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Exploring relationships between working memory and writing: individual differences associated with gender

Abstract

Gender differences in the relationships between working memory (short-term storage and combined storage and processing) in both the visuo-spatial and verbal domains and children's alphabet transcription and text writing abilities were investigated. Data from 81 children (43 males) aged between 5;2 to 8;5 revealed no significant group differences between boys and girls in working memory or writing performance. However, individual differences analyses demonstrated variation associated with age and gender in the memory skills underpinning writing. Regression analyses revealed that verbal short-term memory abilities predicted the alphabet transcription skills of boys but not girls. Although visuo-spatial short-term memory predicted writing quality in both genders, predictors of writing fluency differed with verbal working memory skills predicting boys' writing fluency and visuo-spatial short-term memory predicting writing fluency in girls. The need to consider gender differences more critically from the perspective of individual differences in cognitive skills underpinning writing development and the strategic application of these skills during writing is discussed.

1. Introduction

Since the inception of the English National Curriculum, increasing standards in reading and mathematics have been reported, although writing appears more resistant to improvement (DfE, 2012). The poor writing performance of boys relative to girls has been raised as an issue of particular concern in the UK and elsewhere (Lee, 2013; Miller & McCardle, 2011; Ofsted, 2003) with a gap of some 15% - 19% in the proportion of boys leaving UK primary schools having attaining expected levels in writing (DCSF, 2010).

1.1. Gender differences in writing development

Many factors have been proposed to underpin this gender divide; linguistic factors (Maccoby & Jacklin, 1974), attitudes towards writing (Knudson, 1995), motivation and self-efficacy (Klassen, 2002), teacher perceptions (Jones & Myhill, 2004) and individual differences in the cognitive skills underpinning writing. Within the latter context gender differences in writing have been investigated in detailed analyses of the writing product of factors proposed to support writing processes. Some studies report that girls produce text of a higher quality than boys. For example, Bourke & Adams (2011) found a significant advantage for girls at even the very earliest stages of writing development (aged 4-5 years) both when rated on a number of educationally relevant criteria and on the linguistic features of texts. Beard & Burrell (2010) assigning ordinal scores for ratings in categories such as purpose and organisation, grammar, spelling and handwriting to the texts of 9-10 year-old children also revealed a significant advantage for girls. Comparisons of the overall quality of the written product have not always identified gender differences though (Cameron, Lee, Webster, Munro, Hunt & Linton, 1995; Williams & Larkin, 2013). Moreover, even when gender differences in quality have been claimed it may be necessary to interpret these with caution. For example both Stainthorp and Rauf (2009) and Berninger and Fuller (1992) reported gender differences in writing quality although significant interactions between age and gender which were not explored suggested an inconsistent developmental pattern. It may be especially difficult to elucidate gender differences in writing at the level of the linguistic or textual features which characterise overall impressions of quality (Berman & Verhoeven, 2002). Jones and Myhill (2007) found gender differences graduated with increasing specificity of assessment from text level aspects of writing to sentence level features. Given such inconsistency further research examining the developmental pattern of gender differences in writing quality is certainly warranted.

Advantages for girls in writing fluency, the number of words produced within a given time limit, appear more reliably in the literature (Berninger & Fuller, 1992;Williams & Larkin, 2013) and it has been proposed that rather than difficulty composing the message boys may have particular problems with the mechanics of producing texts (Daly, 2003). Differences in handwriting fluency also have an impact on the quality of the text produced though (Connelly & Hurst, 2001). Berninger, Whitaker, Feng, Swanson and Abbott (1996) found higher ratings for the quality of girls' text content and organisation disappeared when compositional fluency was statistically controlled. Girls may automise lower level transcription skills earlier or more effectively than boys allowing them to focus on the later developing high-order composition skills which impact on perceptions of text quality (McCutchen, 1996). This account, based on the impact of working memory (WM) skills on writing, is consistent with more robust gender differences in writing fluency than writing quality.

1.2. Working memory and writing development

Models of WM include short-term storage (STM) alongside attentional and skill co-ordination processes required to complete complex, everyday tasks (Baddeley, 2007; Engle, Tuholski, Laughlin &

Conway, 1999), although models differ in the extent to which these aspects are considered distinct (see Cowan, 2010; Miyake & Shah, 1999 for an overview). Writing is one such complex, resource demanding task, incorporating a spectrum of processes (e.g. generating ideas, translating these into linguistic forms to be transcribed) which together achieve the written product (Alamargot & Chanquoy, 2001). Research from a variety of WM perspectives has confirmed the important role WM plays in writing; in adults (Kellogg, Whiteford, Turner, Cahill & Mertens, 2013) in writing development (Bourke & Adams, 2010; McCutchen, Covill, Hoyne & Mildes, 1994; Swanson & Berninger, 1996) and writing disabilities (Berninger, 2009).

