Computerised assessment of handwriting and typing speed

Joanna Horne, Jonathan Ferrier, Chris Singleton & Caroline Read

This paper reports on two studies using computer-based dictation tasks for measuring speed of typing and handwriting. In the first study, 952 students aged 11 to 17 years attending 19 different secondary schools hand wrote and typed passages dictated by a computer. For both handwriting and typing, a very high correlation was found between speed calculated by the computer and that calculated by a human assessor, establishing that computerised calculation is a reliable as well as convenient and time-saving method of establishing writing speed. There were greater age-related gains in speed of typing compared with handwriting and greater variation in typing skill than handwriting skill. However, almost half of students with slow handwriting (below standard score 85) were found to have average or better typing speeds.

In the second study, 55 students aged 13 to 14 years were administered these tasks together with the Hedderley Sentence Completion Test of handwriting speed. Despite the clear differences between the two test formats, a significant moderate level of correlation was found between them (r=0.54). Almost one-third of students with slow handwriting in the computer-based task had not previously been identified as having support needs but would potentially be disadvantaged in written examinations. By eliminating the 'thinking' time involved in free writing, computerised dictation tasks give 'purer' measures which can reveal physical handwriting and/or typing problems. They also simulate examination requirements more closely than mechanical repetitive tests of writing speed, and should be particularly helpful in establishing whether students need access arrangements in examinations.

Keywords: *assessment; handwriting speed; typing speed; access arrangements; computers.*

DESPITE the widespread use of computers in schools, the majority of students still write by hand rather than using a keyboard. Children spend 31 to 60 per cent of their school day engaged in handwriting tasks (McHale & Cermak, 1992) and consequently handwriting ability remains an important factor in learning and assessment.

Handwriting is a complex perceptual-motor skill that is vulnerable to a wide variety of dysfunctions, including weak fine motor control, poor sensory awareness of the fingers, problems with timing of movements, difficulties in integrating visual and kinaesthetic information, inadequate pen grip and limitations of attention (Cornhill & Case-Smith, 1996; Exner, 1989; Feder & Majnemer, 2007; Karlsdottir & Stefansson, 2002; Maeland, 1992; Malloy-Miller, Polataijko & Ansett, 1995; Schoemaker et al., 2005; Tseng & Cermak, 1993; Tseng & Chow, 2000). All these factors contribute to the speed as well as the legibility of handwriting (Volman, van Schendel & Jongmans, 2006), and both components have been shown to have a wider impact on educational attainment throughout schooling and on into higher education (Berninger & Graham, 1998; Berninger, Mizoikowa & Bragg, 1991; Connelly et al., 2006; Dockrell & Barnett, 2005; Graham, Harris & Fink, 2000; Jones & Christensen, 1999; Roaf, 1998). Prevalence of handwriting difficulties varies from five per cent to 27 per cent of school-age children, depending on age and method of assessment used (Alston, 1985; Hamstra-Bletz & Blöte, 1993; Karlsdottir & Stefansson, 2002; Maeland, 1992; Smits-Engelsman & Van Galen, 1997). However, a deficit in the integration of visual and motor information (commonly associated with dyslexic and

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dyspraxic-type difficulties) seems to be the most significant underlying aetiological factor for those with poor handwriting (Volman et al., 2006; Williams et al., 1993).

Assessing handwriting skills is a controversial field. Rosenblum, Weiss and Parush (2003) reviewed a wide variety of different approaches and concluded that all have significant drawbacks. Graham (1986a, 1986b) has also critically examined various instruments. Hence establishing how fast students can write is not a trivial matter. In a variety of studies, handwriting speed has been found to increase steadily during the school years, with most studies reporting a levelling off at about age 13 to 14 (Connelly, Gee & Walsh, 2007; Graham et al., 1998). Girls tend to be faster writers than boys throughout childhood (Alston, 1995; Bishop & Estgate, 2001; Zivani, 1984) and right-handers faster than left-handers (Graham et al., 1998). However, regardless of the mode of production, speed of writing is largely a function of task demands and content, and different approaches to assessment may yield very different speeds. Free writing tasks will produce different speeds to copying or repetitive writing tasks. The nature of the sample will also affect the findings. Two examples of large-scale studies will suffice to illustrate these issues.

