Procedure

The study was approved by the university institutional review board. The participants signed a consent form indicating that all personal details would be kept confidential. The study goals, process, and requirements were described. The study took place in a quiet room that included a computer screen and keyboard. Participants sat in an office chair near the table that was adjusted to comply with standard ergonomic guidelines; a footrest or other support was provided as necessary. Each participant individually completed a 1-hr testing session. To reduce any influence of fatigue on the results, tests were administered in different orders for successive participants.

Data Analysis

Analyses were performed using SPSS Version 12 (SPSS, Inc., Chicago). Pearson correlation coefficients were used to determine the associations between handwriting and keyboarding performance as well as between these modes of written communication and performance skills. With the purpose of comparing the fast and slow keyboarders in relation to handwriting performance and performance component skills, we used a multivariate analysis of variance while controlling for the number of hours the participants keyboarded per week. The decision to control for hours of keyboarding was based on the fact that the groups significantly differed in relation to this factor \((p = .04; \text{see Participants section})\).

Results

First, using Pearson correlations we examined the relationship between speed and accuracy of keyboarding and the speed, accuracy, and legibility of handwriting (see Table 2). Handwriting and keyboarding speed were significantly correlated \((r = .52, p < .00)\). Linear regression analysis indicated that handwriting speed accounted for 25.5\% of the variance in keyboarding speed \( (F[1, 16] = 22.236, p < .00) \). In comparing the mean speed in handwriting \( (M = 141.96, SD = 24.24) \) and keyboarding \( (M = 122.05, SD = 35.54) \), we found that students’ handwriting was approximately 10\% faster than keyboarding, yet there was a greater variance in students’ keyboarding speed.

By contrast, there was no significant correlation between handwriting legibility and accuracy and keyboarding accuracy. Both legibility and accuracy measures were included in the analysis to examine the relationship to keyboarding in terms of a functional measure of handwriting (legibility) and a measure that was similarly defined (accuracy). Students’ percentage of accuracy in keyboarding was very high \( (M = 97.28, SD = 2.51) \).

To examine outcomes in greater detail, we looked at slow and fast keyboarders separately. Among the slow keyboarders, typing speed was approximately 60\% slower than handwriting speed \( (M = 86.16, SD = 12.81, \text{and } M = 130.58, SD = 21.99, \text{respectively}) \). In addition, we found no significant correlation between the speed in handwriting and keyboarding \( (r = .19, p = .50) \). By contrast, the fast keyboarders typed somewhat faster than they wrote \( (M = 167.71, SD = 32.62, \text{and } M = 156.37, SD = 28.65, \text{respectively}) \), and although not significant, these measures had a higher correlation \( (r = .46, p = .06) \).

We also examined the relationship between handwriting and keyboarding performance and various performance skills. As shown in Table 2, most performance skills were not correlated with handwriting performance except for a few

<p>| Table 2. Correlation Between Handwriting and Keyboarding Accuracy and Speed and Performance Skills |
|--------------------------------------------------|--------------------------------------------------|
| Handwriting                                      | Keyboarding                                      |</p>
<table>
<thead>
<tr>
<th>Legibility</th>
<th>Accuracy</th>
<th>Speed</th>
<th>Accuracy</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDT</td>
<td>-.01</td>
<td>-.14</td>
<td>.08</td>
<td>.03</td>
</tr>
<tr>
<td>FKTT</td>
<td>-.32*</td>
<td>.04</td>
<td>-.04</td>
<td>-.20</td>
</tr>
<tr>
<td>Dominant hand</td>
<td>-.16</td>
<td>.12</td>
<td>.26*</td>
<td>.21</td>
</tr>
<tr>
<td>Both hands</td>
<td>-.22</td>
<td>.10</td>
<td>.28*</td>
<td>.19</td>
</tr>
<tr>
<td>Assembly</td>
<td>-.30*</td>
<td>.21</td>
<td>.33*</td>
<td>.20</td>
</tr>
<tr>
<td>Pencil excursion</td>
<td>.17</td>
<td>.09</td>
<td>-.06</td>
<td>.06</td>
</tr>
<tr>
<td>Ratio</td>
<td>.10</td>
<td>.11</td>
<td>.11</td>
<td>.28*</td>
</tr>
</tbody>
</table>

Note. \( N = 63 \). FDT = Functional Dexterity Test; FKTT = Finger Keyboarding Tapping Test; DEM = Developmental Eye Movement.

