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Handwriting automaticity: the search for performance thresholds

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Evidence is accumulating that handwriting has an important role in written composition. In particular, handwriting automaticity appears to relate to success in composition. This relationship has been little explored in British contexts and we currently have little idea of what threshold performance levels might be. In this paper, we report on two linked studies that attempted to identify performance levels in handwriting automaticity for children at two ages, below which their success in writing composition might be considered to be at risk. We conclude by suggesting interpolated levels for children at different ages, although we recognise the tentative nature of these suggestions.

Keywords: handwriting; composition; writing; performance; thresholds

Introduction

As we argued in a previous paper in this journal (Medwell and Wray 2008), handwriting has had a relatively low status in literacy education. Both its pedagogy and understandings of its role in the development of writing as a whole are still somewhat underdeveloped, and in our 2008 paper we argued for a re-assessment of the importance of handwriting as a key aspect of the development of writing, in particular the development of writing composition. An important element to this re-assessment is, we argued, a more developed understanding on the part of teachers and schools of what aspects of handwriting are important and what useful development in handwriting might look like. We reviewed current practice in terms of the assessment of handwriting and made the following points:

> Handwriting is statutorily assessed as part of the Standard Assessment Tasks and Tests (SATs), the marking schemes for which allocate up to 40 marks for writing at age 7 (Key Stage 1) and 50 marks at age 11 (Key Stage 2). At both ages, up to 3 marks can be awarded for handwriting. The assessment for these three marks is made on a sample of handwriting done during a composition assessment and the criteria include letter formation, orientation, relative size and fluency. As this is a product analysis, fluency must be taken to mean evidence of the effective joining of letters. Speed of writing is not included in the assessment. In short, this is an assessment of handwriting style, not of handwriting efficiency. (Medwell and Wray 2008, 34)

On the basis of existing and continuing research into the development and effects of handwriting, it seemed there was a need to establish more robust and effective assessments of aspects of handwriting related to composition, and to explore some aspects of what development in handwriting automaticity might look like.

The aim of the current paper is to report on two linked studies that have explored relationships between handwriting automaticity and writing composition in Year 2 (six- to seven-year-old) children (Study 1) and Year 6 (10–11-year-old) children (Study 2). A key objective of both these studies was the establishment, if possible, of some clear indicators of

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the level of handwriting automaticity that was likely to cause major difficulties for children in writing composition. In short, we have been searching for cut-off points for variously aged children below which the likelihood would be that these children would struggle to achieve expected levels of performance in writing more generally.

To contextualise these studies, we will briefly review the international evidence that handwriting automaticity is implicated in success in writing composition, although limited space precludes a complete review. In our earlier paper, we explored the key role of working memory in writing development, and in this paper we will elaborate that discussion to make the point that levels of automaticity in handwriting can impact negatively or positively upon success in writing composition. Part of our argument will be that this aspect of writing has been overlooked by researchers, and especially by teachers, for many years, to the detriment of writing development among school-aged children.

Handwriting is a language act

Writing is a complex process (Hayes 1996; DfEE/QCA 2000; Wray et al. 2002) and Hayes and Flower (1980) identify translating, reviewing and planning as underlying processes. Berninger and Swanson (1994) identified two separate components of translation as text generation and transcription. Transcription refers to representing the language as written symbols and involves the skills of handwriting and spelling (Berninger et al. 2002). Handwriting has generally been seen by teachers as a relatively simple, mechanical part of this process and has not been viewed as intrinsic to composing, but as a presentation skill. In England, the National Curriculum English requirements (DfEE/QCA 2000) concentrate on the formation and orientation of letters in handwriting and speed is mentioned only for typing. The recent draft proposals for revised National Curriculum requirements for English (DfE 2012) do mention speed as one element of handwriting, although the bulk of the requirements refer to letter formation. For Year 5/6 children (9–11-year-olds), the target is stated that children should 'write legibly, fluently, with increasing speed and personal style' (23). Yet research suggests that it is *automatic* handwriting that may have a significant effect on children's composing, and that automaticity matters more than simple speed.

A US programme of research (e.g. Berninger and Graham 1998; Berninger et al. 2006) developed the insight that handwriting is not simply a motor act. Berninger and Graham (1998) stress that it is 'language by hand' and their research suggests that orthographic and memory processes (the ability to recall letter shapes) contribute more to handwriting than do motor skills (Berninger and Amtmann 2004). Handwriting does not merely involve training the hand; it involves training the memory and hand to work together to generate the correct mental codes for production of letters and translate these into motor patterns of letters – automatically and without effort! If this is the case, then handwriting is important in writing as a language act, rather than just a motor act used to record writing. It may, therefore, be that focusing teaching and assessment exclusively upon letter formation and neatness, and even speed, can address only a small part of the importance of handwriting in writing.

Understanding how different writing processes (translation, planning, reviewing) are accomplished using the same, limited, working memory space seems to be particularly important for understanding the development of children's composition. Gathercole et al. (2004) note that working memory is particularly associated with the literacy scores of younger children. If young writers have to devote large amounts of working memory to the control of lower-level processes such as handwriting, they may have little working memory capacity left for higher-level processes such as idea generation, vocabulary selection, monitoring the progress of mental plans and revising text against these plans. Indeed, in

contrast to skilled writers, developing writers engage in little explicit planning and revision (Bereiter and Scardamalia 1987). It may be that handwriting can 'crowd out' composing processes.

One way of managing limited working memory capacity is to automate some processes, such as handwriting, so that they can be done without the need for cognitive attention (La Berge and Samuels 1974). This frees up cognitive resources to deal with higher-level processes. The development of skill in writing may require the automatisation of lower-level skills so that they use less of the available working-memory resources. The importance of automatic handwriting in composing is emphasised in research internationally – in Australia (Jones and Christensen 1999), the USA (Berninger and Amtmann 2004) and France (Olive et al. 2009). Some studies have suggested that automatic letter writing is the single best predictor of length and quality of written composition in the primary years (Graham et al. 1997), and in secondary and post-compulsory education (Jones 2004; Connelly et al. 2006; Peverley 2006). The idea that handwriting becomes more automatised in higher grades was observed by Olive et al. (2009) in a French context, who found that handwriting was more automatised and contributed less to cognitive effort for older children (Grade 9) than in younger children (Grade 5). However, we do not know when handwriting typically becomes automatic for children, in terms of age or rate of letter production. As we have seen, English national testing does not currently assess handwriting automaticity. It seems likely that we are currently failing to assess an important aspect of writing, even though researchers such as Connelly et al. (2006) have offered convincing evidence that, for many children, handwriting continues to be a demanding activity into the secondary years and beyond.