Phelps, Stempel and Speck (1985) required children to copy a story of 197 words, with the first two minutes of writing being scored. Results from 1365 US children showed a near linear growth, from 25 letters per minute at age 8 to 9 to 72 letters per minute at age 13 to 14. Wallen, Bonney and Lennox (1996) created a simple speed of writing test that required children to copy the sentence 'The quick brown fox jumps over the lazy dog' as many times as possible in two minutes. Results from 1292 Australian children revealed an almost linear growth from 54 letters per minute at age 8 to 9 to 133 letters per minute at age 17 to 18. Since the sentence contains nine words and a total of 35 letters (excluding spaces) there are 3.89 letters per word and thus writing rate in words per minute (wpm) progresses from 13.88 (age 8 to 9) to 34.19 (age 17 to 18). These rates are somewhat faster than those reported by Phelps et al. (1985), but copying the same sentence over and over again is a considerably easier task than copying a story, in which reading imposes an additional cognitive load. In fact, the growth lines from the two studies are almost parallel, suggesting the same developmental processes are at work. Graham et al. (1998) have also observed that the relatively slower speeds obtained by Phelps et al. (1985) were likely to have been due in part to the inclusion of large numbers of students with special needs in their study, whereas the study by Wallen et al. (1996) used an unselected sample.

Typing skills also increase steadily with age, but the speed of typing tends to lag behind that of handwriting throughout primary school. Connelly et al. (2007) measured the handwriting and typing speeds of 312 UK children aged 4 to 11 years, using the task devised by Wallen et al. (1996). From age 7 onwards, handwriting speed increase was found to be near linear and broadly consistent with the findings of Wallen et al., from 33 letters per minute (lpm) (8.48 wpm) at age 7 to 65 lpm (16.71 wpm) at age 11. When typing the same task, performance also increased linearly with age, but speeds were considerably below those of handwriting: 28 lpm (7.20 wpm) at age 7 to 46 lpm (11.23 wpm) at age 11. A significant correlation between the two modes of text reproduction was found (r=0.70; p<0.001).

Unfortunately, there is a dearth of studies of typing speed in the secondary school years and comparisons of handwriting and typing skills during childhood are also rare in the research literature. Most studies in this field have used compositional writing rather than copying or writing to dictation. Christensen (2004) gave two 20-minute compositional writing tasks (topics specified) to 276 students aged 12 to 15 (average age 13 years 3 months), one handwritten and the other typed into a computer. Significant relation-

ships were found between the two types of text production (r=0.51; p<0.001); this correlation was somewhat lower than that reported by Connelly et al. (2007) although the children were older than in the latter study. A measure of orthographic-motor integration involving writing the alphabet in lower- and upper-case as quickly and as many times as possible in one minute (Berninger et al., 1991) was also found to be significantly related to the amount of text handwritten (r=0.30; p<0.001) and typed (r=0.55; p<0.001). Orthographic-motor integration was found to account for 28 per cent of the variance in quality and speed of handwriting, and 30 per cent of the variance in quality and speed of typed composition.

Rogers and Case-Smith (2002) examined the relationships between handwriting speed and the speed of typing in students aged 11 to 12. These students (N=40), all of whom had already participated in a school keyboarding class, were asked to copy a familiar poem by hand and also when using a keyboard. Typing and handwriting speed were found to correlate significantly (r=0.36; p=0.026); this correlation was lower than those reported by Christensen (2004) and Connelly et al. (2007), but in the Rogers and Case-Smith study the students had received typing tuition, which was not the case in the other two studies. Handwriting speed was found to account for 12 per cent of the variance in typing speed. Seventy per cent of the sample produced more text using a keyboard than when writing by hand, and 30 per cent of those who were the slowest hand writers had relatively fast typing speeds. The relative speeds of handwriting and typing have also been found to affect the quality of narrative writing. Dunn and Reay (1989) studied 52 students aged 12 to 13 and found that those whose typing speed equalled or exceeded that of their handwriting speed produced better quality compositions when using a keyboard; those whose handwriting speed equalled or exceeded that of their typing speed produced better quality handwritten compositions.

Assessment of handwriting speed is necessary in order to apply for examination access arrangements in the UK and many other countries. Students who have significant difficulties in handwriting will usually be entitled to access arrangements such as additional time, use of an amanuensis (scribe) or a word processor (Backhouse, Dolman & Read, 2007). Of all the students who were granted access arrangements in the 2009–10 GSCE exams, 44 per cent were given extra time, 11 per cent used a scribe, and seven per cent used a word processor (Ofqual, 2010). Although a few of these students will be granted use of a scribe, for the vast majority of them examinations will still entail writing by hand or word processing (Ofqual, 2010). Thus, even for these students, speed of written production usually remains critical. Over the past 30 or more years professional opinions have varied regarding the most appropriate method to adopt in order to assess handwriting speed (see Ashton, 1997; Bishop & Esgate, 2001; Bonney, 1992; Hedderly, 1992, 1995, 1996; Sawyer, Francis & Knight, 1992; Sawyer, Gray & Champness, 1996; Turner, 1997). Suggested methods range from the purely mechanical (e.g. writing a series of letters or symbols as fast as possible in a short time), through copying exercises and free writing tasks, to complex diagnostic scales. Writing speed varies according to the nature of the task, and it is debatable what approach is most appropriate for determining whether or not a student should be entitled to additional time in examinations. The Hedderly Sentence Completion Test (Hedderly, 1995) is among the most popularly used instruments. This requires the student to complete 40 sentences (e.g. 'I like…', 'The happiest time…') by writing the first thing that comes into their head, provided it makes a complete sentence; the task is timed and the speed of handwriting calculated. Norms in wpm are provided from ages nine (average eight wpm) to 18 (average 16.9 wpm). Bishop and Esgate (2001) pointed out that short tests may not be good predictors of writing speed in longer examination conditions, a conclusion that receives strong

