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A comparison of keyboarded and handwritten compositions and the relationship with transcription speed

Vincent Connelly*, Deborah Gee and Elinor Walsh
Department of Psychology, Oxford Brookes University, UK

Background. It is well established that handwriting fluency constrains writing quality by limiting resources for higher order processes such as planning and reviewing. According to the 'simple view of writing' then slow keyboarding speed should hinder the quality of keyboarded essay compositions in the same way that slow handwriting hinders handwritten essay compositions. Given a lack of touch-typing instruction in UK schools it was hypothesized that children's written compositions produced via the keyboard would be worse than produced by hand.

Aims. To extend the work of Christensen (2004) and Rogers and Case-Smith (2002) by examining the relationship between handwriting fluency and keyboarding fluency throughout the primary school and studying the link between word-processed compositional quality and keyboarding fluency.

Samples and methods. The handwriting fluency and keyboarding fluency of 300 children in primary school were measured. Year 5 and year 6 children completed a measure of compositional quality by hand and by keyboard.

Results and comment. There was a high correlation between handwriting and keyboarding speed and handwriting speed was consistently faster than keyboarding speed across all ages. Only a small minority of children in years 5 and 6 had faster keyboarding than handwriting speed. Results showed that children's compositional quality was superior in the handwritten scripts as opposed to the keyboarded scripts. Keyboarded scripts were up to 2 years behind handwritten scripts in development. Writing by keyboard does not necessarily lead to improvements in script quality, compared with handwritten scripts. Explicit keyboarding instruction (touch-typing) is needed to develop keyboarding fluency and unlock the full potential of the word processor for children's writing.

Writing is a difficult and complex form of language production for children. Many children, for example, take years to master the intricacies of writing and composing a persuasive essay (Bereiter & Scardamalia, 1987). In order to chart writing development

* *Correspondence should be addressed to Vincent Connelly, Department of Psychology, Oxford Brookes University, Gipsy Lane, Oxford OX3 0BP, UK (e-mail: vconnelly@brookes.ac.uk).*

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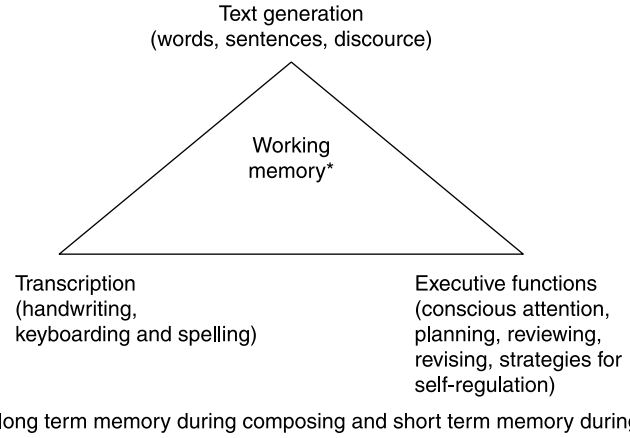
in children, Berninger and colleagues (2002) proposed the 'simple view of writing'. In their 'simple view' learning to write can be modelled by a triangle that encompasses a short-term working and long-term memory component (see Figure 1). At the base, supporting text generation are transcription and executive processes.

According to Berninger (1999), transcription processes are the first in the model to develop and provide the foundation for writing, as they directly allow the writer to convert ideas and language into a written form on the page. For the majority of children at school, transcription development, in reality, refers to the growth of a fluent and accurate form of handwriting and a thorough knowledge of spelling. The executive processes develop after transcription and move from being externally regulated to self-regulated. Both executive processes and transcription processes support text generation where ideas are turned into appropriate language.

All three components in the 'simple view' draw on the same limited cognitive resources of memory (see Torrance & Galbraith, 2005 for a review of the different ways to model limitations on the cognitive resources of memory in the writing process). Put simply, an increase in the amount demanded by one component, such as transcription, will mean fewer cognitive resources are available for the other components. Therefore, if children are slow or inaccurate at transcription (e.g. slow handwriting and poor spelling), then their overall compositional quality will suffer as they will have to devote more resources to this area than the others.