In the simple view of writing (Berninger, 2000) transcription skills (handwriting and spelling) and attentional processes which control the cognitive resources underpin text generation and composition with all processing being conducted within the capacity limitations of WM. As writing develops from mark making through the production of individual words then phrases to structured, coherent text (Berninger & Chanquoy, 2012) so the underlying cognitive processes are proposed to change (Berninger & Swanson, 1994). For novice writers transcribing orthographic symbols is considered to be a far more resource-demanding process than for experienced writers (Berninger, Yates, Cartright, Rutberg, Remy & Abbott, 1992). Unpractised transcription skills demanding more of the limited WM resources divert resources away from high-level composing skills (McCutchen, 1996). Using structural equation modelling Wagner, Puranik, Foorman, Foster, Wilson, Tschinkel and Kantor (2011) confirmed this distinction of text quality from productivity and handwriting fluency in the elementary/primary grades. How the storage and attentional control features within WM may impact upon these different aspects of writing has also been explored. Differential relationships have been identified between WM capacity and compositional fluency and quality (Berninger, Yates et al., 1992), between text generation and transcription and verbal WM capacity versus STM (Swanson & Berninger, 1996) and between writing performance and STM and WM in both the visual and verbal domains (Vanderberg & Swanson, 2007). However, these studies examined the writing of children at very different stages of development and since associations between memory and writing vary depending on the writer's age and skill (Bourdin & Fayol, 1994) a complete developmental account, incorporating both storage and WM capacity in the visual and verbal domains has yet to be fully determined. The present study aims to identify the extent to which STM and WM in the visuo-spatial and verbal domains are associated with writing quality, writing fluency and basic transcription skills in the very early stages of writing.

1.3. Working memory, gender & writing

Surprisingly little evidence has examined whether differences in WM resources are able to account for variation in the development of writing across gender. Perhaps since gender differences in WM have generally neither been examined nor identified (Bourke & Adams, 2011; Pickering & Gathercole, 2001) they might seem an unpromising explanation of gender differences in writing despite their accepted role in developmental and individual differences accounts of writing abilities (Swanson & Berninger, 1996). A resolution to this paradox is not aided by the fact that the few published studies considering whether memory abilities might underpin gender differences in writing have provided equivocal evidence. Berninger, Neilsen, Abbott, Wijsman and Raskind (2008) found in children with dyslexia that the poorer writing skills of boys were accompanied by poorer verbal WM. In contrast, although in much younger children (aged between 4-5 years), Bourke & Adams (2011) found that gender differences in writing were not accompanied by differences in WM. The situation may, however, be more complex than gender differences in writing arising from directly comparable differences in WM. It may be the application of available resources to support writing which differs between boys and girls.

Gender differences in the application of cognitive skills to tasks such as reading (Johnston & Thompson, 1989), mathematics (Carr & Davies, 2001) and writing (Berninger et al., 2008) have been identified. Such differences are usually interpreted within Siegler's (1996) overlapping waves model which proposes that the strategy an individual applies will be determined by their knowledge, their ability to apply the strategy and the demands of the task. Crucially strategy differences do not always translate to perceptions of task ability. Thompson (1987) found boys relied on a phonological reading strategy more than girls even when overall reading ability did not differ. Thus even in the presence of comparable WM skills and indeed writing ability girls and boys may differ in the way these skills are applied to support the writing process.

1.4. The present study

The extent to which memory processes are able to explain individual differences in writing both across and within gender is examined, addressing a number of related questions. First, are different aspects of memory related to writing fluency and quality measures? Measures of both storage (STM) and storage and processing reflecting WM capacity (WM) in both the verbal and the visual-spatial domains will be assessed (Conway, Cowan, Bunting, Therriault & Minkff, 2002). Second, are gender differences evident in all aspects of writing performance? Both writing quality and two measures of writing production, alphabet transcription and the number of words in the text (writing fluency*)* were analysed separately. This was to reflect debate regarding the distinction of text length from writing quality (Jewell & Malecki, 2005), the extent to which handwriting execution might be discriminated from writing fluency generally (Sumner, Connelly & Barnett, 2014) and their specific relationships with verbal STM (Adams, Simmons, Willis & Porter, 2013). Third, are the relationships between memory and writing consistent across genders? Individual differences in the facility to support specific writing processes with particular memory skills may differentiate the performance of boys from girls.