A number of children experience difficulties with handwriting throughout their schooling, but estimates of how many children are affected vary enormously, as do the basis of the estimates, which range from as high as 44% (Rubin and Henderson 1982; Alston 1985) to as low as 12–22% (Graham and Weintraub 1996). These figures suggest that lack of handwriting automaticity may affect a significant number of primary and secondary aged children, although the question of how far that automaticity may relate to the generation or production of letter codes and movements may be an issue for graphonomics research, involving the use of tablets to measure acceleration in writing movements (Tucha, Ticha, and Lange 2008). Such research has identified the importance of 'in air' time, that is, pauses during writing. This is also noted by Connelly et al. (2012) and Sumner, Connelly, and Barnett (2012) who consider 'burst length' in children with dyslexia and note that children with dyslexia pause more often. For these children reduced automaticity of letter production may be manifest in pauses, rather than slow production.

Internationally, studies (Jones and Christensen 1999; Christensen 2005; Olive et al. 2009) have used a simple alphabet-writing task, first designed by Berninger, Mizokawa and Bragg (1991) to measure orthographic-motor integration (the ability to generate the mental patterns and motor codes necessary to write letters) and to identify children with automaticity problems.

The present studies

The works of Jones and Christensen (1999) in Australia and of US researchers (Berninger, Mizokawa, and Bragg 1991; Graham et al. 1997; Olive et al. 2009) suggest a strong relationship between automaticity in handwriting and successful composition. It is important to explore whether these findings can be generalised to the British context, where the extent of difficulty with handwriting is as yet undetermined and children tend to learn a simpler writing script than those generally taught in the USA or in France. One small study of

a mixed age sample (Connelly and Hurst 2001) has tentatively suggested that this link between handwriting automaticity and composition is likely to be true for England.

The studies reported here used larger samples focussed on two age groups, Study 1 involving six- to seven-year-old children and Study 2 involving 10–11-year-olds. These studies aimed to explore the extent of handwriting difficulties by looking at levels of automaticity in the whole range of mainstream school children at the two age points. This was seen as a first step towards the development of a screening instrument that could identify children with handwriting difficulties who might benefit from targeted interventions to improve automatic letter production.

In both studies, we addressed the question of how children's handwriting speed and letter generation were related to their composition. To do this, we examined children's national test scores for composition (excluding spelling and handwriting) and compared these to measures of handwriting.

Study 1: seven-year-olds

The sample was composed of 186 Year 2 pupils in four randomly selected primary schools in the Midlands of England, and can be described as follows:

- It included 108 boys (58%) and 78 girls (42%).
- The mean age of the sample was 7:6.
- Eighty-seven per cent were recorded as White British, somewhat higher than the 79% of children so recorded in the total primary school population of England (DfES/Ofsted 2006).
- The remaining 13% belonged to other ethnic groups.
- The children came from a range of economic backgrounds and 17% were entitled to a free school meal, close to the national average of 18% (DfES/Ofsted 2006). (The proportion of pupils receiving free school meals is commonly used in the UK as a measure of social deprivation in schools.)
- Twenty per cent were on the special needs register within their school, close to the 21% of children with special educational needs (SEN) nationally (DfES/Ofsted 2006).
- Eleven per cent were left handed (as reported by the teachers), compared to the 10–15% of the population of England who are left handed (Bentley and Stainthorp 1993).

This data suggests, therefore, that these children were not particularly 'different' from the national population. We included children with special needs in the sample because we were interested in the whole range of children in primary classes.

Measures of composition

The writing of these children was assessed as part of the statutory national assessment at the end of Y2 (age six to seven years). Assessment of composition required the writing of two pieces – a longer and a shorter piece, of two contrasting text types. The pieces were marked by teachers using task-specific criteria that offered 30 marks for composition, broken down as follows:

(1) Longer task (possible 18 marks)
   - Sentence structure: up to 4 marks

- Punctuation: up to 4 marks
- Composition and effect: up to 10 marks

(2) Shorter Task (possible 12 marks)

- Sentence structure and punctuation: up to 5 marks
- Composition and effect: up to 7 marks

Marking of papers was moderated within schools and across schools as part of the local arrangements for moderation of national assessments.

Measures of handwriting

Three measures of handwriting were used, to address different aspects of handwriting ability.

Measure 1 (Handwriting SAT)

Handwriting style and neatness while composing is statutorily assessed as part of the national Standard Assessment Tasks (SAT) and up to 3 marks can be awarded for handwriting using the following criteria:

1 mark: Writing is legible and letters are usually correctly formed and orientated. Generally, upper and lower case letters are not mixed within the word.

2 marks: Letters are correctly formed and orientated. Writing may be in a controlled printed style, with letters generally neat and regular in size, and ascenders and descenders usually distinguished. Alternatively, there may be evidence of the ability to join letters, although this detracts from the overall regularity of the handwriting.

3 marks: Letters correctly formed and orientated. Handwriting is neat and regular in size, with ascenders and descenders usually distinguished. There is evidence of fluency and the ability to join letters.

The assessment for these three marks is made on a sample of handwriting done during a composition assessment and is a product analysis. Fluency is taken to mean evidence of the effective joining of letters. Speed of writing or efficiency of letter generation is not included in the assessment.

Measure 2 (Handwriting speed)

The Handwriting Speed Test (Wallen, Bonney, and Lennox 1996) was used to assess handwriting speed, giving a score in letters per minute (LPM). This test asks children to read and reproduce a sentence containing all the letters of the alphabet ('The quick brown fox jumps over the lazy dog') as many times as possible in three minutes. It does not assess neatness (although letters have to be correctly formed) or ability to generate letters. All letters, including crossings-out, were counted and the tests were each marked by two separate markers, generating a high level of inter-marker reliability ($r = 0.99$, using Pearson's product-moment correlation).