Handwriting fluency

A number of studies has shown that fluent handwriting is, indeed, associated with the generation of well-structured and imaginative text well into the teenage years and that slow handwriting has impacts on compositions even into adulthood for slow handwriters or those with dyslexia (Connelly, Campbell, MacLean, & Barnes, 2005; Connelly, Dockrell, & Barnett, 2005). The amount of variance in composition quality accounted for by handwriting fluency declines from 67% at the early primary level of schooling (Christensen & Jones, 2000) to 16% at the middle secondary school level (Berninger, 1999) in Australia and the USA. Very similar results have been found in the UK (Connelly *et al.*, 2005; Connelly & Hurst, 2001). This decrease in the variance



Note. *Activates long term memory during composing and short term memory during reviewing.

Figure 1. The 'simple view of writing' by Berninger *et al.* (2002).

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accounted for by handwriting suggests that as mechanical low level handwriting skills become fluent they have less impact on cognitive load and are less likely to constrain the expression of ideas in written text. This is supported by data indicating that children from age 11 onwards, and adults, are better able to produce written texts when writing them, than when dictating them (Bereiter & Scardamalia, 1987). Prior to this age children produce better essays that are dictated rather than written (De La Paz & Graham, 1995). Some recent studies have also shown that intervening to improve handwriting fluency also improves the quality of written compositions (Berninger *et al.*, 1997; Jones & Christensen, 1999).

There is a strong link between developing fluency in handwriting and the ability to produce high quality written compositions. Therefore, fluent transcription is an important component of the writing process that needs to be developed in children and is presently done so through handwriting instruction in the classroom. However, children are now expected to produce writing via computer keyboards and not just handwriten texts.

Computers and the teaching of writing skills

The use of computers in the school classroom has become almost universal in the United States and Western Europe. This growth has mirrored the evolving importance of this technology in the wider working environment. It is considered vital to familiarize and teach children the fundamentals about working with information communication technology (ICT) and learning to write using a keyboard is seen as a key skill.

Educationally, ICT has also been seen as a potentially powerful learning tool. This is particularly so in the teaching of language and literacy where the computer has been heralded as useful for actually developing writing skills. The word processor, it is hypothesized, allows the child to carry out more in-depth revision, check spelling and grammar and so improve writing skills. It also allows children to present work in a professional and well laid out manner so building confidence in their skills (e.g. MacArthur, 1999). Therefore, many educational texts have encouraged teachers to use word processors to encourage and teach children writing skills. For example, teachers of 6-year-old children in the UK are told to 'Encourage children to get their ideas on screen quickly and to make corrections later; they shouldn't type from a handwritten draft. This will help them appreciate that ICT can help them develop their writing and is not just a presentation tool' (Schemes of Work, ICT at key stages 1 and 2 (Year 2), Unit 2A: Writing stories: communicating information using text, Section 8: Integrated Task. Department for Education and Skills, 2004).

However, there has been little research into the actual effectiveness of the word processor on writing skills in the classroom. A comprehensive recent UK review and meta-analysis in this area showed almost no effect of ICT on standards in literacy (Torgerson & Zhu, 2003). There was no evidence that showed that using ICT in teaching reading, spelling or writing contributed any more than traditional methods. In fact, there was some evidence that the work produced was poorer in quality.

We hypothesize that this may be due to children not developing automaticity in skills such as keyboarding. They thus find themselves constrained in the quality of work they can produce by having fewer cognitive resources available to tackle an ICT-based task effectively.

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Transcription can involve either handwriting or keyboarding

Berninger and colleagues (2002) 'simple view of writing' in Figure 1, assumes that the same constraints that operate on handwriting fluency would also apply to the keyboard. Transcription can be completed in any way that allows children to produce written language and so can just as easily substitute keyboarding fluency for handwriting fluency. Therefore, in order for writing skill to develop to its full potential using a word processor then writers would need to develop fluent keyboarding skills, as a first step, in much the same way as children have to learn to handwrite fluently to be successful in paper and pencil compositions.