2. Method

2.1 Participants

Ninety children from Years 1 and 3 were recruited from six schools in North West England. Nine children who had English as a second language were excluded from the analyses. This resulted in a subsample of 81 children (43 males) ranging in age from 5;2 to 8;5 years. As an indication of socio-economic status, the proportion of children eligible for free school meals at the participating schools ranged from 7.4% - 53.4% (mean 24.1% SD = 17.34) comparable to the national average of 19.3%.

2.2. Working memory measures

Six assessments representing two tasks for each memory component from the Automated Working Memory Assessment battery (AWMA, Alloway, 2007) a computer-based assessment were administered. For all tasks practice trials of two or three items with feedback were presented followed by six trials at each level of difficulty (block). If successful on the first four trials in a block credit was given for the remaining trials and the level of difficulty of the next block increased by one item. If unsuccessful on four or more trials in a block testing ceased for that task.

2.2.1. Visuo-spatial short-term memory (VSSTM)

Mazes Memory: the child is shown a route through a maze which they must retrace from memory onto a blank maze. The number of correctly traced routes is reported. *Block Recall*: the child watches an image of a series of blocks being tapped which they must replicate. The total number of correctly recalled sequences (correct blocks in the correct order) is reported.

2.2.2. Verbal short-term memory (VSTM)

Word Recall: the child listens to a sequence of semantically unrelated words and is asked to recall them. *Non-word Recall*: follows the same procedure with pseudoword stimuli. For both assessments the total number of lists recalling the correct word/nonwords in the correct order is reported.

2.2.3. Visuo-spatial working memory (VSWM)

Odd-one-out: the child views an array of three shapes and points to the odd one. Initially only one array is presented with the number of arrays increasing in later items. After the array or arrays have been presented the child must recall the position of the odd shapes in each of the arrays by pointing to one of three possible on-screen locations, representing the order in which they appeared. An item is considered correct if the child recalls the correct position or positions of the odd shapes in each array in the correct order. The raw score is the total number of items correctly recalled. *Spatial Recall*: the child views pairs of shapes where the shape on the right has a red dot within it. This shape is either in the same orientation as the shape on the left, or it has been rotated. After viewing each pair of shapes the child has to say whether the shape on the right is the same or opposite to the shape on the left and also remember the position of the red dot. At the end of a trial (a series of arrays or array) the child is presented with three possible positions for the location of each of the red dots and is asked to recall the correct position for each in the order in which they were presented. The number of correctly recalled sequences of red dot locations is scored. All participants were given the extended practice session for this test which included training on the concept of ‘opposite’.

2.2.4. Verbal working memory (VWM)

Listening Recall: the child judges whether a presented sentence is true or false also retaining the final word of the sentence. Initially only one sentence is presented, with the number of sentences increasing in later items. An item is considered correct if the sentence-final word or words are recalled in the correct order, with the raw score being the total number of correctly recalled items. *Backward Digit Recall*: the child listens to a sequence of digits and recalls them in reverse order. An item was scored correct if the child repeated the correct digits in a reversed temporal order. The number of correctly recalled sequences is scored.

2.3. Writing skill measures

2.3.1. Alphabet Transcription

Alphabet transcription provided a measure of orthographic-motor integration (Chistensen, 2004) independent of spelling or text construction (Sumner, Connelly & Barnett, 2013). Adopting the procedure from the Wechsler Individual Achievement Test (WIAT-II [uk], Wechsler, 2005) children were presented with a sheet of lined paper, which included the initial letter of the alphabet in lower-case, on which to write, and asked to continue writing the alphabet in lower-case for 30 seconds. The number of unambiguous lower-case letters produced (excluding repetitions of the initial letter, upper-case letters, and letter reversals) was recorded. Inter-rater reliability was calculated on 15% of the sample using blind marking by a second scorer. The correlation between the two raters was r = .93, p<.001.

2.3.2. Writing fluency and quality

A picture prompt of a line drawing showing a dog and a frog playing with a ball initiated text generation. The children were asked to write for five minutes about the picture and given a warning with one minute remaining. For children in these school grades this is a common procedure and appropriate time scale for curriculum-based assessments with performance related to standardised writing assessment tools (see McMaster & Espin, 2007 for a review).

2.3.2.1. Writing fluency

Appraisal of the number of words in the text followed the method of Kim, Al Otaiba, Puranik, Folsom, Greulich & Wagner, 2011 and was recorded as the number of real words discernible as a sequence of one or more letters delineated by spaces, which although not necessarily correctly spelled, were recognisable in the context of the child's writing. Random strings of letters not discernible as a word were not counted. The inter-rater reliability (15% of sample) for this measure was very good, $r = .99$ $p < .001$.