Measure 3 (Alphabet Task–Handwriting Automaticity)

Orthographic-motor integration of handwriting involves mentally coding visual representations of letter patterns and integrating them with motor patterns (Berninger 1994) and the level of automaticity at which this could be achieved was measured using an alphabet-writing task described by Berninger, Mizokawa, and Bragg (1991) for use with children

with special needs. This task involved writing in lower case as many letters of the alphabet in order as possible in one minute. The present study used the version used by Jones and Christensen (1999) and Christensen (2005) with mainstream children in their studies. Children who completed all 26 letters in lower case continued the task using upper case. Although children have plenty of opportunity to write all these letters in the course of their school work, they rarely write the whole alphabet from memory in sequence, so this task is not well rehearsed and demands organisation and retrieval of letter forms in visual memory as well as the generation of the relevant motor patterns. We chose to include both capital letters and small letters as Jones and Christensen (1999) and Christensen (2005) did, reasoning that letter generation in written composition applies to both representations. Other authors have used only lower case letters (Olive et al. 2009; Sumner, Connelly, and Barnett 2012) and the DASH (Barnett et al. 2007) has also used this format.

Scores were calculated by counting letters that were recognisable out of the context of the rest of the writing. Omissions, reversals, transpositions (of case) and substitutions did not count towards children's scores. Scores were given in alphabet letters per minute (ALPM). Each test was marked by two separate markers and a high level of inter-marker reliability obtained ($r = 0.98$, using Pearson's product-moment correlation).

Findings

The range of scores on the Alphabet Task was 3–44 ALPM with a mean of 16.7 (SD = 8.4). This is directly comparable with the findings of Jones and Christensen (1999) who found, for children of the same age, a range of 3–32, a mean of 18.0 (SD = 5.8). The English children produced a wider range of performance on this task.

The range of scores for the Handwriting Speed Test was 9–75 LPM with a mean of 33.7 (SD = 11.9). In an American study, Graham et al. (1997) report a mean copying speed of 19.0 LPM (SD = 7.0) for Grade 1 children. It may be that copying a passage is more demanding than repeatedly copying one sentence.

In the Handwriting SAT, 30.6% of children scored 1 point, 43.0% scored 2 points and 21.5% scored 3 points. The mean was 1.9. This shows a surprisingly large number of children still struggling with orientation and regularity of letter formation but in the absence of data about targets or teacher expectations in this area it is not possible to know whether this is a matter for concern.

The range for composition was 3–29, with a mean of 18.0 (SD = 6.0). The sample seems to have been close to the national average in their writing outcomes with 69% of pupils achieving Level 2b or above in writing, where the national average was 62% (DfES/Ofsted 2006).

The relationship between handwriting and composition

The full correlation matrix (Appendix 1) shows a very high correlation between performance on the Alphabet Task and Composition ($r = .58$). Alphabet Task performance accounted for 34% of the variance in composition for these children. This is higher than the correlation for speed alone (Handwriting Speed Test) at $r = .44$ or the correlation with neatness and letter formation (indicated by the Handwriting SAT score) of $r = .54$. The Handwriting Speed Test involves copying and is a pure measure of speed, which may well contribute to composition by allowing the child to write more in a given time. However, the Alphabet Task measures the mental generation and motor production of the letter symbols and it is automatic performance at this orthographic-motor integration that may account

Table 1. Stepwise multiple regression of handwriting measures against composition score (Study 1).

Variable	Multiple *R*	Adjusted *R* square	B	Standard error	Beta	Significance of *t*
ALPM	.58	33.8	.24	.05	.34	$p < .001$
Handwriting SAT	.67	44.4	2.73	.48	.36	$p < .001$
Handwriting speed	.68	45.6	6.97	.04	.14	$p < .05$

for its stronger prediction of composition quality because it frees up the working memory to focus on composing. Speed alone is not enough.

Interestingly, these results are different from those reported in studies outside England. Jones and Christensen (1999) report scores on the Alphabet Task as accounting for 67% of the variance in composing scores for Y2 Australian children. Berninger and Graham (1998) report handwriting automaticity accounted for 25% of the variance in compositional quality in primary grades in the USA. This sample of English Y2 children falls between the findings in these two English-writing countries.

Stepwise multiple regression of handwriting predictors of composition

A multiple regression analysis of the three handwriting predictors of composition is presented in Table 1. The Alphabet Task is entered first because it is the best single predictor of composition. The scores on the Alphabet Task and the Handwriting Speed Test are highly correlated ($r = 0.60$) but not synonymous. Thus, adding Handwriting Speed to the regression increases the multiple *r* to .67, explaining an additional 10% of the variance in composition. Handwriting Speed may well contribute to composition by allowing the child to write more in a given time. Finally, the Handwriting SAT makes only a minimal addition to the prediction of composition, explaining just an additional 1.2% of the variance.

Causal relationship between ALPM and composition

What has been demonstrated above is only a correlation between performance on the Alphabet Task and composition scores. This is not sufficient to establish a causal role for automatic letter production in relation to composition. The correlation might arise from the influence of a third factor that determines both ALPM and composition scores. It may be, for example, that reading, as a measure of general literacy competence, underpins both high ALPM and high composition scores (Graham and Weintraub 1996; Jones and Christensen 1999). A partial correlation was therefore computed to establish the relationship of ALPM with composition, independent of the influence of reading proficiency. The measure of reading proficiency used was the SAT reading levels for each child, as assessed using the national SAT reading test administered at seven-year-olds. Children can achieve a Level W (working towards 1), Level 1, Level 2c, Level 2b, level 2a or Level 3. The following standard scale of points is used to convert the levels to scores: W = 3, 1 = 9, 2c = 13, 2b = 15, 2a = 17, 3 = 21.