Evidence for this assumption has come from a small number of recent studies that have investigated children's writing by hand and keyboard. Christensen (2004) demonstrated that there was a significant correlation ($r = .54$, $p < .001$) between fluency in keyboarding and quality of keyboarded composition in a sample of Australian secondary school students. There was also a significant correlation between keyboarding fluency and handwriting fluency. Christensen (2004) also showed that by improving the keyboarding speed of a sample of slow keyboarders the quality of keyboarded compositions improved. She concluded that children's word-processed writing benefited from being taught keyboarding and that slow keyboarding constrained writing with a word processor.

Rogers and Case-Smith (2002) investigated the links between handwriting and keyboarding performance in sixth graders in the United States. They found that most students were able to keyboard faster than they could handwrite after a 12-week keyboarding instruction class. Rogers and Case-Smith also found a positive correlation between handwriting and keyboarding. This has been found in many other studies (e.g. Dunn & Reay, 1989; Pisha, 1993). However, Rogers and Case-Smith also found that 30% of their sample who were slow handwriters were, in fact, fast keyboarders. These students were able to produce more text via keyboard than by hand. This would point to keyboarding providing a way for students with slow handwriting to circumvent their problems. This result was not found by earlier studies looking at the keyboarding skills of children with learning difficulties which found that the slower handwriters produced less via keyboard (Pisha, 1993). Rogers and Case-Smith were looking at children in the classroom not those specifically learning disabled. They were also studying children who had been exposed to an extensive keyboarding development programme.

Keyboarding requires the writer to find and select the appropriate keys to produce a letter. Therefore, it is simpler than handwriting where letters are required to be formed by hand and so motor processes are easier for keyboarding. Despite this advantage, development of fluency in keyboarding will still be required according to the 'simple view of writing' in order to free up resources for complex compositions. Without fluency in keyboarding, children will have to allocate more resources to finding the appropriate key to press. However, schools in the United Kingdom are not required to teach fluency in keyboarding skills and are only encouraged to do so. Therefore, it is predicted that the keyboarding of children in the UK will be slower than their handwriting. However, it is not known how prevalent in UK schools will be children who have keyboarding skills that are more fluent than handwriting skills. Will it be the case that some children in the UK with slow handwriting may have preferentially developed keyboarding skills that are superior to their handwriting in the absence of explicit instruction? It is important to know whether these children gravitate towards

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using the computer to overcome their slow handwriting speed. Our study will provide an opportunity to investigate this issue.

Therefore, the study here aims to extend the Christensen (2004) paper and the Rogers and Case-Smith (2002) paper by examining the relationship between handwriting fluency and keyboarding fluency throughout the primary school and also studying the link between word-processed compositional quality and keyboarding fluency at the latter end of primary schooling. Rogers and Case-Smith surveyed US sixth graders in their sample and Christensen studied secondary school pupils in her sample. This study will extend the sample range to younger children and consider all the year groups in the primary age range in the UK, as use of computers is now prevalent across all of the school.

STUDY 1

Method

Participants

Two primary schools were used in this study, one from Oxfordshire and one from Dorset. In each school, one class from each year group, reception class to year 6, were tested, giving a total of 312 students in the whole sample from ages 4 to 11 years old. The sample contained a total of 178 boys with an average age of 97.5 months and a total of 157 girls with an average age of 97.8 months.

ICT teaching in the primary school and ICT in the curriculum

Each primary school taught ICT lessons as a class in a separate computer suite for 1 hour a week. ICT lessons involved some keyboard familiarization in the early years but a progressive touch-typing course was not part of the school curriculum in either school. The suite was primarily used to show children how to use word processors, presentation packages such as Powerpoint, and specific software for the teaching of spelling, reading and mathematics. There was also an emphasis on using the Internet for research in curricular areas such as science, history and geography as well as an introduction to e-mail and ICT as a communication tool.

Writing and ICT in the ICT suites were integrated primarily through demonstration and use of word processor packages. These concentrated on allowing the children to develop revising and editing skills and use of spellcheckers. Different writing genres were introduced and practised through ICT, such as formal letters, invitations, book reviews etc. These different genres were introduced using a range of other ICT software packages such as Powerpoint. The topics chosen for integration generally supported class topics in literacy current at that point in time.