2.3.2.2. Writing quality

Writing quality was assessed using *The Big Writing Criterion Scale* (BWCS, Wilson, 2012). This scale assesses a range of aspects of writing closely aligned with the achievement criteria of Assessing Pupils' Progress (DCSF, 2009). The advantage of this tool is its close association with the teaching and progression of writing skills in schools, the arena within which gender differences are most vociferously claimed. Five assessment foci were measured. *Mark Making* captures early attempts at writing awarding credit for progress made before discernible words are produced. *Composition and Effect* assesses the use of vocabulary and voice, for example introducing adjectives for detail or audience awareness. *Structure and Organisation* assesses the ability to sequence information and use connectives. *Sentence Structure and Punctuation* assesses the use of correct and more sophisticated grammar and punctuation. *Spelling* assesses the accurate spelling of mono- or polysyllabic words. Each child's text was evaluated against these criteria (with the exception of 24 criteria which could not be applied e.g. because assessment required comparison across a range of texts). The total number of assessment criteria achieved was summed. Reliability for the 15% sample evaluated by the two raters was $r = .93$ $p < .001$.

2.4. Procedure

Every child participated in four assessment sessions each lasting 30 minutes. The first three sessions were conducted individually in a quiet area of the school. The first comprised the *Mazes Memory, Word Recall* and *Odd-one-out* tasks, the second the *Block Recall*, *Non-word Recall,* and *Listening Recall* and the third *Spatial Recall* and *Backward Digit Recall*. The alphabet transcription task and the picture prompt writing task were presented in a final small group session.

3. Results

3.1. Descriptive statistics

The descriptive data in relation to each year group and for each gender are presented in Table 1. Within the whole sample all variables were normally distributed with the exception of writing fluency (kurtosis = 2.79), *Mark Making* and *Sentence Structure and Punctuation* (kurtosis = 3.39 and 3.05 respectively), although the total *BWCS* was normally distributed.

Table 1: Descriptive Statistics as a function of year group and gender

Measure	Year 1 (n = 42) Mean (SD)	Male Yr1 (n = 21) Mean (SD)	Female Yr1 (n = 21) Mean (SD)	Year 3 (n = 39) Mean (SD)	Male Yr3 (n =22) Mean (SD)	Female Yr3 (n = 17) Mean (SD)
Age	69.14 (3.37)			94.46 (4.04)		
Visuo-spatial STM						
Mazes memory	9.83 (6.41)	10.19 (6.78)	9.48 (6.16)	15.90 (5.04)	16.73 (5.66)	14.82 (4.00)
Block recall	14.33 (3.31)	14.48 (3.23)	14.19 (3.46)	18.85 (4.17)	19.27 (3.92)	18.29 (4.54)
Verbal STM						
Word recall	16.90 (3.77)	16.33 (2.61)	17.48 (4.64)	18.23(3.98)	18.18 (4.33)	18.29 (3.60)
Non-word recall	14.69 (3.23)	14.81 (2.77)	14.57 (3.71)	16.36 (4.28)	16.41 (3.91)	16.29 (4.83)
Visuo-spatial WM						
Odd-one-out	11.81 (3.58)	11.71 (4.23)	11.90 (2.88)	13.15 (3.58)	12.64 (2.72)	13.82 (4.46)
Spatial recall	7.52 (4.09)	6.24 (4.24)	8.81 (3.59)	10.49 (5.16)	9.68 (4.63)	11.53 (5.76)
VerbalWM						
Listening recall	6.83 (2.58)	5.95 (2.29)	7.71 (2.61)	9.13 (2.60)	9.32 (2.19)	8.88 (3.10)
Backward digit recall	8.05 (2.90)	7.43 (3.32)	8.67 (2.33)	10.28 (2.95)	10.64 (2.44)	9.82 (3.52)
Writing						
Alphabet transcription	6.33 (3.57)	5.76 (3.42)	6.90 (3.71)	9.11 (7.65) [1]	9.33 (8.89)[2]	8.80 (5.75)[3]
Writing fluency	11.90 (7.86)	10.52 (8.51)	13.29 (7.09)	52.54(24.77)	52.54 (24.94)	52.53 (25.33)
Writing quality						
BW - Mark Making (MM)	6.86 (1.85)	6.48 (2.34)	7.24 (1.14)	8.97 (1.09)	8.82 (1.05)	9.18 (1.13)
BW - Composition & effect (C&E)	2.98 (3.09)	2.19 (2.85)	3.76 (3.18)	9.90 (3.30)	9.91 (3.02)	9.88 (3.72)
BW - Structure & Organisation (SO)	0.50 (1.04)	0.52 (1.17)	0.48 (0.93)	4.23 (2.41)	3.95 (1.96)	4.59 (2.92)
BW - Sent. Structure & Punctuation (SSP)	1.00 (1.08)	0.67 (1.06)	1.33 (1.02)	4.15 (2.38)	3.77 (2.20)	4.65 (2.57)
BW – Spelling	3.38 (2.55)	2.48 (2.71)	4.29 (2.05)	6.49 (1.12)	6.50 (1.14)	6.47 (1.12)
BW – Total	13.88 (7.55)	11.81 (8.12)	15.95 (6.48)	29.92 (6.87)	29.32 (6.10)	30.71 (7.89)