support from findings by Summers and Catarro (2003) and O'Mahony, Dempsey and Killeen (2008). Free writing tests tend to be longer, for example, the test devised by Allcock (2001) employs a 20-minute free writing task on a topic to be chosen by the student, with two minutes planning time allowed. Norms in wpm are provided from ages 11 (average 13.9 wpm; compared with 12 wpm for Hedderly's test) to 16 (average 16.9 wpm; compared with 20 wpm for Hedderly's test). However, free writing tests are highly dependent on topic and may not accurately reflect writing speed: the student may not be writing continuously during that time because they are thinking about what to write next, or pondering how to spell words they wish to use, or trying to think of synonyms (Ashton, 1997).

A further problem is where to set the cut-off below which a student is judged to have sufficiently slow writing to warrant additional time in examinations. Using a 20-minute free writing test, Roaf (1998) selected 15 wpm as the cut-off speed below which students were judged to be 'slow' writers; 25 per cent of an unselected sample of 1273 students aged 11 to 16 fell into this category, with 4.5 per cent falling below 10 wpm. The current regulations of the Joint Council for Qualifications (JCQ), which refer to public examinations in England, Wales and Northern Ireland, specify that in order to qualify for extra time on the grounds of slow writing speed, there must be evidence that a student '…is unable to complete a timed assessment in the time allowed' (JCQ, 2010, p.4). Evidence can come from various sources, including 'low standardised scores' using assessments of writing speed, samples of unfinished mock exams or other timed assessments. Neither Hedderly nor Allcock provide norms for their tests that enable one to determine 'low standardised scores'; however, Hedderley states that at age 16 a speed of 14 wpm or less places a student in the bottom 10 per cent, and Allcock specified that at age 16 a speed of 12.7 wpm is 25 per cent slower than average (which she indicates warrants for extra time) and 10.1 wpm is 40 per cent slower than average (which she indicates warrants use of a scribe). In the absence of a serious alternative, these apparently arbitrary '25 per cent slower' and '40 per cent slower' rates have become widely applied.

The two studies presented in this paper investigated the use of a computer-based dictation task for measurement of speed of typing and handwriting. Dictation was chosen rather than free writing in order to standardise the task, to remove (as far as practicable) the differential effects of content and topic knowledge on speed, and to eliminate 'thinking' time, which is a confound in free writing tasks. Repetitive copying of words or sentences was rejected in favour of extended passages of meaningful text because the former was considered too far removed from the normal process of writing. Straightforward copying of passages was rejected because writing performance is confounded with reading and spelling ability. Computerised assessment of writing speed was chosen mainly because of the time, cost and efficiency savings that it affords (McDonald, 2002; Singleton, 2001) and because of evidence of less gender bias compared with conventional assessment methods (e.g. Horne, 2007, compared computerised assessments of reading and spelling with their pen-and-paper equivalents and found significant gender differences in the latter but not in the former; the reasons for this are complicated and the topic warrants further research). Conventional tests of writing are often impractical for many teachers because administering a writing task, counting the number of words written, and processing the results can be very time consuming, especially when larger numbers of students need to be assessed. Computerised assessment not only frees the teacher from the tasks involved in delivering and scoring the test, but also enables more efficient assessment of groups of students using networked computer systems.

Study 1

Participants

The participants in the first study were a total of 952 students aged 11 years 0 months to 17 years 11 months, attending 19 schools from geographically separate regions of the UK, selected to give a representative spread of types of school and socio-economic profiles. The students were selected for participation by class on a randomised basis, and were all tested in groups in computer suites in their schools, using network computers running Windows operating systems.

Tasks

Two tasks were used in the study: 1. Typing to computerised dictation; 2. Handwriting to computerised dictation. Four dictation passages, each of approximately 200 words, were devised. The content was created in order to be exciting to teenagers and, as far as practicable, with interest for both sexes. Passage 1 concerned the adventures of a student's dog, passage 2 was on the various challenges of learning to keep bees, passage 3 was about the exploits of a student on a family canal boating holiday, and passage 4 centred on the thrills of quad biking. In order to avoid confounding spelling skills with typing and writing speeds, the passages were designed to impose minimal demands on spelling skills in the early paragraphs. The content and length of these passages was arrived at after pilot investigation with students of different ages and varying competencies in writing. Pilot investigation also indicated that within-subject variance for writing the whole of each passage was not significantly different across the four passages, thus demonstrating equivalence.