Reading score is a good predictor of both composition ($r = .84$) and performance on the Alphabet Task ($r = .55$), so is a relevant control variable. The zero-order correlation of ALPM and composition is 0.58 (see Table 2). After controlling for reading score, the partial *r* drops slightly to 0.43, but remains highly statistically significant ($p < .001$). Thus, there is a strong relationship between ALPM and composition even when variation in reading attainment is accounted for. This is important since it establishes that the correlation between

Table 2. Range, mean and SD of writing test scores (Study 2).

	N	Range	Mean	SD
ALPM	197	1–78	31.7	11.4
LPM	197	4–113	64.2	19.1
Handwriting SAT scores	196	1–3	1.7	0.67
Composition SAT scores	196	5–38	20.7	6.9
Reading SAT scores	196	2–47	30.7	9.6
Maths SAT scores	197	7–100	60.1	22.7

performance on the Alphabet Task and composition is not simply mediated by both being related to good reading. It does not definitively establish that low handwriting automaticity causes poor composition, but it makes it more likely that there is some direct association in the correlation.

When lack of automaticity is a problem

It is important to establish if there is a threshold of automatic letter production for children of this age, below which a lack of automaticity has a particularly negative impact on composition quality. Our approach to identifying a threshold level of automaticity was to look at the relationship of Alphabet Scores with an external criterion. For seven-year-olds, the national expectation is that the typical pupil should achieve Level 2b in writing. A logistic regression was computed to identify the relationship between ALPM and the probability of achieving Level 2b or above in the national writing test. Figure 1 gives a graphical presentation of the results.

The results reveal that for a pupil achieving a score of 12 ALPM on the Alphabet Task the predicted probability of achieving Level 2b or above falls to 40%. This is a level where children in our sample may be 'at risk' of not achieving Level 2b. Our sample is close to the national average in terms of their writing attainment, with 58% of pupils achieving Level 2b or above compared to the 2006 national average of 60%. The results are therefore suggestive for the general population.

However, the overall success rate of a cut-off point of 12 ALPM in identifying who will or will not achieve writing Level 2b is only 73%. Some pupils do achieve Level 3 even with ALPM <10: equally, some pupils with ALPM as high as 27 still only achieve Level 1. Although these figures do not offer sufficient predictive accuracy to make ALPM a valid screening test on its own, the high relative 'risk' suggests that 12 LPM or less is a rough threshold for these seven-year-old children.

Study 2: 11-year-olds

The Sample

The sample was composed of 198 Y6 pupils from four randomly selected primary schools in the Midlands of England, and can be described as follows:

- It included 101 boys (51%) and 97 girls (42%).
- The mean age of the sample was 11:1.
- Eighty-six per cent were recorded as White British, compared to 79% of children so recorded in the total primary school population of England (DfES/Ofsted 2006).
- The remaining 14% were from a range of other ethnic groups.

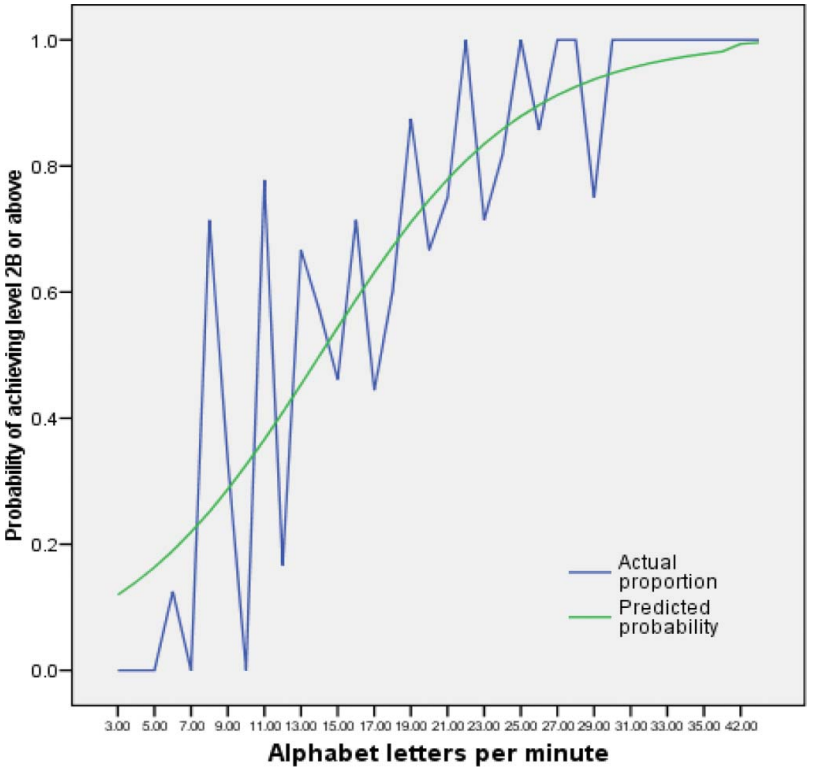

Figure 1. Logistic regression of ALPM against the probability of achieving Level 2B or above in the KS1 writing test.

- The children came from a range of economic backgrounds and 18% were entitled to a free school meal, the same as the national primary school average (DfES/Ofsted 2006).
- Forty-three pupils (21%) were recorded as having special educational needs (SEN), the same as the national proportion of pupils (DfES/Ofsted 2006).
- Twenty-two per cent were left handed (as reported by the teachers), compared to 10–15% of the population of England (Bentley and Stainthorp 1993).

Again, this data suggests that these children were not particularly 'different' from their average counterparts elsewhere in the country. We included children with special needs in the sample because this study was interested in the whole range of children in primary classes.