\( *p < .05. \quad \ast p < .01. \)
measures of finger function. The accuracy measure of the FKTT had a low but significant correlation with handwriting legibility (\( r = -.32, p = .01 \)), indicating that the more accurate the FKTT performance was, the more legible the handwriting would be. The three measures of the Purdue Pegboard test had a low but significant correlation with handwriting speed (Dominant Hand, \( r = .26, p = .04 \); Both Hands, \( r = .28, p = .03 \); Assembly, \( r = .33, p = .01 \)). By contrast, keyboarding accuracy was correlated only with eye movement as measured by the DEM (Horizontal, \( r = -.28, p = .03 \); Ratio, \( r = .28, p = .03 \)). This indicates that the better the horizontal or total eye movement was, the more accurate the keyboarding was.

On the basis of previous results showing that the correlation patterns in good and poor handwriters are different (e.g., Tseng & Chow, 2000; Tseng & Murray, 1994), we examined the relationship between handwriting and keyboarding performance and the different performance component skills in each of the keyboarding speed groups separately (see Table 3). As hypothesized, results showed different correlation patterns in each of the groups. Among the slow keyboarders, handwriting speed had a medium and significant correlation with the accuracy measure of the FKTT (\( r = .57, p = .03 \)). Keyboarding accuracy had a medium and significant correlation with the DEM (Horizontal, \( r = -.58, p = .02 \); Ratio, \( r = .54, p = .04 \)). By contrast, speed of keyboarding significantly correlated with the Dominant Hand and Both Hands subtests of the Purdue Pegboard (\( r = .61, p = .01 \), and \( r = .68, p = .00 \), respectively). Among the fast keyboarders, handwriting legibility was significantly correlated with the Both Hands subtest (\( r = -.52, p = .03 \)), indicating that the better the participants performed on this subtest, using both their hands, the more legible their handwriting was. By contrast, keyboarding speed had a medium and significant correlation with the speed measure of the FKTT.

Finally, we compared the slow and fast keyboarders in relation to their performance skills. Results showed that the fast keyboarders also wrote by hand significantly faster than did the slow keyboarders (\( t(45) = -2.82, p = .01 \)). However, as can be seen in Table 4, the two groups did not significantly differ in any of their performance skills.

**Discussion**

The goal of this study was to characterize the relationship between handwriting and keyboarding performance. An additional purpose was to examine whether these two writing modes share underlying performance skills. This is one of the first studies to examine these relationships among young, healthy adults.

**Relationship Between Handwriting and Keyboarding Performance**

In examining the relationship between handwriting and keyboarding performance, we found significant correlations only in relation to speed. These findings differ from those of Rogers and Case-Smith (2002), who found a low but significant correlation between handwriting legibility and keyboarding speed. Our findings are similar to those of Preminger et al. (2004), who did not find significant correlations between keyboarding and handwriting accuracy. The results showing significant correlation between handwriting and keyboarding speed correspond to the findings of earlier studies showing that although handwriting and keyboarding require common skills, they also differ in their demands or require different skill levels (Green, Kameda, & Freeman, 2004; Preminger et al., 2004; Rogers & Case-Smith, 2002).

**Table 3. Correlation Between Handwriting and Keyboarding Performance and Performance Skills by Keyboarding Speed Groups**

<table>
<thead>
<tr>
<th></th>
<th>Slow Keyboarders (( n = 15 ))</th>
<th>Fast Keyboarders (( n = 17 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Handwriting</td>
<td>Keyboarding</td>
</tr>
<tr>
<td></td>
<td>Legibility Accuracy Speed</td>
<td>Accuracy Speed</td>
</tr>
<tr>
<td>Finger function (FKTT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>.05</td>
<td>-.15</td>
</tr>
<tr>
<td>Speed</td>
<td>.29</td>
<td>-.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purdue Pegboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant hand</td>
<td>.28</td>
<td>.18</td>
</tr>
<tr>
<td>Both hands</td>
<td>.15</td>
<td>.21</td>
</tr>
<tr>
<td>Assembly</td>
<td>-.01</td>
<td>.08</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye movement (DEM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>-.06</td>
<td>-.36</td>
</tr>
<tr>
<td>Ratio</td>
<td>.23</td>
<td>.55*</td>
</tr>
</tbody>
</table>

*Note: FKTT = Finger Keyboarding Tapping Test; DEM = Developmental Eye Movement.