All passages were dictated by the computer using digitised speech, a short phrase (four to six words) at a time, followed by a pause. Delivery rate was under the control of the student, who was required to press the 'page down' key to hear the next phrase. If desired, the student could press the 'control' key to hear that phrase repeated. A maximum of seven minutes was allowed for each passage, this duration being chosen partly because of the criticism in the research literature of both shorter and longer tests, but also as a result of the pilot investigations. It was discovered that if dictation tasks are too long, students tend to get bored and lose attention, reducing test reliability. Speed was measured by the computer, based on the number of words dictated and – in the case of the typed passages – typed, in the time period.

Although passage equivalence had been established, nevertheless topic and content clearly differed across the four passages. We wanted to see whether any differences between handwriting and typing found in one group using two particular passages would be replicated in a different group using passages with different topics and content. Consequently, the sample was divided into two groups, with 439 students in the first group, who wrote passage 1 by hand and typed passage 2, and 513 students in the second group, who wrote passage 3 by hand and typed passage 4. Speed of handwriting estimated by the computer was compared with speed of writing calculated by a human assessor who independently counted up the number of words written and who also scored both typing and handwriting samples for spelling errors.

Results

Table 1 shows the descriptive statistics for both tasks. Performance of Group 2 was found to be significantly better than that of Group 1 in typing [$F(1,951)=4.94$; $p=0.026$], but not in handwriting [$F(1,874)=1.48$; NS]. However, the effect size of the difference between the groups in typing speed was very small (Cohen's d=0.14) – in fact, the average typing speed of Group 2 was only 4.7 per cent faster than that of Group 1 – and the difference was not significant when age was statistically controlled for [$F(1,951)=0.312$; NS] The computer estimation of the number of words handwritten (based on the number of words dictated in the time allowed) was compared with an independent

Table 1: Descriptive statistics for typing and handwriting to dictation.

		Group 1 (*N*=439)		Group 2 (*N*=513)		All (*N*=952)	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	
Typing	No. of words typed	150.45	51.79	157.55	46.78	154.28	49.26
	Typing speed (wpm)	21.49	7.40	22.51	6.68	22.04	7.04
Handwriting	No. of words handwritten [computer estimation]	146.57	34.82	149.13	27.89	147.93	31.32
	Handwriting speed (wpm) [computer estimation]	20.94	4.97	21.30	3.98	21.13	4.47
	No. of words handwritten [human count]	145.27	34.65	147.76	27.71	146.60	31.14
	Handwriting speed (wpm) [human count]	20.75	4.95	21.11	3.96	20.94	4.45

count by a human assessor. There was a highly significant correlation between computer estimation and human count (r=0.95; p<0.001) and no significant difference was found between the two methods of calculation [F(1,870)=1.98; NS]. The average discrepancy was 2.01 words or 1.37 per cent (SD 9.53 words). In all except three cases, the discrepancy was an overestimation by the computer due to the student not attempting to write all the words that had been listened to. In 7.5 per cent of cases the discrepancy between the human and computer calculation was greater than ±5 per cent and 2.3 per cent of discrepancies were greater than ±10 per cent.

On average, students typed rather more words than they wrote by hand, and mean typing speed was significantly faster than mean handwriting speed [F(1,870)=46.00; p<0.001]. However, average typing speed was only 4.1 per cent faster than handwriting speed and the effect size was very small (d=0.15). In addition, the standard deviations for typing were considerably higher than those for handwriting, indicating a much greater variability in skill. To some extent this is accounted for by greater age-related gains in speed of typing compared with handwriting; this is also reflected in a slight negative skew in the distributions of typing scores due to some of the older students being particularly fast typists. There was a moderate correlation between student age and the overall number of words typed (r=0.60, p<0.001) but only a weak correlation between student age and the overall number of words written by hand (r=0.19, p<0.001). Handwriting and typing speeds were found to be correlated only weakly (r=0.14, p<0.001).

Figure 1 depicts age-related growth in typing and handwriting speeds. It can be seen that the development curve for typing is steeper than that for handwriting, particularly between the ages of 11 and 14 years. Although the speed increase for both is less marked after age 14, development of typing

ability progresses further and faster than that of handwriting ability. Figure 2 charts the age-related changes in relative typing and handwriting speeds. At age 11 over 70 per cent of students have faster handwriting than typing; by age 17 the picture is reversed completely, with 85 per cent of students being able to type faster than they can write by hand.

Approximately one-in-five students (19.01 per cent) were found to have slow handwriting for their age, i.e. they wrote at speed below standard score 85; this figure is roughly what would be expected in a normally distributed sample. However, almost half (48.70 per cent) of those with slow handwriting had typing speeds above standard score 85: i.e. even though they were slow writing by hand they could type at a reasonable rate.