1. n = 36
2. n = 21
3. n = 15

Test-retest reliability correlation coefficients for the memory measures are as follows (Alloway, 2007); Mazes memory .86, Block recall .90, Word recall .83, Non-word recall .69, Odd-one-out .88, Spatial recall .79, Listening recall .88, Backward digit recall .86.

3.1.1. Composite measures of memory assessments and writing quality

To reduce the influence of task-specific variance principal component analyses were conducted to create composite variables as follows; VSSTM comprised *Block Recall* and *Mazes Memory*; VSTM, *Word* and *Nonword Recall*; VSWM, *Odd-one-out* and *Spatial Recall* and VWM, *Listening Recall* and *Backward Digit Recall.*

Table 2: Principal Components Analyses statistics

	Correlation between tasks	Bartlett's Test of Sphericity	Variance explained
VSSTM	.504 **	$\chi^2(1) = 23.01$ **	75.2%
VSTM	.310 **	$\chi^2(1) = 7.91$ *	65.5%
VSWM	.428 **	$\chi^2(1) = 15.85$ **	71.4%
VWM	.430 **	$\chi^2(1) = 16.07$ **	71.6%
Writing Quality (BWCS)	.607-.886 **	$\chi^2(1) = 412.22$**	80.6%

Note: For all memory variables Kaiser-Meyer-Olkin = .50. For writing quality KMO = .832 (both adequate according to Kaiser, 1974).
* $p < .005$ ** $p <.001$

The composite measure of writing quality comprised each of the five indices from *BWCS*. Summary statistics for the PCAs (see Table 2) indicated that all assumptions were satisfied.

3.1.2. Gender and age effects

Gender and age differences in alphabet transcription, writing fluency and writing quality were explored using a series of ANOVAs. A significant effect of year group on alphabet transcription was identified, $F(1,74) = 4.13$, $p < .05$, $\eta_p^2 = .053$, but no significant effect of gender, $F(1,74) = .05$, $p > .05$, $\eta_p^2 = .001$. No significant interaction was identified $F(1,74) = .39$, $p > .05$, $\eta_p^2 = .005$. There was also a significant effect of year group on writing fluency, $F(1,77) = 98.87$, $p < .001$, $\eta_p^2 = .562$, but again no significant effect of gender, $F(1,77) = 0.11$, $p >.05$ $\eta_p^2 = .001$ and no significant interaction, $F(1,77) = 0.12$, $p >.05$, $\eta_p^2 = .001$. A significant effect of year group on writing quality was identified, $F(1,77) =$

97.81, $p < .001$, $\eta_p^2 = .560$. The effect of gender on writing quality just failed to reach traditional levels of significance, $F(1,77) = 3.39$, $p = .069$, $\eta_p^2 = .042$. There was no significant interaction between these variables, $F(1,77) = .49$, $p > .05$, $\eta_p^2 = .006$. In this sample therefore gender differences in writing were not identified. MANOVA explored age and gender differences in each of the measures of memory. Using Pillai's trace a significant effect of year group was identified, $F(4, 74)= 9.93$, $p < .001$, although the effect of gender just failed to reach significance, $F(4, 121)= 2.23$, $p = .07$ with univariate analyses showing that this pattern was consistent for all the memory measures. Partial eta squared values for year group ranged from .058 (VSTM) to .319 (VSSTM) and for gender from .001 (VSTM) to .040 (VSWM).

3.1.3. Relationships between memory and writing

The relationships between memory and writing were initially evaluated through bivariate correlations for the whole sample, within gender and within age (see Table 3). Distinctive patterns in the correlations across age and gender are noted below.

3.1.3.1. Patterns across year group

Although the relationship between alphabet transcription and VSSTM, VSTM and VWM remain constant across year group the non-significant relationship with VSWM in the whole sample masks a significant relationship at Year 1. Fisher's $r - z$ transformation (1-tailed) confirmed that only these latter correlation coefficients were significantly different, $z = 2.71$, $p < .01$. Significant associations between written fluency and STM and WM in the whole sample were replicated in Year 1 with the exception of the relationship with VSTM. In contrast writing fluency was not significantly associated with any of the memory measures in Year 3. Significant associations between writing quality and memory identified in the whole sample were maintained across both year groups for all memory measures other than VSTM which failed to reach significance for either year group.

