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Creative expressiveness in childhood writing predicts educational achievement beyond motivation and intelligence: A longitudinal, genetically informed study

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Background. Creativity is linked with educationally relevant constructs such as achievement, intelligence, and motivation. However, very few studies have explored longitudinal links between the constructs or the aetiology of individual differences in childhood creativity.

Aims. The study addresses the gap in the literature of developmental studies on the relationship of creativity with other educationally relevant measures. Additionally, the present study is the first adequately powered genetically informative analysis of childhood creativity.

Sample(s). The present study utilized data from 1,306 twins, a subsample from a longitudinal, representative twin sample in the UK.

Methods. Creativity was operationalised as a *Creative Expressiveness* score, using the Consensual Assessment Technique on stories written by 9-year-olds. Intelligence and writing motivation were assessed at age 9. Academic achievement was collected at ages 9, 12, and 16.

Results. *Creative Expressiveness* was associated with intelligence and motivation, all measured at age 9. It also predicted variance in English grades at ages 9 and 16. The associations were weak, but significant, over and above intelligence, motivation, and earlier English grades. The variance in *Creative Expressiveness* was explained by genetic

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(35%), shared environmental (21%), and non-shared environmental (45%) influences. The phenotypic correlations with other study variables were mainly mediated genetically.

Conclusions. The results provide information that can be used for planning educational content. First, creativity can be detected in childhood writing. Second, childhood creativity may be overlooked in early educational assessments. Third, the results from the genetic analyses are important indications on the role of environments in the development of creativity.

The importance of creativity is recognized in education. There are recommendations for creative development to be included as an objective in education (e.g., NACCCE, 1999). Creativity has been associated with many educational constructs, such as enjoyment of learning, intelligence, and educational achievement (Csikszentmihalyi, 1997; Gajda, Karwowski, Karwowski, & Beghetto, 2017; Getzels & Jackson, 1962). However, several questions, such as the link between creativity and educational achievement, remain poorly understood. This is partly due to the limited number of longitudinal and experimental studies. Moreover, very little is known about the aetiology of creativity and of its links with educational achievement, intelligence, and motivation. Better understanding of the aetiology of creativity will aid in countering some common myths and stereotypes about creativity. An example of a misconception about creativity in educational contexts is that creative abilities are determined at birth (Plucker, Beghetto, & Dow, 2004). Additionally, the lack of a precise definition of creativity hinders the application of any research findings in educational practice (Plucker et al., 2004).

The most commonly used, broad definition of creativity states that creativity requires originality and effectiveness (Barron, 1955). According to this definition, originality is a necessary but not sufficient characteristic of creativity (Guilford, 1950; Runco & Jaeger, 2012). A creative process with an outcome, which is evaluated in its social context, must also meet the criteria of effectiveness. This means that the outcome has to be useful in correspondence with the set task demands (Runco & Jaeger, 2012). This definition has guided the operationalization of many creativity measures, such as divergent thinking and creative problem-solving tasks (Fasko, 2001; Gajda, Karwowski, et al., 2017). However, the relevance of these measures of creative cognition has been questioned in educational contexts due to their narrow view on creativity (Baer, 2014; Barbot, Besançon, & Lubart, 2015; Zeng, Proctor, & Salvendy, 2011). For example, divergent thinking test scores are often viewed as indicators of general creativity even if they, for example, only measure an ability to come up with original responses to common household objects (Baer, 2014). In addition, creative thinking and the benefits it may bring are outcomes not only of students' intrinsic characteristics but are also dependent on environmental factors, such as interactions between students and teachers. One recent study showed a positive association of $r = .52$ between creativity (as measured by a cognitive creativity measure) and academic achievement in classrooms with more extended and exploratory interactions between students and teachers (Gajda, Beghetto, Beghetto, & Karwowski, 2017).

Several studies have used other than cognitive measures to investigate creativity among school children. One alternative measure is to assess the creativity of a product, based on a social recognition of it being creative (Amabile, 1982). This method is more ecologically valid method to investigate creativity in primary education, in comparison with test-based assessment. For example, previous research has measured creativity in children's musical compositions, creative play and storytelling (Hennessey & Amabile, 1988; Hickey, 2001; Howard-Jones, Taylor, & Sutton, 2002).