A personal computer was present in each classroom, which was used occasionally by pupils throughout the school day. Again, this was used for a variety of curricular subjects, writing included. As with the computers in the ICT suite, writing was integrated with ICT mainly through the use of word processor packages. Progressive touch-typing instruction was not covered in the classroom. Children worked either alone or in pairs on the PC in the classroom. Often, this would involve a development or progression from their most recent ICT suite lesson.

Both handwriting and keyboarding skills in both schools were taught in line with current government guidelines.

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A one-way analysis of variance showed no significant difference between the two school samples used in this study for both handwriting speed, $F(1,311) = 0.701; p = .40$ and keyboarding speed, $F(1,311) = 0.925$; $p = .34$. Therefore, the results from both schools have been grouped together for statistical analysis in Study 1. In Study 2 only children from one school were used.

Materials

For the handwriting task, students were given 2 minutes in which to copy a simple sentence printed at the top of a sheet of lined paper; 'The quick brown fox jumps over a lazy dog'. The answer sheet was designed with the sentence in bold, black Times New Roman font style with 21-point font. Underneath the sentence were dotted lines with 1.5-line spacing in between. The students were given verbal instructions on how to complete the handwriting task by the experimenter. Each student was provided with a sharpened HB pencil.

For the keyboarding task, the same answer sheet was presented on the computer screen as a saved document in Microsoft Word. The students were given 2 minutes to copy out the same simple sentence using the keyboard. The students were given verbal instructions on how to complete the keyboarding task by the experimenter. Each individual sample was then saved onto a floppy disk as a Word file.

Procedure

The handwriting task involved the children copying a simple sentence that contained every letter of the alphabet 'The quick brown fox jumped over the lazy dog'. The students were asked to copy the sentence in their 'usual handwriting' and their 'normal speed' and were told they would be asked to stop after 2 minutes. The students were asked not to rub out or cross out any mistakes and if they paused or stopped before the task ended they were encouraged by the experimenter to continue and copy the sentence out again.

Handwriting speed was the total number of correct letters produced in the 2-minute task. A letter was counted as correct if it was in the correct place in the sequence to be copied and was legible. For example, the response 'brwon' instead of 'brown' would score 3 out of a possible 5 as two letters were out of sequence. A letter was classed as legible if, in the marker's opinion, it would have been recognizable alone on the page, without cues from other letters to help identify it. If it was illegible it was not counted towards the total score.

The keyboarding task involved the children copying the same simple sentence that contained every letter of the alphabet, 'The quick brown fox jumped over the lazy dog'. The students were asked to copy the sentence as it appeared on the screen and using their 'normal speed' and were told they would be asked to stop after 2 minutes. The students were asked not to delete or edit out any mistakes and if they paused or stopped before the task ended they were encouraged by the experimenter to continue and copy out the sentence again.

Keyboarding speed was the total number of correct letters produced in the 2-minute task. A letter was counted as correct if it was in the correct place in the sequence to be copied. No legibility criterion was applied as the letters produced were uniform. Two minutes was taken as the time for the task, rather than the usual 1 minute, as it was important to avoid floor effects in the very young children,

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particularly for keyboarding. None of the children tested complained that the time taken was excessive and they all persevered with the task until the end of the 2 minutes. Inter-rater reliability scores for the handwriting task were very high ($r = .98$) as was the inter-rater reliability score for the keyboarded task ($r = 1.0$).

Results

The results for the handwriting and keyboarding fluency tests by year are shown in Figure 2. It can be seen that handwriting, on average, was always faster than keyboarding across all year groups. This conforms to our original hypothesis about the superiority of handwriting fluency over keyboarding fluency in UK primary schools without explicit keyboarding instruction.

The children in reception and year 1 were all able to complete the tasks but since some of them had the additional handicap of not being able to read the copying sentence unaided, then this may have had some impact on their copying speed. All analyses reported below produced the same results without the reception and year 1 children and since the pattern shown by reception and year 1 children conformed to the overall pattern their results were taken as valid and included.