Measurement of composition

The writing of all the children in the sample was assessed as part of the statutory national testing at the end of Y6 (age 10–11 years). Assessment of composition required the writing of two pieces – a longer and a shorter piece, of two contrasting text types. These pieces were marked by external markers (and nationally moderated) using task-specific criteria that offered 40 marks for composition, broken down as follows:

(1) Longer task (possible 28 marks)
- Sentence structure and punctuation: up to 8 marks
- Text structure and organization: up to 8 marks
- Composition and effect: up to 12 marks

(2) Shorter Task (possible 12 marks)
- Sentence structure, punctuation and text organization: up to 4 marks
- Composition and effect: up to 8 marks

The KS2 writing test has been the subject of debate since its inception, principally because of the use of a test, rather than teacher assessment. Doyle and Godfrey (2005) questioned the reliability and predictive validity of these tests. However, Strand (2006) noted that KS2 tests are highly correlated with pupils' subsequent performance in national tests and examinations and showed good predictive validity. These tests, in common with the composition measures used for most of the US, Australian and French studies, above, use two pieces of writing, of different text types. The criteria for marking are genre specific and results can be standardised. It is well established that domain knowledge constrains writing (McCutchen 1996) and that poor performance may reflect lack of domain knowledge rather than lack of writing skills. In this respect, the national curriculum tests are substantially piloted to ensure equitable domain knowledge.

The KS2 writing test provides measures used for many purposes and Ray (2000) criticised ill-founded attempts to derive formative classroom planning from KS2 writing test scores. The criteria for the writing tests were designed as a summative test of writing against national curriculum levels against which pupil performance is judged. The writing tests in this study were externally marked and marking is moderated in a national system. The results of these high-stakes tests are used not only to report individual pupil progress but also to measure school effectiveness as part of league tables and Ofsted inspection. As such, we chose to use these tests to measure composition for the present study partly because this measure is highly meaningful to teachers, and thresholds relevant to achieving expected levels are comprehensible to them.

The Bew Report has recommended that, in future, writing be assessed only through summative teacher assessment (Bew 2011). This appears to be based not on limitations of the composition test, but rather the political wish to use instead a test of spelling, punctuation, vocabulary and grammar.

Measurement of handwriting

The three measures of handwriting used in the study were the same as those used in Study 1.

Measure 1 (Handwriting SAT)

The rubric for awarding marks for handwriting as part of the national test is slightly different from that used with the younger children, although, again, up to 3 marks can be awarded using the following criteria:

- 1 mark: The handwriting is legible and shows some features of regularity in size and spacing. However, overall the script is disjointed and uneven.
- 2 marks: Overall, the handwriting is regular with some flow and movement. Letters and words are usually appropriate in size and position but there is some variation.

- 3 marks: The handwriting is consistent and fluent with letters and words appropriately placed. The handwriting maintains a personal style to engage the reader.

Measure 2 (Handwriting speed)

Copying test (Wallen, Bonney, and Lennox 1996): ('The quick brown fox jumps over the lazy dog'.) giving a score in LPM.

Measure 3 (Alphabet Task)

The alphabet-writing task, giving a score of ALPM.

Findings

The range, mean and SD of the writing test scores are presented in Table 2.

The range of scores on the Alphabet Task was 1–78 ALPM with a mean of 31.7. This was approximately twice the score of the seven-year-olds in Study 1 (mean 16.7) that suggests that performance on the Alphabet Task was very strongly age related.

The range of scores for the Handwriting Speed Test was 4–113 LPM with a mean of 64.2. In the Handwriting SAT, 38.4% of children scored 1 point, 48.0% scored 2 points and 12.6% scored 3 points. The mean was 1.7. The range of composition SAT scores was 4–46, with a mean of 26.5. The sample seems to have scored a little less than the national average in their writing outcomes with 57.6% of pupils achieving Level 4 or above in writing, where the national average was 67% (DfES/Ofsted 2006).

The table also shows the SAT scores for reading and mathematics for these children, whose use to exclude the influence of reading proficiency and mathematics achievement is described below.

The relationship between handwriting and composition

The full correlation matrix (Appendix 2) shows a high correlation between performance on the Alphabet Task and Composition ($r = .46$). This is higher than the correlation with writing speed alone (LPM; $r = .32$) or with neatness and letter formation as indicated by the Handwriting SAT score ($r = .34$).

The Alphabet Task performance accounted for 21.5% of the variance in composition for these Y6 children, which is lower than the equivalent figure for Y2 children (34%). This may indicate that as writers develop, there are other issues that account for more of the variance.

Stepwise multiple regression of handwriting predictors of composition

A multiple regression analysis of the three handwriting predictors of composition is presented in Table 3. The Alphabet Task was entered first because it is the best single predictor of composition. Only scores on the Alphabet Task and Handwriting SAT score (neatness) were significant. Thus, adding the SAT score for handwriting (neatness) to the regression increases the multiple r to .56, explaining an additional 10% of the variance in composition. Pure handwriting speed plays no part in predicting composition scores after automatic letter production (the Alphabet Task) and neatness (SAT Handwriting score) are accounted for. This is in contrast to the Y2 results, where handwriting speed did account for a further 10% of the variance.

Table 3. Multiple regression of handwriting measures against writing composition score (Study 2).

	Unstandardised coefficients (B)	Standard error	Standardised coefficients (Beta)	*t*	Significance
Constant	11.307	1.700		6.651	.000
Alphabet letters per minute	.251	.050	.384	5.060	.000
Letters per minute	.036	.028	.096	1.287	.200
Handwriting score 1 (vs. 2)	−3.343	.922	−.234	−3.626	.000
Handwriting score 3 (vs. 2)	3.119	1.325	.150	2.355	.020

Note: Dependent variable: KS2 composition score.

Causal relationship between ALPM and composition

As in Study 1, what has been demonstrated here is only a correlation between performance on the Alphabet Task and composition scores, and not a causal relationship. The correlation might arise from the influence of a third factor that determines both ALPM and composition scores. A partial correlation was computed to establish the relationship of ALPM with composition, independent of the influence of reading proficiency and mathematics achievement. The measures of reading proficiency and mathematics achievement used were the SAT reading and mathematics scores for each child, assessed using the national tests. The range, mean and SD of these can be seen in Table 2.

Total reading and mathematics score is a good predictor of both composition ($r = .63$) and performance on the Alphabet Task ($r = .50$), so is a relevant control variable. The zero-order correlation of ALPM and composition is 0.46 (see Table 2). After controlling for mathematics and reading scores, the partial r drops to 0.22, but remains statistically significant ($p < .005$). Thus, there is a strong relationship between ALPM and composition even when variation in reading and mathematics attainment is accounted for. This is important since it establishes that the correlation between performance on the Alphabet Task and composition is not simply mediated by both being related to good reading or general intelligence. It does not definitively establish that low handwriting automaticity causes poor composition, but it makes it more likely that there is some direct association in the correlation.