Although there were slightly more spelling errors in typing (5.44 per cent) than in handwriting (5.08 per cent) this difference was not statistically significant. The correlation between age and percentage of spelling errors was higher for typing (r=–0.28, p<0.001) than it was for handwriting (r=–0.15, p<0.001).

Figure 1: Age-related growth in speed of typing (solid line) and handwriting (hatched line) from age 11 to 17 years (words per minute).

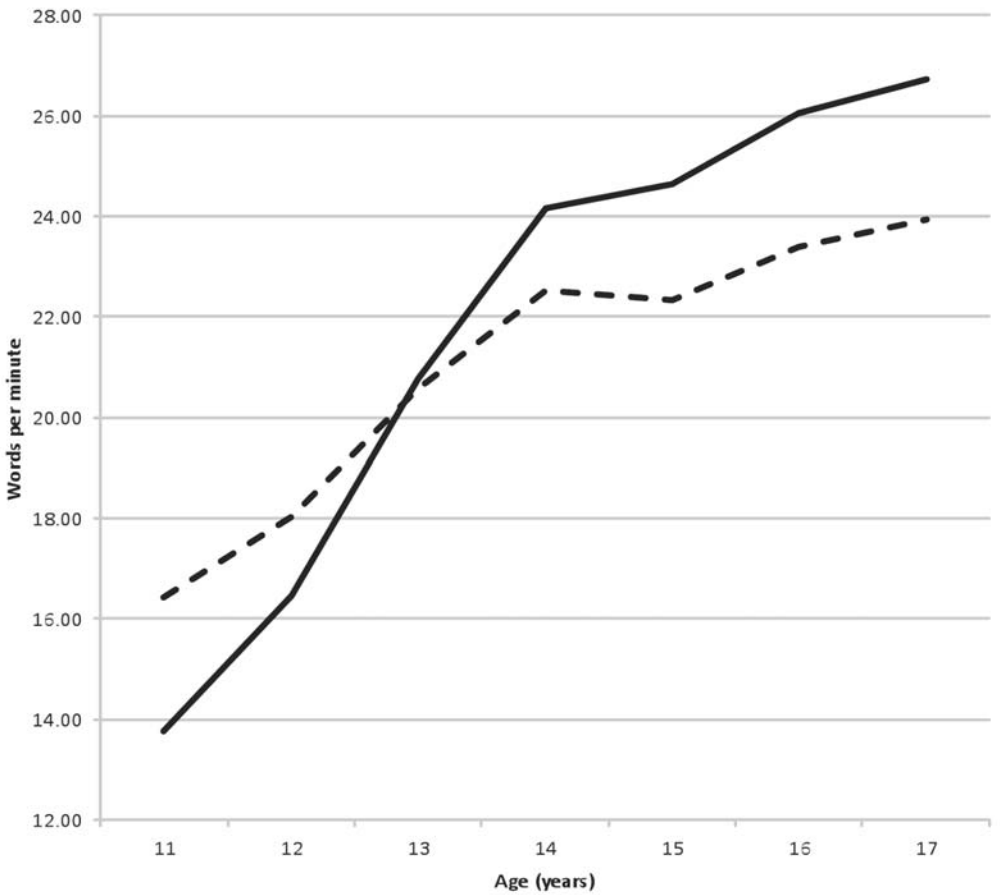
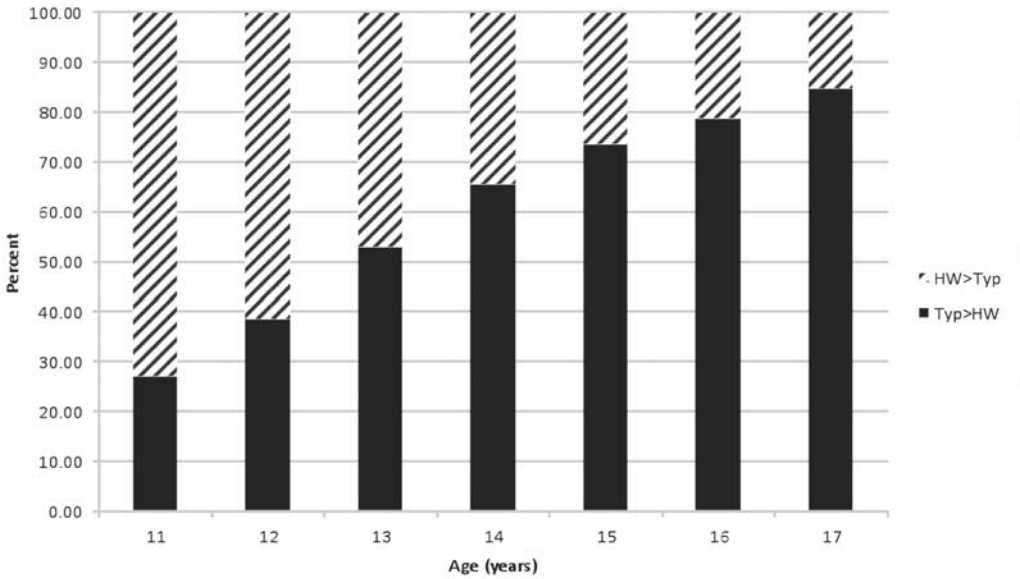