This hypothesis was statistically confirmed using a repeated measures analysis of variance. Method of text production was the within-participants variable (handwriting and keyboarding) and year group (reception year to year 6) the between-participants variable. It was found that there was a main effect of method of text production ($F(1,307) = 428$, $p < .001$, $\eta = .6$) and a main effect of year group ($F(6,307) = 128$, $p < .001$, $\eta = .7$). There was also a significant interaction between method of text production and year group ($F(6,307) = 9.1$, $p < .001$, $\eta = .1$). Planned comparisons showed that handwriting was superior to keyboarding across all year groups apart from between years 2 and 3. There was no growth in speed of method of text production across years 2 and 3. There was growth in writing speed across all other years. This is likely to be a Type 1 error given the comparisons made.

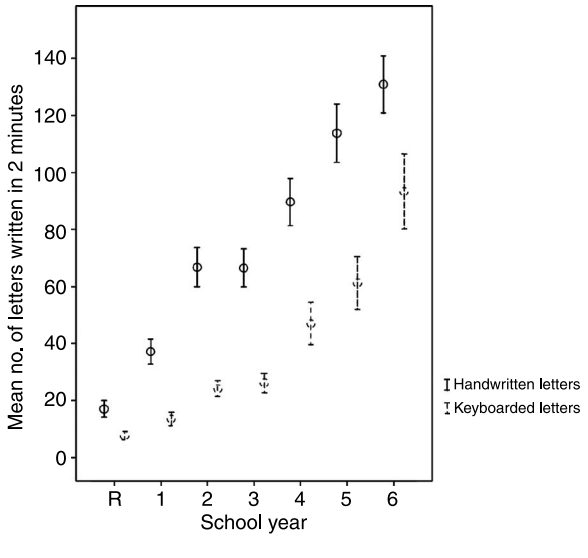

Figure 2. Handwriting speed and keyboarding speed by year group (95% confidence intervals).

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There was a significant correlation between handwriting fluency and keyboarding fluency within the sample ($r(314) = .7, p < .001$, CI = 0.64–0.75). This contrasts with the Rogers and Case-Smith study in which a considerably lower correlation was found. However, it is similar to the correlation found by Christensen (2004) and Pisha (1993).

Rogers and Case-Smith found a considerable proportion of their sample had more fluent keyboard skills than handwriting skills. We examined our data to investigate students in our sample who were more fluent at keyboarding then handwriting. Out of 312 students we found 11 students who had a superiority of over 1 word a minute keyboarding over their handwriting. Ten of these students were in years 5 and 6 and one was from year 4. Therefore, in practice, there was no population of students from reception to the end of year 4 that showed superior keyboarding skills. Approximately 6% of the year 5 and 15% of the year 6 sample displayed superior fluency in keyboarding over handwriting. This is much below the level of 30% that Rogers and Case-Smith found in their sample of US sixth graders who had been exposed to keyboarding instruction.

STUDY 2

We have shown in the first study above that keyboarding speeds in UK classrooms without explicit keyboarding instruction are slower than handwriting speeds. However, does this lower speed have an impact on the quality of compositions produced by children via the keyboard? Theoretically it should as the children will have to devote more effort to keyboarding than handwriting and so less resources will be available for other aspects of writing via a keyboard. Therefore, we gave a writing composition task via both keyboard and hand to a sample of children and compared the products of the different mediums. It was hypothesized that since, on average, keyboarding is less fluent than handwriting in these UK classrooms without keyboarding instruction, then the quality of the written composition will be superior in the handwritten product compared with the keyboarded product.

However, it is interesting to speculate whether the sample of children who are faster keyboarders than handwriters will be able to produce written text via the keyboard that is superior in quality to their handwritten texts. Since we only saw examples of keyboarding superior in speed to handwriting in years 5 and 6 then we limited ourselves to sampling essay compositions from these year groups.

Method

Participants

A subset of the year 5 and year 6 groups from our sample in Study 1 were used in this second study. There were 48 children in the sample, comprising 25 females and 23 males. There were 29 year 5 children and 19 year 6 children. They were the complete year groups drawn from one of the schools in the Study 1 sample. They were chosen as the headteacher was very keen to continue the study and gave permission for this more detailed data collection sessions.

Materials

The Weschler Objective Language Dimensions (WOLD) written expression subscale (Rust, 1996) was used to sample writing skills. This is a UK standardized assessment of

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writing ability. The task is a 15-minute free writing task to a written prompt. Two different prompts are provided for test and retest purposes.