When lack of automaticity is a problem

One of our aims was to establish if there was a threshold of automatic letter production for children of this age, below which a lack of automaticity had a particularly negative impact

Table 4. Pupils in different score bands on ALPM (Study 2).

Alphabet Task Score band	Frequency	Valid (%)	Cumulative (%)	% achieving Level 4+ in writing test
1: Bottom 16% (0–22)	32	16.2	16.2	27.3
2: Low (23–25)	22	11.2	27.4	47.2
3 low-middle (26–29)	38	19.3	46.7	52.4
4: High-middle (30–34)	37	18.8	65.5	53.7
5: High (35–42)	35	17.8	83.2	76.2
6: Top 16% (43+)	33	16.8	100.0	88.0
Total	197	100.0		58.8

Note: One case was missing for ALPM score.

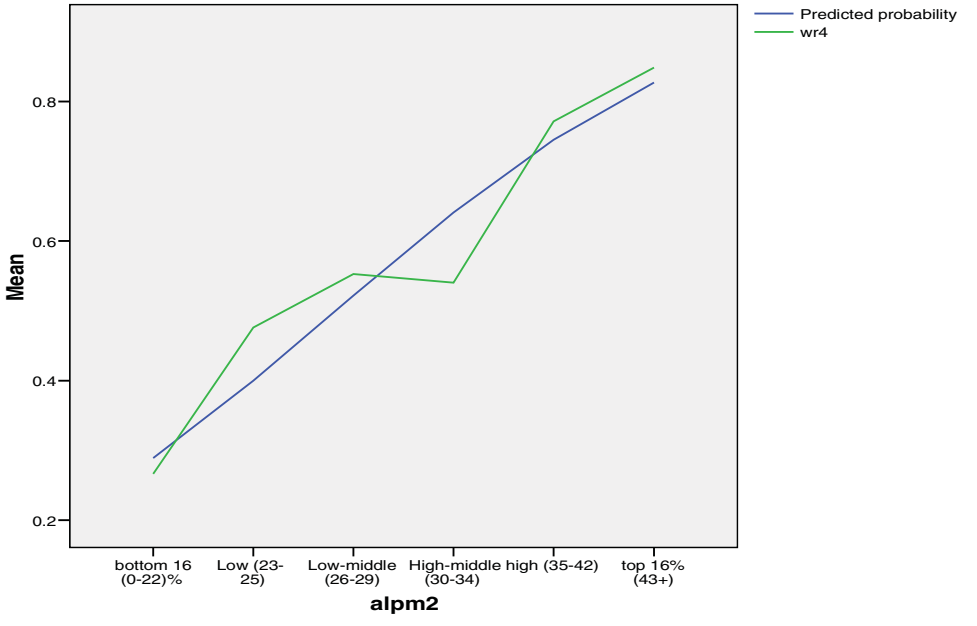

Figure 2. Logistic regression of ALPM against the probability of achieving Level 4 or above in the KS2 writing test.

on composition quality. To identify such a threshold level, we took a normative approach and looked at the relationship with an external criterion. Within the sample, the Alphabet Task scores were grouped into six bands each containing approximately 17% of the sample (Table 4).

This banding reduces the correlation with composition slightly, but not excessively (r drops from .46 to .45). For these 11-year-olds, the national expectation is that the typical pupil should achieve Level 4 in writing. A logistic regression was computed to identify the relationship between ALPM and the probability of achieving Level 4 or above in the national writing test. Figure 2 gives a graphical presentation of the results in Table 4.

For the two middle groups (Bands 3 and 4), the probability is around the sample average. However, for Band 5 this rises to 76% and to 88% for Band 6. Conversely, for Band 2 the probability drops to 47% and to only 27% for Band 1. This suggests an ALPM of 22 or less indicates a significant risk of not achieving Level 4 in writing. However, overall accuracy of prediction is only 67%. If Handwriting SAT score (neatness) is also included, the accuracy

Table 5. Interpolated threshold scores for primary children.

Year group	Empirically suggested threshold scores on ALPM	Interpolated threshold scores on ALPM
6–7-year-olds	12	
7–8-year-olds		15
8–9-year-olds		17
9–10-year-olds		20
10–11-year-olds	22	

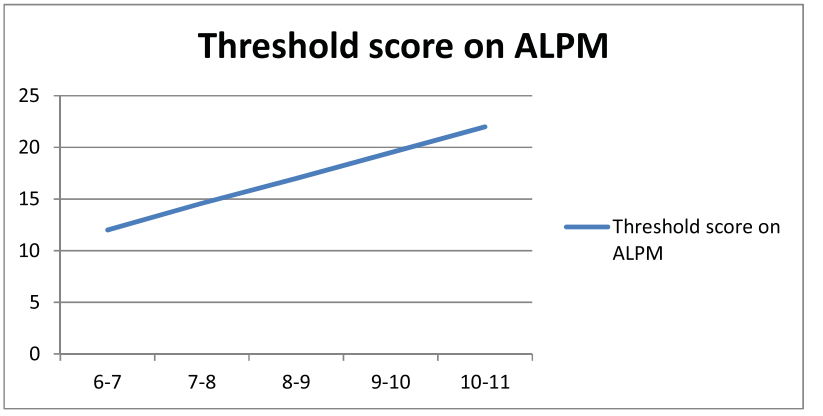

Figure 3. ALPM threshold scores, with interpolations.

is raised to 73%. Speed is not a significant predictor of risk when ALPM and handwriting are included.

Although these figures again do not offer sufficient predictive accuracy to make ALPM a valid screening test on its own, the high relative 'risk' suggests that 22 LPM or less is a rough threshold at which teachers should consider further diagnostic and intervention work.