Table 3: Correlations between memory composite scores and writing assessments both within gender and age and across the whole sample

	VSSTM	VSTM	VSWM	VWM
Alphabet transcription	.321**	.414**	.060	.169
Yr1	.209	.351*	.397**	.229
Yr3	.287	.416*	-.204	-.034
Male	.426**	.696**	.066	.176
Female	.154	-.022	.051	.160
Writing fluency	.532**	.230*	.359**	.490**
Yr1	.309*	.180	.317*	.379*
Yr3	.185	.055	.228	.247
Male	.494**	.199	.265	.547**
Female	.587**	.268	.486**	.423**
Writing quality	.617**	.308**	.489**	.583**
Yr1	.354*	.240	.423**	.368*
Yr3	.354*	.175	.425**	.487**
Male	.641**	.359*	.476**	.633**
Female	.635**	.246	.494**	.510**

*p <.05 **p < .01

3.1.3.2. Patterns across gender

Alphabet transcription was not related to any memory measure in girls although it was related to STM in both the visual and verbal domains in boys. Writing fluency was related to VSSTM and VWM in both genders but was not related to VSTM in either gender. However, VSWM was related to writing fluency in girls but not boys. Writing quality demonstrated comparable associations within girls and boys for all memory measures with the exception of VSTM which bore a significant association in boys but not girls. Where significance levels might lead to the drawing of different conclusions about the associations between memory and writing across the genders, Fisher's r – z transformation (1-tailed) was used to determine whether the disparity between the correlation coefficients should be considered meaningful. Fisher's r – z transformation revealed that the correlation coefficients for boys and girls were not significantly different in magnitude for either VSWM and writing fluency or VSTM and writing quality, z = -1.12, p = .13 and z = .54, p = .29 respectively. However, Fisher's r – z transformation revealed that the relationship between VSTM and alphabet transcription was significantly different between boys and girls, $z = 3.81$ $p < .001$ and was marginally significant in the visuo-spatial domain, $z = 1.3$, $p = .09$. It therefore appears that STM skills may predict alphabet transcription in boys but not girls (VSSTM predicted 18.1% of the variance in the alphabet transcription skills of boys, but only 2.3% in girls. VSTM predicted 48.4% of the variance in boys and only 4.8% in girls).

Since the memory variables were themselves related, multiple regression analyses were conducted to identify the degree of independence of associations observed between writing and memory. The four composite memory variables were entered simultaneously as predictors of each of the outcome writing variables for each gender separately (see Table 4).

Table 4: Multiple regression analyses predicting writing performance within gender on the basis of four composite measures of working memory.

Alphabet Transcription								
	Girls				Boys			
Step 1	b	SE B	ß	P	b	SE B	ß	p
VSSTM	.91	1.15	.19	p = .43	1.51	1.23	.23	p = .23
VSTM	-.78	.97	-.17	p = .43	4.81	.99	.69	p = .001
VSWM	-.60	1.16	-.13	p = .61	-.26	1.04	-.04	p = .80
VWM	1.10	1.18	.23	p = .36	-1.80	1.20	-.28	p = .14
Note: R^2 = .063 girls; R^2 = .526 boys								

Writing Fluency								
	Girls				Boys			
Step 1	b	SE B	ß	p	b	SE B	ß	p
VSSTM	12.71	5.23	.46	p = .02	8.60	5.91	.31	p = .15
VSTM	-2.70	4.39	-.10	p = .54	-4.79	4.70	-.17	p = .31
VSWM	4.16	5.04	.16	p = .41	-4.41	5.00	-.15	p = .38
VWM	3.45	5.11	.12	p = .50	13.08	5.77	.48	p = .03
Note: R^2 = .376 girls; R^2 = .347 boys								

Writing Quality								
	Girls				Boys			
Step 1	B	SE B	ß	p	b	SE B	ß	p
VSSTM	.52	.18	.52	p = .01	.40	.19	.39	p =.05
VSTM	-.18	.15	-.19	p = .23	-.03	.15	-.03	p = .84
VSWM	.09	.17	.09	p = .61	.12	.16	.11	p = .46
VWM	.27	.17	.27	p = .12	.29	.19	.29	p = .13
Note: R^2 = .466 girls R^2 = .478 boys								