A set of six analytical scores was produced as part of the assessment of the writing task. The analytic procedure obtains ratings in the following areas: ideas and development; organization, unity and coherence, vocabulary, sentence structure and variety; grammar and usage; capitalization and punctuation. There was a maximum possible score of 4 for each analytic element.

The rater carried out the full training and familiarization programme for the WOLD scoring scheme according to the published manual. The 8 example scripts for the holistic scoring criteria and the 15 example scripts for the analytic scoring criteria were all studied from the manual. A sample of the essays (50%) was also marked by one of the authors and the inter-rater reliability (Cronbach's alpha) was .91. This is a very good reliability rating for an analysis of writing and such reliabilities are not uncommon with the WOLD measure. Other scoring methods can produce more complex and subtle measures but display much lower reliabilities (see Westby & Clauser, 1999 for a review of writing assessment reliabilities).

Procedure

Data were collected 1 week after the handwriting fluency measures referred to above were administrated to the children. For the WOLD handwriting test, the year 5 and year 6 classes were given a clean sheet of A4 lined paper each and a sharpened HB pencil. Writing prompt 1 from the WOLD for a creative writing piece was given to each student and the experimenter gave verbal instructions from a printed sheet. The experimenter used a stopwatch to time the 15-minute test.

For the WOLD keyboarding test, the year 5 and year 6 classes were sat in front of a computer with a Microsoft Word blank document. Writing prompt 2 from the WOLD for a creative writing piece was provided for each student and the experimenter gave verbal instructions from a printed sheet. The experimenter used a stopwatch to time the 15-minute test. The samples were saved onto a floppy disk and hard copies of each sample were printed off.

Results

The mean scores for each of the analytical scoring categories by method of production are shown in Table 1. A total score summing all the analytic elements is also shown in Table 1. It would appear that handwriting essay quality is superior to keyboarded essay quality.

This hypothesis was confirmed with analysis of variance where method of text production was the within-participants variable (total WOLD score from the handwritten texts and total WOLD score from the keyboarded texts) and year group (year 5 and year 6) the between-participants variable. It was found that there was a main effect of method of text production ($F(1,46) = 35.78$; $p < .001$, $\eta = .45$). The handwritten essays, on average, received higher WOLD total scores than the keyboarded essays. It was also found that the year 6 group consistently scored more highly than the year 5 groups across both handwritten and keyboarded texts ($F(1,46) = 9.46$; $p = .004$, $\eta = .2$). No interaction was found between method of text production and year group, $F(1,46) = 0.02$, $p = .89$. Therefore, handwritten texts received higher WOLD scores

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Table 1. Mean number of letters copied by hand and by keyboard during the 2-minute copying period

Year	Handwriting	95% CI	Keyboarding	95% CI
Reception	17.0	14.1–19.9	7.7	6.2–.9.1
1	37.2	32.7–41.6	13.5	11.2–15.8
2	66.8	60.0–73.6	24.1	21.3–26.9
3	66.5	59.9–73.0	26.7	22.7–29.6
4	89.6	81.3–97.8	47.0	39.5–54.4
5	113.8	103.5–124.1	61.4	52.1–70.6
6	130.9	120.8–141.0	93.2	80.1–106.4

than the same writing task keyboarded across both year groups. Year 6 had higher total WOLD scores than year 5 across both methods of text productions.

An identical pattern of results was shown when a repeated measures analysis of variance was carried out comparing all the analytic scores from the keyboarded and handwritten essays and comparing across year groups. There were main effects of method of text production ($F(1,46) = 36.9$, $p < .001$, $\eta = .45$), year group ($F(1,46) = 9.4$, $p = .004$, $\eta = .2$) and analytic score ($F(1,46) = 25.3$, $p < .001$, $\eta = .35$). No interactions were significant. All the analytic scores for handwritten essays were significantly higher than the analytic scores for keyboarded essays. The year 6 children scored more highly than the year 5 children across all the essays produced. The capitalization and punctuation scores were higher than the other scoring categories.