Figure 2: Age-related changes in relative typing and handwriting speeds – percentages of students whose typing speed is faster than their handwriting speed (solid bars) and percentages of students whose handwriting speed is faster than their typing speed (hatched bars).



Study 2

Participants

The participants in the second study were 54 Year 9 students who attended a large comprehensive school. These students (mean age 13 years 10 months; *SD*=4 months) were selected out of the total roll of 155 Year 9 students by the following process. First, those students in the two top groups whose literacy skills were not of concern (based on the results of previously-administered conventional tests) were ruled out. Second, the remaining students from the two top groups (i.e. those whose literacy skills did give some cause for concern), together with the rest of the students in the year who had not yet been assessed, formed a pool of students available for participation. Third, the 54 who actually took part in the study were selected because they were available when the school's computer facilities were accessible so that the computerised tasks could be carried out.

Tasks and tests

All participants completed the computerised handwriting and typing to dictation task. Other tests that were administered include the Cognitive Abilities Test (Lohman et al., 2001), WRAT4 Spelling Test (Glutting & Wilkinson, 2005), the Suffolk Reading Scale (Hagley, 1987) and the Hedderley Sentence Completion Test (SCT), although student absences on some testing sessions meant that there were a few gaps in the data set. Participants were assessed in groups using the school's networked computer suite.

Results

The results of all the measures used in this study are shown in Table 2. The mean of the Cognitive Abilities Test scores is 87.9 (*SD*=10.1), suggesting that this group of students was of slightly below average general ability, and reading skills as assessed

by the Suffolk Reading Scale were rather poor (M=78.72, SD=7.45), while spelling skills (as assessed by WRAT-4) were average. This apparent disparity is most likely to have been due to differences between the two tests in standardisation samples and dates, reflecting different educational standards as well as cohort effects (the Suffolk Reading Scale was standardised on UK samples in the mid-1980s, while the WRAT-4 Spelling Test was standardised on US samples in the early 2000s). However, speeds on all three writing measures were average, which is not particularly surprising.

Correlational analysis revealed strong significant relationships between reading, spelling and two of the three cognitive ability measures (see Table 3). However, the picture for relationships with handwriting and typing speeds was somewhat mixed. Both handwriting and typing speeds based on the computer tasks had moderate correlations with verbal ability (this was not significant for handwriting owing to the relatively small size of the sample) and also with spelling skills. But the scores from the Hedderley Sentence Completion Test had only a weak negative correlation with verbal ability (r=–0.16; NS); in fact, the Sentence Completion Test had low and/or non-significant correlations with all the other measures except the computerised measure of handwriting (r=0.54, p<0.01).

The participants were categorised into four different groups based on relative handwriting and typing speed (standard scores (SS)): 1. Below SS 95 for both handwriting and typing speed; 2. Below SS 95 for handwriting speed but SS 95 or greater for typing speed; 3. SS 95 or greater for handwriting speed but below SS 95 for typing speed; 4. SS 95 or greater for both handwriting and typing speeds. The results are shown in Table 4.

Significant group differences were found only on CAT Verbal scores [F(3,42)=4.36; p<0.01], where a clear pattern of increasing scores was seen across the groups 1 to 4. Post-hoc multiple comparisons revealed significance only when comparing Group 1 with Group 4 [Tukey HSD; p=0.028], but the effect size of the difference between these two groups was large (d=1.30). Differences on spelling scores approached significance [F(3,28)=2.87; p=0.057]. Group 1 performed consistently poorly, with standard scores below 90 across all measures. Three-quarters of this group were already on the school's SEN register and/or had identified educational support needs such as ADHD, speech and communication difficulties, moderate, borderline or specific learning difficulties, or spoke English as an additional language (EAL). When all 26 students in this sample who had handwriting speed below SS 95 (i.e. Groups 1 and 2) were considered, 31 per cent were found not to be on the school's SEN register and had not been identified as having educational support needs.

Discussion

The aim of these two studies was to investigate the use of computer-based dictation for measurement of speed of typing and handwriting. The first study, which used a large unselected sample of 952 students aged 11 to 17 years, demonstrated that the computerised tasks were effective in measuring both handwriting and typing speeds. Results showed that handwriting speed increased

Table 2: Descriptive statistics for all measures used in Study 2 (standard scores).