\( *p < .05 \), \( **p < .01 \).
Table 4. Means (Ms) and Standard Deviations (SDs) of Slow and Fast Keyboarders on Performance Skills

<table>
<thead>
<tr>
<th></th>
<th>Slow Keyboarders (n = 15)</th>
<th>Fast Keyboarders (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Finger function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDT</td>
<td>23.01</td>
<td>6.24</td>
</tr>
<tr>
<td>FKTT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>99.58</td>
<td>0.94</td>
</tr>
<tr>
<td>Speed</td>
<td>79.47</td>
<td>17.51</td>
</tr>
<tr>
<td>Purdue Pegboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant Hand</td>
<td>14.67</td>
<td>2.06</td>
</tr>
<tr>
<td>Both Hands</td>
<td>10.67</td>
<td>1.95</td>
</tr>
<tr>
<td>Kinesthetic processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pencil Excursion</td>
<td>1.53</td>
<td>0.61</td>
</tr>
<tr>
<td>Eye movement (DEM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal</td>
<td>31.11</td>
<td>5.11</td>
</tr>
<tr>
<td>Ratio</td>
<td>0.44</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note. FDT = Functional Dexterity Test; FKTT = Finger Keyboarding Tapping Test; DEM = Developmental Eye Movement.

A more in-depth examination indicated that the relationship between handwriting and keyboarding speed was different among the slow and fast keyboarders. We found that among the slow keyboarders, handwriting speed was substantially faster than their speed in keyboarding. By contrast, among the fast keyboarders, the speed of keyboarding was somewhat faster than handwriting speed. Balajthy (1988) stated that for keyboarding to be a useful writing mode, students need to reach a typing speed that is at least as fast as handwriting speed. Thus, one could question whether keyboarding would serve as an efficient alternative to handwriting for the slow keyboarders. Conversely, if keyboarding results in a much more legible means of communication, it would most likely serve as a useful alternative to handwriting, albeit somewhat slower.

A possible explanation for the differences in these two groups is the fact that the fast keyboarders spent significantly more time on the computer than did the slow keyboarders. As several researchers have previously stated, proficient keyboarding, as for any skill, requires many hours of practice (e.g., Freeman et al., 2005). Support for this explanation is the fact that we found a significant correlation between keyboarding speed and the number of hours the participants keyboarded per week (r = .31, p = .01). Perhaps during the many hours spent on the computer, the fast keyboarders reached a similar level of automaticity in keyboarding as they have in handwriting. By contrast, in the slow keyboarding group, it appears that the participants still did not reach the same automaticity in keyboarding that they have in handwriting. However, handwriting speed in the slow keyboarding group was also significantly slower than that in the fast keyboarding group. These results suggest that the speed of handwriting cannot be a reliable predictor of keyboarding speed among the slow keyboarders. Moreover, other factors beyond hours of practice likely account for handwriting and keyboarding performance and the relationship between them.

Relationship Between Handwriting and Keyboarding Performance and Performance Skills

In examining the entire sample, our results indicated that the few performance skills that significantly correlated with handwriting legibility and speed (i.e., finger function) were different from those that correlated with keyboarding accuracy (i.e., eye movement). Similarly, when examining each of the keyboarding speed groups separately, different correlation patterns were found in each of the groups. In the slow keyboarding group, none of the performance skills were related to handwriting legibility, but both handwriting and keyboarding accuracy were moderately correlated with eye movement (oculomotor function). By contrast, handwriting and keyboarding speed were moderately related to finger function. However, whereas handwriting speed was correlated with the FKTT accuracy subtest, keyboarding speed was correlated with the Dominant Hand and Both Hands subtests of the Purdue Pegboard. By contrast to the previously mentioned results, in the fast keyboarding group, handwriting legibility was significantly correlated with the Both Hands subtest of the Purdue Pegboard, and the speed of keyboarding was related to the speed measure of the FKTT measure.