Table 2 shows the standard scores and age equivalent scores drawn from the WOLD manual. The children are scoring normally for their age on the handwritten task. However, they are a full standard deviation below the normal for the keyboarded essay in year 5 and are still 10 standard points behind the handwritten product in year 6. The age equivalent scores show an even bigger gap with keyboarded essays, on average 18–24 months behind the equivalent handwritten product.

There were significant correlations between performance on the handwriting and keyboarding fluency measures and the WOLD total scores. Those who were fast handwriters and keyboarders produced, on average, the better quality essays (handwriting fluency and handwritten essay total WOLD score $r(48) = .45$, $p < .001$, 95% CI = 0.19–0.65; keyboarding fluency and keyboarded essay total WOLD score $r(48) = .42$, $p = .002$, 95% CI = 0.1–0.63). Handwriting fluency was also positively associated with the compositional quality of the keyboarded essay and vice versa (handwriting fluency and keyboarded essay total WOLD score $r(48) = .38$, $p = .008$, 95% CI = 0.11–0.60, keyboarding fluency and handwritten essay total WOLD score $r(48) = 0.44$, $p = .003$, 95% CI = 0.16–0.63). Therefore, those students whose essays are receiving high marks are generally those students who can write or keyboard letters more fluently.

There were four children in this sample who were faster keyboarders than handwriters. None of these children scored more highly in their keyboarded essays than their handwritten essays. There were another four children who scored more highly on their keyboarded essay rather than their handwritten essay. All of these children showed faster handwriting speed than keyboarding speed and three out of the four had very fast handwriting speed compared with their peers. Therefore, there is no evidence that even when a small proportion of children do have faster keyboarding speed than handwriting

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Table 2. Mean essay quality scores by group for the WOLD handwritten and keyboarded task (standard deviations in brackets)

	Group			
	N = 29, CA = 10.0		*N* = 19, CA = 11.0	
Analytic scoring elements	Year 5 handwritten WOLD	Year 5 keyboarded WOLD	Year 6 handwritten WOLD	Year 6 keyboarded WOLD
Ideas and development (max = 4)	2.07 (0.7)	1.55 (0.8)	2.31 (0.6)	2.10 (0.8)
Organization, unity and coherence (max = 4)	1.93 (0.9)	1.48 (0.7)	2.42 (0.8)	1.95 (0.7)
Vocabulary (max = 4)	1.75 (0.8)	1.27 (0.5)	2.21 (0.5)	1.8 (0.7)
Sentence structure/variety (max = 4)	1.79 (0.8)	1.45 (0.7)	2.42 (0.6)	2.01 (0.7)
Grammar (max = 4)	1.93 (0.7)	1.52 (0.6)	2.47 (0.6)	2.05 (0.6)
Capitalization/punctuation (max = 4)	2.48 (1.0)	2.03 (0.9)	3.05 (0.4)	2.52 (0.6)
Total scores (max = 24)	11.9 (4.6)	9.3 (3.4)	14.9 (2.7)	12.4 (3.2)
WOLD Age standard scores	96	83	104	93
WOLD Age equivalent scores	9.6	8.0	13.3	9.6

Note. CA = chronological age.

speed that this proves an advantage in overall writing quality. In the absence of explicit keyboarding instruction the quality of handwritten essays is still superior to those keyboarded.

DISCUSSION

We have shown in this study that children who do not receive keyboarding fluency instruction produce fewer characters via the keyboard than when handwriting and that they also produce poorer essays when keyboarding than handwriting. This confirms and extends previous research in this area.

It has also been shown that without keyboarding fluency instruction there does develop a proportion of children who are faster keyboarders than handwriters in years 5 and 6 of primary school. Further research is needed to determine how much exposure to computers is required for them to develop this fluent keyboarding speed.

We also found a significant correlation between the ability to handwrite quickly and the ability to keyboard quickly. This correlation was much higher than that reported by Rogers and Case-Smith (2002). This may be due to Rogers and Case-Smith also including legibility scoring in their handwriting fluency score. Rogers and Case-Smith also took their measurements after a keyboarding instruction programme had been completed. Therefore, we can say that in the absence of keyboarding fluency instruction that children who are fast handwriters will generally be fast keyboarders. It would be interesting to see whether this effect was independent of exposure to computers. In the later years of primary school, as we noted, there may be a few exceptions to this rule.