Sex differences in ALPM within the samples

These studies found highly statistically significant differences on the Alphabet Task at Y6 that relate to sex. The Y6 boys scored on average five letters per minute lower than girls ($p < .001$). This is close to what Wallen, Bonney and Lennox (1996) reported for the Australian Handwriting Speed Test (4 LPM advantage for girls). The boys in the Y2 sample scored on average 3.5 LPM lower than girls ($p < .003$). The finding that the difference in ALPM on the Alphabet Task that relate to gender is greater in older children suggests that this difference may be related to the current perceived underachievement of boys in writing (UKLA/PNS 2004).

Conclusions

The results of these studies suggest that a high proportion of the variance in composition for the children included was related to their handwriting and, in particular, to their ability to generate letters automatically, as measured by the Alphabet Task. This supports the idea that letter generation makes cognitive demands on children and may take up working memory capacity that is, therefore, not available for higher level composing tasks. There are commercial handwriting tests that include this task (Barnett et al. 2007) but such tests do not attempt to offer thresholds related to an external composition criterion.

We suggest that these studies present an important finding, given the widespread assumption that handwriting is simply a matter of presentation. Both studies reported here go some way towards identifying levels at which 7- and 11-year-olds might benefit from improving their automaticity, in order to facilitate their composing. Seven-year-olds who scored around 12 ALPM, or less, on the Alphabet Task had only a 40% chance of achieving Level 2b in the Handwriting SAT, and 11-year-olds scoring 22 ALPM or less had a similar chance of achieving the expected Level 4 in their Handwriting SAT. Although the Alphabet Task is not a screening mechanism for identifying all children at risk of achieving a low

SAT score, it does identify many children for whom poor handwriting automaticity may be affecting their composing.

It is, of course, tempting to interpolate likely threshold scores on the Alphabet Task for children between these ages. A graphical representation of the threshold scores we have found (see Figure 3) suggests that these thresholds are likely to be those given in Table 5.

In this paper, we have begun the process of establishing the relationship between handwriting fluency (orthographic-motor integration) and composition ability. The evidence we have provided suggests that there is such a relationship, and that this may be much more important than hitherto realised. Our attempts to establish thresholds for handwriting automaticity that might help predict composition ability for children of various ages are, we accept, tentative. There is further research to do to explore the complex nature of the relationships we have uncovered, including work about ways in which children with specific literacy difficulties may experience these relationships (Sumner, Connelly, and Barnett 2012). Yet, we are convinced that these are potentially very fruitful lines of enquiry, for both researchers and for teachers of writing.

References

Alston, J. 1985. "The Handwriting of Seven to Nine Year Olds." *British Journal of Special Educational Needs* 12: 68–72.

Barnett, A., S.E. Henderson, B. Scheib, and J. Schulz. 2007. *DASH – Detailed Assessment of Speed of Handwriting*. London: Pearson.

Bentley, D., and R. Stainthorp. 1993. "The Needs of Left Handed Children in the Infant Classroom: Writing is Not Always Right." *Reading* 27: 4–9.

Bereiter, C., and M. Scardamalia. 1987. *The Psychology of Written Composition*. Hillsdale, NJ: Lawrence Erlbaum.

Berninger, V.W. 1994. *Reading and Writing Acquisition: A Developmental Neuropsychological Perspective*. Dubuque, IA: Brown and Benchmark.

Berninger, V.W., R.D. Abbott, J. Jones, B. Wolf, L. Gould, M. Anderson-Youngstrom, S. Shimada, and K. Apel. 2006. "Early Development of Language by Hand: Composing, Reading, Listening and Speaking Connections; Three Letter Writing Modes; and Fast Mapping in Spelling." *Developmental Neuropsychology* 29, no. 1: 61–92.

Berninger, V.W., and D. Amtmann. 2004. "Preventing Written Expression Disabilities Through Early and Continuing Assessment and Intervention for Handwriting and/or Spelling Problems: Research into Practice." In *Handbook of Research on Learning Disabilities*, eds. L. Swanson, K. Harris, and S. Graham, 345–363. New York: Guilford Press.

Berninger, V.W., and S. Graham. 1998. "Language by Hand: A Synthesis of a Decade of Research on Handwriting." *Handwriting Review* 12: 11–25.

Berninger, V.W., D.T. Mizokawa, and R. Bragg. 1991. "Theory-Based Diagnosis and Remediation of Writing Disabilities." *Journal of Educational Psychology* 29: 57–59.

Berninger, V.W., and H.L. Swanson. 1994. "Modifying Hayes and Flower's Model of Skilled Writing." In *Advances in Cognition and Educational Practice*, eds. E.C. Buttereld and J.S. Carlson, 57–81. Greenwich: JAI Press.

Berninger, V., K. Vaughan, R. Abbott, K. Begay, K. Byrd, G. Curtin, H.J. Minich, and G. Steve. 2002. "Teaching Spelling and Composition Alone and Together: Implications for the Simple View of Writing." *Journal of Educational Psychology* 94: 291–304.

Bew, P.Lord. 2011. *Independent Review of Key Stage 2 Testing, Assessment and Accountability*. London: Department for Education.

Christensen, C.A. 2005. "The Role of Orthographic-Motor Integration in the Production of Creative and Well Structured Written Text for Students in Secondary School." *Educational Psychology* 25, no. 5: 441–453.

Connelly, V., S. Campbell, M. MacLean, and J. Barnes. 2006. "Contribution of Lower Order Skills to the Written Composition of College Students with and without Dyslexia." *Developmental Neuropsychology* 29: 175–196.

Connelly, V., J. Dockrell, K. Walter, and S. Critten. 2012. "Predicting the Quality of Composition and Written Language Bursts from Oral Language, Spelling, and Handwriting Skills in Children with and without Specific Language Impairment." *Written Communication* 29: 278–302.