It is difficult to compare our results with those of previous studies (e.g., Berninger et al., 2006; McClurg & Kercher, 1989; Preminger et al., 2004) that examined the relationship between finger function and keyboarding performance because the various studies used different measures and yielded inconsistent results. Moreover, it is not clear why the Purdue Pegboard test rather than the FKTT, which is more of a simulation of keyboarding (controlling for linguistic ability), was correlated with keyboarding speed. We noted that the FKTT requires the tapping of only a single key by one finger on each hand—a task that probably does not sufficiently mimic the complexity of the keyboarding task. By contrast, the Purdue Pegboard test requires the use of various fingers to perform a sequence of movements and is more reminiscent of keyboarding. Thus, further studies are required using performance assessments, which more closely entail the skills used while handwriting and keyboarding.

As stated earlier, most studies were not able to demonstrate a significant correlation between handwriting and keyboarding performance and kinesthetic processing, even though both writing modes would appear to rely on this ability (Cornhill & Case-Smith, 1996; Sudsawad et al., 2002). Similarly, in our study, Pencil Excursion, which measures
kinesthetic ability in a graphomotor task (Levine, 1984), was not significantly correlated with handwriting or with keyboarding. This finding is somewhat different from that of a previous study among fifth-grade students showing that Pencil Excursion had a low but significant correlation with keyboarding speed (Preminger et al., 2004). A possible explanation for this result is that most of the participants in this study relied on visual rather than kinesthetic feedback (i.e., they were not touch typists); the lack of a significant correlation between kinesthetic processing and keyboarding performance is thus less surprising. However, this does not explain why kinesthetic processing was not correlated with handwriting performance. It is clear that a deeper understanding of the underlying performance skills of these two writing modes will be achieved only if kinesthetic processing measures that have similar requirements to these writing activities are measured. Therefore, future studies should include tests that measure kinesthetic abilities that are more similar to those required in the different writing modes.

Note that, in contrast to the findings by Preminger et al. (2004) showing that eye movement (as measured by the DEM) was significantly correlated with handwriting and keyboarding speed, our results showed that eye movement was significantly correlated with accuracy and not with speed during these two written communication modes. Two differences in the methodology of these studies (younger vs. older participants and slower vs. faster keyboarders) may account for these discrepancies. However, it does appear that keyboarding and handwriting accuracy while copying a passage (which requires reading ability) relies, to some degree, on the speed of eye movement.

Finally, although the correlation patterns between the two written communication modes and performance skills among slow and fast keyboarders differed, we found no significant differences between these two groups in relation to their performance skills. Additional participants in each skill-level group would have strengthened the statistical power of the various analyses used in this study and perhaps have led to different results. Moreover, although inclusion criteria required that the participants type for at least 3 hr per week, only 2 participants touch-typed without using vision. Future studies should include participants with a wider range of skilled keyboarding.

Conclusions

With the increased use of computers in the classrooms, keyboarding has become more available (Rogers & Case-Smith, 2002) and is often suggested as an alternative mode of written communication for students with handwriting difficulties (Freeman et al., 2005). The underlying assumption of this recommendation is that keyboarding requires different skills from handwriting or similar skills that are easier to master. The results of our study support this assumption; we found that different underlying performance skills uniquely contributed to each writing mode. The results imply that keyboarding may indeed be an alternative writing mode for students with handwriting difficulties.

Moreover, we also found that keyboarding speed and accuracy, as well as handwriting speed and legibility, are correlated with different performance skills. Therefore, before recommending the use of keyboarding, occupational therapists need to establish the type of handwriting difficulties encountered by students. It is clear that if students have poor handwriting legibility, keyboarding, even if not always efficient, can serve as a functional alternative, enabling students to convey their thoughts in a legible manner. By contrast, if speed is a concern, before recommending keyboarding occupational therapists need to thoroughly understand the factors enabling or limiting the students’ performance speed so as to be sure that the performance skills required for keyboarding are intact. For example, the current findings suggest that young adults who encounter difficulty with writing speed resulting from fine motor difficulties may also encounter difficulties with keyboarding speed. Thus, in such a case, the occupational therapist must decide whether the person will gain from switching to keyboarding as a primary writing mode.

In summary, it appears that keyboarding may serve as an alternate mode of written communication for students who encounter handwriting difficulties. Our results and the results of previous studies, however, showed that at all levels of client performance, much effort and practice of keyboarding is required to improve keyboarding speed. Therefore, it is important that occupational therapists who treat students with writing difficulties become more aware of the implications of recommending keyboarding as an alternate writing mode and consider the variety of factors related to this decision before recommending a computer as a support for people with handwriting difficulties. ▲

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References


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