Considerable investment has been made in recent years by the UK government in updating and fitting out large numbers of computers for use in primary schools

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(Torgerson & Zhu, 2003). Large amounts of the school week are allocated to working with computers as part of the curriculum for all primary school subjects. Word processors are seen as particularly good for the development of writing skills in the English language curriculum at the primary school level. However, we have shown that without basic skills, such as fast and fluent keyboarding, then children's true essay writing skills are not being reflected in the work they produce via word processors. Our sample of children overwhelmingly produced better essays by hand than by word processor. Was this because they were able to handwrite faster than keyboard and thus more resources were free to devote to higher order aspects of composition so improving overall essay quality? If so, then our sample of children's writing was, in fact, impeded by the computer, not aided by it.

Christensen (2004) has recently shown that quality of essay writing via the keyboard can be improved with keyboarding fluency instruction. She selected 35 slow secondary school keyboarders. They then received an 8-week keyboarding fluency course, for 20 minutes a day, that developed touch-typing skills. At the end of the course all the students were keyboarding at the same speed or better than their handwriting speed. At post-test the students produced longer essays and, more importantly, better quality essays than compared with their essays before the course. The study clearly showed that the quality of essay writing carried out via a word processor could be improved once children keyboard at least as fast as they handwrite essays. The children in our sample did not have the benefit of receiving an 8-week intensive and direct keyboarding instruction. Another study by Lewis (1998) found that if children only received a 6-week keyboarding fluency course they did not show any long-term improvement in keyboarding speed and quickly reverted back to their original 'hunt and peck' letter finding strategy.

Rogers and Case-Smith (2002) found a sizeable proportion of their sample could keyboard faster than they could handwrite. Their sample had received instruction in fluent keyboarding in their sixth grade classroom. In our sample there was no keyboarding fluency instruction but there was limited evidence that in the final 2 years of primary school some children do develop faster keyboarding than handwriting skills. There was no evidence that any children below year 5 were faster at keyboarding than handwriting. Furthermore, the children who could keyboard faster than they could handwrite were not the slowest handwriters in the sample, unlike the Rogers and Case-Smith study, and the ability to type faster here did not lead to any appreciable gains in writing quality in the essay task. This may have been due to the small differences between keyboarding and handwriting fluency where keyboarding was superior to handwriting, and the small numbers in our sample. Therefore, we can conclude that in the absence of explicit keyboarding fluency instruction, there is no firm evidence that slow handwriters benefit from using a computer for writing essays in our sample or, in fact, that there is any subpopulation that shows increased benefit from writing via the keyboard.

It is likely, given the strong correlations between handwriting and keyboarding and essay quality via both mediums, that children who struggle with handwriting fluency will also struggle with keyboarding fluency. This may not be the case if those children receive coaching in keyboarding fluency, as the results of Rogers and Case-Smith's study appear to show. However, none of the children we studied had been defined as having handwriting difficulties. A different relationship may exist between keyboarding and handwriting in a clinically identified sample. There is, at present, little evidence for or against this opinion.

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Theoretically, we can hypothesize that a very similar relationship exists between the medium of transcription, such as handwriting or keyboarding, and overall essay writing quality. The 'simple view of writing' development that Berninger and colleagues (2002) propose appears to have been borne out by our results. Transcription fluency does constrain composition quality, whatever the medium, as predicted by the model. This reinforces previous research that points to the importance of direct and explicit instruction in the basic skills of writing, such as handwriting fluency and also, as we have shown, keyboarding fluency.

Without instruction to produce fluent keyboarding skills the vast majority of children in the UK will find their writing impeded by the computer, not aided by it. As a recent review pointed out, until there is a proper evaluation of ICT and how to properly integrate and teach ICT in the classroom then the 'policy-makers should refrain from any further investment in ICT and literacy' (Torgerson & Zhu, 2003, p. 9). We would agree with this, as unless children can develop basic skills, such as keyboarding fluency, then they will not be able to make the best use of ICT in the classroom to support the growth of their writing composition skills. A randomly controlled trial of ICT teaching in literacy should more clearly illustrate the way ahead.

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