Connelly, V., and G. Hurst. 2001. "The Influence on Handwriting Fluency on Writing Quality in Later Primary and Early Secondary Education." *Handwriting Today* 2: 5–57.
DfE (Department for Education). 2012. *Draft National Curriculum Documents for Primary English, Mathematics and Science*. London: DfE. http://www.education.gov.uk/schools/teachingandlearning/curriculum/nationalcurriculum/a00210036/sosletter
DfEE/QCA (Department for Education and Employment/Qualifications and Curriculum Authority). 2000. *The National Curriculum Handbook for Primary Teachers in England: Key Stages 1 and 2*. London: HMSO.
DfES/Ofsted (Department for Education and Skills/ Office for Standards in Education). 2006. *National School Improvement Summary Report for Maintained Primary Schools*. London: DfES/Ofsted.
Doyle, L., and G. Godfrey. 2005. "Investigating the Reliability of the Key Stage 2 Test Results for Assessing Individual Pupil Achievement and Progress in England." *London Review of Education* 3, no. 1: 29–45.
Gathercole, S.E., S.J. Pickering, C. Knight, and Z. Stegmann. 2004. "Working Memory Skills and Educational Attainment: Evidence from National Curriculum Assessments at 7 and 14 Years of Age." *Applied Cognitive Psychology* 18: 1–16.
Graham, S., V. Berninger, R. Abbott, S. Abbott, and D. Whitaker. 1997. "The Role of Mechanics in Composing of Elementary School Students: A New Methodological Approach." *Journal of Educational Psychology* 89, no. 1: 170–182.
Graham, S., and N. Weintraub. 1996. "A Review of Handwriting Research: Progress and Prospects from 1980 to 1994." *Educational Psychology Review* 8: 7–87.
Hayes, J., and L. Flower. 1980. "Identifying the Organization of Writing Processes." In *Cognitive Processes in Writing*, eds. L.W. Gregg and E.R. Steinberg, 3–30. Hillsdale, NJ: Erlbaum.
Hayes, J.R. 1996. "A New Model of Cognition and Affect in Writing." In *The Science of Writing*, eds. C. Levy and S. Ransdell, 1–30. Hillsdale, NJ: Erlbaum.
Jones, D. 2004. "Automaticity of the Transcription Process in the Production of Written Text." PhD diss., University of Queensland.
Jones, D., and C. Christensen. 1999. "The Relationship between Automaticity in Handwriting and Students' Ability to Generate Written Text." *Journal of Educational Psychology* 91: 44–49.
La Berge, D., and S.J. Samuels. 1974. "Toward a Theory of Automatic Information Processing." *Cognitive Psychology* 6: 283–323.
McCutchen, D. 1996. "A Capacity Theory of Writing: Working Memory in Composition." *Educational Psychology Review* 8: 299–325.
Medwell, J., and D. Wray. 2008. "Handwriting: A Forgotten Language Skill?" *Language and Education* 22, no. 1: 34–47.
Olive. T., M. Favart, C. Beauvais, and L. Beauvais. 2009. "Children's Cognitive Effort and Fluency in Writing: Effects of Genre and of Handwriting Automatisation." *Learning and Instruction* 19, no. 4: 299–308.
Peverley, S. 2006. "The Importance of Handwriting Speed in Adult Writing." *Developmental Neuropsychology* 29: 197–216.
Ray, R. 2000. "Task Setting and Marking in the Key Stage 2 SAT Writing Test." *Educational Review* 52, no. 3: 279–290.
Rubin, N., and S.E. Henderson. 1982. "Two Sides of the Same Coin: Variation in Teaching Methods and Failure to Learn to Write." *Special Education: Forward Trends* 9: 17–24.
Strand, S. 2006. "Comparing the Predictive Validity of Reasoning Tests and National End of Key Stage 2 Tests: Which Tests are the 'Best'?" *British Educational Research Journal* 32, no. 2: 209–225.
Sumner, E., V. Connelly, and A. Barnett. 2012. "Children with Dyslexia are Slow Writers because They Pause More Often and Not because They are Slow at Handwriting Execution." *Reading and Writing* 25. doi: 10.1007/s11145-012-9403-6.
Tucha, O., L. Ticha, and K. Lange. 2008. "Graphonomics, Automaticity and Handwriting Assessment." *Literacy* 42, no. 3: 145–155.
UKLA/PNS (United Kingdom Literacy Association/ Primary National Strategy). 2004. *Raising Boys' Achievements in Writing*. Hertfordshire: UKLA.
Wallen, M., M. Bonney, and L. Lennox. 1996. *The Handwriting Speed Test*. Australia: Helios Art and Book Co.
Wray, D., J. Medwell, R. Fox, and L. Poulson. 2002. *Teaching Literacy Effectively*. London: RoutledgeFalmer.

Appendix 1. Study 1 correlation matrix

		ALPM (Alphabet Task)	LPM (Speed)	SAT Handwriting	Age in months	Total Handwriting SAT score	Spelling SAT score	Reading SAT score	Composition SAT score
ALPM (Alphabet Task)	*r*	1	.599**	.427**	.075	.618**	.561**	.546**	.581**
LPM (Speed)	*r*		1	.282**	.046	.498**	.473**	.324**	.440**
SAT Handwriting	*r*			1	.109	.636**	.425**	.430**	.540**
Age in months	*r*				1	.091	−.043	−.037	.136
Total Handwriting SAT score	*r*					1	.785**	.798**	.967**
Spelling SAT score	*r*						1	.632**	.664**
Reading SAT score	*r*							1	.814**
Composition SAT score	*r*								1

**$p < 0.001$.
Note: r = Pearson product-moment correlation coefficient.

Appendix 2. Study 2 correlation matrix

		ALPM (Alphabet Task)	LPM (Speed)	SAT Handwriting	Age in months	Total Handwriting SAT score	Spelling SAT score	Reading SAT score	Composition SAT score
ALPM (Alphabet Task)	*r*	1	.609**	.076	.135	.489**	.464**	.465**	.464**
LPM (Speed)	*r*		1	−.002	.133	.366**	.414**	.370**	.321**
SAT Handwriting	*r*			1	−.065	.404**	.219**	.229**	.345**
Age in months	*r*				1	.100	.038	.033	.111
Total Handwriting SAT score	*r*					1	.679**	.685**	.975**
Spelling SAT score	*r*						1	.652**	.559**
Reading SAT score	*r*							1	.637**
Composition SAT score	*r*								1

**$p < 0.001$.
r = Pearson product-moment correlation coefficient.