	CAT Verbal	CAT Non-verbal	CAT Quantitative	Suffolk Reading Scale	WRAT4 Spelling Test	Sentence Completion Test	Handwriting to dictation	Typing to dictation
Mean	88.37	84.85	90.36	78.72	93.62	95.13	96.46	96.80
SD	11.25	8.18	9.79	7.45	10.79	19.57	12.34	15.96

Table 3: Intercorrelations of all measures used in Study 2.

	CAT V	CAT NV	CAT Q	Reading	Spelling	SCT speed	HW speed	Typing speed
CAT V	1	.65**	.54**	.78**	.66**	–.16	.29	.34*
CAT NV	.65**	1	.66**	.61**	.53**	–.18	.16	.07
CAT Q	.54**	.66**	1	.50	.31	–.18	.22	.17
Reading	.78**	.61**	.50**	1	.40*	–.05	.18	.20
Spelling	.66**	.53**	.31	.40*	1	.06	.36*	.47*
SCT speed	–.16	–.18	–.18	–.05	.06	1	.54**	.21
HW speed	.29	.16	.22	.18	.36*	.54**	1	.48**
Typing speed	.34*	.07	.17	.20	.47*	.21	.48**	1

**Significant at $p<.01$ level; *Significant at $p<.05$ level.

Table 4: Performance grouped by relative handwriting and typing speed (standard scores).

Group	N		HW speed	Typing speed	CAT V	CAT NV	CAT Q	Reading	Spelling	SCT speed
1	18	*M*	85.94	83.11	83.40	83.00	88.87	76.15	89.31	89.00
		SD	4.82	8.12	9.64	6.61	10.45	5.79	9.59	17.50
2	8	*M*	86.63	106.50	86.86	84.43	90.00	84.00	96.00	83.33
		SD	5.81	8.65	6.82	8.10	9.18	5.00	1.73	7.09
3	10	*M*	102.80	83.90	88.00	88.50	89.75	79.29	97.00	100.29
		SD	8.43	7.42	10.39	9.83	8.62	8.98	10.12	14.17
4	18	*M*	107.83	113.33	97.08	87.58	95.00	79.80	102.80	109.33
		SD	8.77	6.16	11.35	8.61	9.70	9.68	9.37	26.40

progressively and in a near-linear fashion from about 16 wpm at age 11 to about 22 wpm at age 14, and thereafter began to level out, reaching almost 24 wpm at age 17. When task and age differences are allowed for, this trajectory is consistent with results reported in previous studies that have used conventional rather than computer-based methods (Allcock, 2001; Connelly et al., 2007; Graham, 1986a, 1986b; Phelps et al., 1985; Hedderley, 1996; Rosenblum et al., 2003; Wallen et al., 1996). Typing speed at age 11 (about 14 wpm) lagged behind handwriting speed, but by age 13 (20 wpm) had caught up with, and thereafter steadily overtook, handwriting speed, with students aged 17 attaining an average typing speed of almost 27 wpm. Again, the trajectory up to age 14 was near-linear, levelling off thereafter. However, there appear to be no comparable studies against which to compare the findings for typing speed, although the findings are consistent with those of Rogers and Case-Smith (2002), who reported that 70 per cent of their sample of sixth graders who had received typing tuition achieved typing speeds that exceeded their handwriting speed.

There was a rather low correlation between typing and handwriting speeds (r=0.14), which might at first sight be considered surprising, given figures cited in the research literature. Previous studies have reported higher correlations, ranging from 0.3 to 0.7. However, these involved younger children, and were mostly carried out at a time when computers were not so widely used in schools and home ownership of computers was much less common. It seems likely that the current generation of teenagers is, in general, much more proficient in the use of a keyboard than were their predecessors but also that there are large variations in typing skill (a conclusion supported by the much higher standard deviations for typing than handwriting) and that consequently typing speed in secondary school has become largely dissociated from handwriting speed. The results of this study show that most students increase their typing skills steadily during the secondary school years: while at age 11 the majority of students can write by hand faster than they can type, by the time they have reached age 14 their typing speed has overtaken their handwriting speed, and by age 17 all but a small proportion of students can type faster than they can write by hand. In primary school almost all children use a keyboard by the 'hunt and peck' method – i.e. searching for each key (Kennewell, 2001). Although probably few secondary school age students can touch type – otherwise average typing speeds would have been much higher (Brown, 1988a) – through repeated practice, keyboard familiarity has developed such that automaticity and motor memory has enabled much faster speeds to be achieved than when younger (Twining, 2002). By contrast, the greater complexity of motor control processes needed for letter formation places an inherent limitation on growth of handwriting speed: for most individuals, pressing a key is a faster movement than writing a character and even adults who are experienced two-fingered typists normally type faster than they can write by hand (Brown, 1988b; Rogers & Case-Smith, 2002).