Although the memory variables predicted 52.6% of the variance in boys' alphabet transcription only 6.3% of the variance in girls' alphabet transcription was accounted for. The regression model was not significant for girls, $F(4,31) = 0.52$, $p > .05$, but was for boys, $F(4,37) = 10.28$, $p < .001$. Although none of the predictors were significantly related to alphabet transcription in girls, the standardised beta coefficient for VSTM was significant for boys with the associated part correlation, indicating the unique relationship between VSTM and alphabet transcription, being .547. The memory variables together predicted significant comparable variance in writing fluency, $F(4,33) = 4.96$, $p < .01$ and $F(4,38) = 5.04$, $p < .01$ for girls and boys respectively. However the standardised beta coefficients revealed that only

VSSTM was a significant independent predictor in girls (part correlation = .334) whilst only VWM was a significant unique predictor in boys (part correlation = .297). In contrast to alphabet transcription and writing fluency a similar pattern of relationships between memory and writing quality was identified in both genders. Together the memory variables predicted 46.6% of the variance in writing quality in girls and 47.8% in boys, $F(4,33) = 7.20$, $p < .001$ and $F(4,38) = 8.71$, $p < .001$ respectively. VSSTM was the only variable to present a significant standardised beta coefficient in both groups (part correlation for boys .239 and for girls .375).

4. Discussion

A number of questions were addressed in this study. First, replicating previous work emphasising the importance of memory skills for children's writing (Bourke & Adams, 2003; 2010; McCutchen et al., 1994; Swanson & Berninger, 1996) significant associations were observed between writing ability and STM and WM in the visuo-spatial and verbal domains. Correlational analyses revealed that within the whole sample both visual and verbal STM were related to all three writing criteria. However, whereas both visual and verbal WM were related to both writing fluency and quality they were not related to alphabet transcription skills. Collapsed across gender there is some evidence that memory may be a more critical factor in alphabet transcription and writing fluency in younger children. Second, although trends within the data favoured the writing of girls, within this relatively small sample significant gender effects on writing were not observed. However, these whole sample and group analyses obscured more subtle variations in the cognitive underpinnings of the writing abilities of boys and girls. Regression analyses revealed that although VSSTM was independently related to writing quality in both genders, it was related to writing fluency only in girls. Writing fluency also shared significant variance with VWM but only in boys. Furthermore VSTM was uniquely related to the alphabet transcription skills of boys but not girls.

4.1. Elusive gender differences

The lack of a significant group effect of gender on writing is at odds with some studies (Beard & Burrell, 2010; Bourke & Adams, 2011) although consistent with others (Cameron et al., 1995; Williams & Larkin, 2013). Although both fluency and quality are considered important in children's writing (Wagner et al., 2011) gender differences in writing fluency appear more robust (Berninger & Fuller, 1992; Williams & Larkin, 2013) and have been presumed to arise from boys' difficulty with the mechanics of handwriting (Daly, 2003). Since difficulties with writing production may negatively impact the cognitive resources available for text construction (McCutchen, 2000) gender differences in writing quality could be considered secondary to those in writing fluency and hence perhaps less stable. The lack of group gender effects in alphabet transcription and writing fluency observed here highlights the inconsistencies in this area substantiating the need to temper an absolute gender divide with a more nuanced picture (Younger & Warrington, 2003). Explanation beyond description of the poor performance of some boys requires a more fine-grained analysis of factors which underpin individual differences in writing development. We concur with others (Beard & Burrell, 2010; Williams & Larkin, 2013) that there is a need for a systematic exploration controlling factors such as the age of the writers and the precision of writing aspects assessed across a range of genres and writing environments to understand how the writing products and processes of boys and girls may differ.

4.2. Relationships between writing and memory

Across the whole sample memory abilities in the verbal and visual domains were related to writing, although for writing fluency these effects may arise particularly from the younger children. These relationships pertained to both short-term storage and the combination of storage and processing reflecting WM capacity and are consistent with the proposal that memory skills underpin many aspects of the writing process (Bourke & Adams, 2003; McCutchen et al., 1994). The current data further clarify memory processes' roles in children's writing. The correlational analyses encompassing the whole sample are consistent with previous research (Bourke & Adams, 2010; Bourke, Davies, Sumner & Green, 2013) highlighting the role of visuo-spatial memory skills in early writing. However, since Bourke et al. (2013) included only a single measure of VSWM and no measures of VSSTM, the latent variable correlational analysis conducted here confirms their conclusions of the importance of VSWM skills. It also extends the evaluation to the influence of VSSTM processes and to older children. However, the regression analyses contrasting VSWM with other components of WM cautions that the association may not reflect variance unique to VSWM. Visuo-spatial memory may indeed be an important component of early writing (Berninger, 2009) perhaps required to map sounds onto graphemes (Gathercole & Baddeley, 1993) or in the construction of orthographic knowledge (Ouellete & Senechal, 2008) but further research is required especially to consider its role in gender differences in writing.