The percentage of spelling errors in both the typing and handwriting tasks was low – about five per cent – suggesting that, in comparison with free writing tests, spelling was not a confound in these tasks. The high correlation (r=0.95) between the computer estimation and human count of number of words in the handwriting task, with an average discrepancy of only 2.01 words or 1.37 per cent, indicates that for the vast majority of cases, the computer's estimation can be relied on. Brief visual inspection by the teacher of handwriting samples is enough to determine whether a given student has complied with the task requirements and attempted to type the passage accurately and to the best of their ability. A human count can be carried out when it can be clearly seen that the number of words actually written is far fewer than the figure estimated by the computer. This situation, which was rare in this study, may arise if the student has skipped a large proportion of the words in the passage. In this study the discrepancy between the human and computer calculation was greater than ±5 per cent in only 7.5 per cent of cases and greater than ±10 per cent in 2.3 per cent of cases. It is likely that good preparation of students before assessment – for example, by warning them that the teacher will be able to detect when they have failed to undertake the task properly – would reduce these figures further.

The second study examined the relationships between speeds of typing and handwriting and various other measures. This was a much smaller-scale study in which the participants were not an unselected group and mean general ability was found to be a little below the average range. However, the computerised measure of handwriting was found to have a fairly strong correlation (r=0.54; p<0.01) with scores from a widely-used conventional test of handwriting speed (Hedderly Sentence Completion Test), which may be considered to provide a modest degree of validation for the computerised test. In contrast to the findings of the

first study, in which a relatively low correlation between typing and handwriting speeds was found (r=0.14), in the second study this correlation was much larger (r=0.48; p<0.001) and more consistent with correlation figures reported in the literature. However, it should be remembered that the sample in this study was not unselected and was below average in reading. Students with poorer verbal and reading skills are more likely than other students to struggle with writing generally, regardless of the mode of text production (Berninger et al., 1991), and hence a higher correlation between typing and handwriting speeds would be expected. Both the computerised measures of handwriting and typing speeds were found to have moderate correlations with verbal ability (this was not significant for handwriting owing to the relatively small size of the sample) and also with spelling skills. However, this does not necessarily undermine the conclusion drawn earlier – namely that spelling was not a confound in the computerised tasks – because such correlation figures would be expected in a group in which students with below-average ability predominated (Berninger et al., 1991).

When participants were grouped according to their relative performance in typing and handwriting, significant differences between groups were found for verbal ability, with the difference for spelling closely approaching significance. In particular, the group with both typing and handwriting below SS 95 were found to be below average in all measures, including reading, spelling and general abilities: most of the students in this group were already known to have special educational needs or require additional learning support.

It is not an oversight that the matter of legibility of handwriting has not been addressed in this paper. This is clearly an important factor (see Feder & Majnemer, 2007; Graham et al., 1998; Roaf, 1998; Rosenblum et al., 2003; Zivani, 1984; Zinavi & Elkins, 1984) which warrants detailed analysis. However, consideration of legibility was precluded here not only because of space but also because the large size of the data set in the first study means that analysis of legibility is a lengthy task which has yet to be completed. It is envisaged that a future paper will report the findings on this topic.

In conclusion, these two studies indicate that computer-based tasks provide a feasible and practical solution to the problems of assessing speed of handwriting and typing in secondary school students. The size of the data set in the first study (952 students) and the normal distribution of scores obtained from both the typing and handwriting tasks enabled standardisation to be carried out so that raw scores could be expressed in standard scores in yearly age bands, which are recommended when ascertaining eligibility for additional time in examinations (Backhouse, Dolman & Read, 2007). The availability of normative rates for typing for this task, together with the comparison of the two modes of writing, also enables teachers to decide whether it would be appropriate to advocate that a student use a word processor in examinations or whether an amanuensis would be more suitable. However, it is accepted that students who have typing and/or handwriting speeds within the average range for their age may still have difficulties in the production of ideas that would slow them down significantly in a free writing task, and that such skills also need to be taken into account when considering eligibility for additional time. Nevertheless, it is argued that, by eliminating the 'thinking' time involved in free writing, the computerised dictation tasks provide 'purer' measures of speed which can reveal physical handwriting and/or typing problems. The computer tasks also simulate examination requirements more closely than mechanical repetitive tests of writing speed, and should be particularly helpful in establishing whether students need access arrangements in examinations. It is notable that when all those in the second study who had below average handwriting speed were examined, almost one-third were found not to be on the

school's SEN register or not to have any identified educational support needs. Given that such students would potentially be disadvantaged in written examinations, the uncovering of their needs neatly illustrates the educational value in using a computer-based test that can easily be administered to all students.

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Address for correspondence:
Dr Joanna Horne
Department of Psychology,
University of Hull,
Hull, HU6 7RX, UK.
Email: j.k.horne@hull.ac.uk

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