Much research demonstrates the impact of verbal memory skills on children's writing (Bourke & Adams, 2003; 2010; Swanson & Berninger, 1996), with evidence of verbal WM becoming more critical than STM beyond the earliest stages of writing development (Vanderberg & Swanson, 2007). In the present study correlational analyses identified that VSTM was related to alphabet transcription at both ages but bore significant unique variance only in the male sample. Since VSTM has been proposed to be more effective than VSSTM for retaining sequenced information (Baddeley, 2000), it may be this feature of the alphabet transcription task that underpins this relationship (Berninger & Fuller, 1992), in a similar manner as has been proposed for spelling (Williams & Larkin, 2013). The association appears particularly strong in boys, however, evident not only in alphabet transcription but also writing quality, although the association may not be unique. It may be that learning the alphabet sequence is delayed in males forcing a reliance on VSTM processes for transcription with the relationship acting as a marker of the insecure knowledge[1]. This account could be explored by examining alternative transcription tasks considering especially the cognitive processes which underpin them (Sumner, Connelly & Barnet, 2014). Alternatively VSTM may play a role in the translation of ideas into linguistic structures (Adams et al., 2013; Chenoweth & Hayes, 2003) constraining the quality of writing particularly for boys.

The observed significant relationship between writing quality and VWM appears consistently in the literature (Bourke & Adams, 2003; McCutchen et al., 1994; Vanderberg & Swanson, 2007) and may reflect the need to co-ordinate many complex processes in writing (McCutchen, 2000). Mastery of lower level transcription skills is proposed to reduce their resource demands increasing the resources available to support higher-level skills such as introducing more complex linguistic constructions and improving the text structure (McCutchen et al., 1994). Significant associations between VWM and writing fluency and quality are consistent with this account. However, VWM was not a unique predictor of writing quality and only of writing fluency in boys. This pattern may reflect the greater demands placed upon VWM resources in the absence of effortless transcription skills in boys.

The current evidence confirms that relationships between memory processes and writing change with age. Tantalisingly the data are also consistent with an account in which the developmental pattern of associations between memory and writing may differ for boys and girls. Since there were no significant group effects of gender on memory these differences may arise in the application of memory skills when writing. Siegler's (1996) overlapping waves model proposes that for any task the strategy applied will depend upon the individual's knowledge, their ability to apply the strategy effectively and the specific task demands. It has been used to identify gender differences in strategy preferences and their effective use in mathematics (Carr & Davies, 2001) and reading (Johnston & Thompson, 1989). Critically differences in strategy use have been identified in the absence of differences in overall

[1] The authors thank an anonymous reviewer for this suggestion.

performance levels. Thompson (1987) concluded that even when reading abilities were equated boys relied more on processing the phonological aspects of words than did girls. Similarly in the present study comparable writing products may disguise gender differences in the ability to effectively apply cognitive skills to underpin the writing process.

The need to temper an absolute gender divide has been advocated previously (Jones, 2011). Large within-gender variation (Berninger & Fuller, 1992) and the differential distributions of the genders with males over-populating the extremes (Jones & Myhill, 2007) suggest that simply focussing on the disparity between average scores may obscure our understanding of what differs in the writing development of boys and girls (Beard & Burrell, 2010; Marinelli, Horne, McGeown, Zoccolotti & Martelli, 2014) moreover as this study shows may conceal more nuanced differences between boys and girls.

4.3. Limitations

Although effect sizes rather than significance levels drove the exploration of the gender effects, conclusions about the developmental trajectory of gender differences in associations between WM and writing should remain tentative until the findings can be replicated in a larger sample. An increased sample size would also allow additional cognitive measures to be contrasted within the regression analyses, for example the contribution of reading, spelling and vocabulary skills to writing fluency and quality (Sumner et al., 2014). It is also important to extend these findings to consider how the text genre (Beard & Burrell, 2010) and assessment metrics applied (Berninger, Whitaker, et al., 1996; Malecki & Jewell, 2003) may affect the conclusions drawn about the relative skills of boys and girls.

5. Conclusions

The present study highlights the difficulty replicating gender differences in writing observed in educational standards in empirical analyses of writing based on models of the cognitive skills which underpin writing development. Individual differences in STM skills were a more critical determinant of alphabet transcription skills in boys than girls and the memory skills underpinning writing fluency differed between the genders although those for writing quality did not. To understand whether the developmental trajectory of writing does indeed differ between boys and girls the relationships between cognitive skills and writing must be investigated at the level of individual differences which may be associated with gender.

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