Still, most research on creativity in developmental samples relies on cognitive and self-reported creativity measures. A recent meta-analysis of 120 studies concluded that creativity, assessed using cognitive or self-reported measures, has a modest cross-sectional association with educational achievement as indicated by standardized tests or grade-point averages (r = .22; Gajda, Karwowski, et al., 2017). To date, only a few longitudinal studies have investigated the relationship between creativity and educational achievement. One study has shown that, among 315 UK students (M_{age} = 12.56), creativity measured as a composite of verbal, figural, and numerical cognitive tasks predicted end-of-school grades (GCSEs) four years later in English (β = .25), Maths (β = .22), and Science (β = .16; Mourgues, Tan, Hein, Elliott, & Grigorenko, 2016). However, this study did not include any control variables, such as intelligence, associated with both creativity educational achievement, which may have accounted for some variance in grades.

A meta-analysis, which compiled the results from the studies on creativity, measured as divergent thinking, and intelligence, reported an overall effect of r = .17 (Kim, 2005). This positive association between intelligence and creativity could be due to more efficient cognitive processing, such as better working memory capacity or faster information processing speed. It is therefore possible that creativity predicts educational achievement via the same processes that explain the links between intelligence and educational achievement (Deary et al., 2007). However, despite much research into the relationship between creativity and intelligence, this relationship remains relatively poorly understood. Some studies have concluded that intelligence is an essential part of creativity but not, on its own, sufficient to explain creativity (Karwowski et al., 2016). Furthermore, some hierarchical intelligence models incorporate some creativity related cognitive processes, such as idea fluency (Carroll, 1993). Other studies have shown that the relationship between creative cognitive measures and intelligence is not linear, but rather that there is a positive relationship up to a certain threshold, after which the association disappears (Jauk, Benedek, Dunst, & Neubauer, 2013).

Another psychological construct that has been associated with both creativity and educational achievement is intrinsic motivation. Intrinsic motivation drives an individual to run the extra mile and mull over a problem that requires a creative solution (Amabile, 1983). Several studies have supported the positive relationship between intrinsic motivation and creativity. For example, a meta-analysis on the relationship between intrinsic motivation and creativity of a product reported an overall correlation of r = .30 (de Jesus, Rus, Lens, & Imaginário, 2013). A recent longitudinal study has shown that intrinsic reading motivation, measured as reading enjoyment, has a reciprocal relationship with educational achievement in late childhood (Malanchini et al., 2017).

Sources of individual differences in childhood creativity are poorly understood. To date, only a few quantitative genetic studies have explored genetic and environmental influences on individual differences in creativity, as well as its mechanistic associations with other constructs, such as intelligence and motivation. A Dutch adolescent and young adult sample of 3,370 twins reported a modest heritability on creative writing (Vinkhuyzen, Van der Sluis, Posthuma, & Boomsma, 2009). Another study also reported a modest heritability, when creativity was measured with a figural divergent thinking task, utilizing a German adult twin sample of 650 participants (Kandler et al., 2016). The same study also established a higher heritability when creativity measurement was based on self- and peer-reports (Kandler et al., 2016). The variation in the estimates of genetic and environmental influences on creativity could be due to the diversity of creativity measures as well as sample-specific factors, such as the age of participants.

To build on previous research, the present study uses longitudinal data from a large twin sample in the UK to investigate how creativity, measured in written stories of 9-year-old children, relates to educational achievement, above and beyond intelligence and motivation. Additionally, the study explores the aetiology of creativity. Specifically, the present study addresses three research questions.

1. Is creativity in writing at age 9 associated with intelligence and writing motivation at the same age?
2. Does creativity in writing at age 9 explain variance in National Curriculum grades for English Writing at ages 9 and 12; as well as in English General Certificate of Secondary Education (GCSE) examination grade at age 16, above and beyond intelligence and writing motivation?
3. Does the genetic and environmental aetiology of individual differences in creativity in writing overlap with the aetiology of individual differences in intelligence, writing motivation and educational achievement?

Methods

Participants

The participants are part of a large, longitudinal twin study in the UK, the Twins Early Development Study (TEDS). TEDS is a representative sample of the population in England and Wales (Rimfeld et al., 2019). Participants in the present study (n = 1,306) were a subsample of TEDS twins for whom data on the written stories were available at age 9, as well as for other study variables at ages 9 and 16; 628 of these participants also completed data collection at age 12. The elicitation of stories from the children was originally designed to assess children's written language. As such, these are scores generated using post hoc coding as a basis for creativity scores.

Of the 1,306 twins, 331 were monozygotic (MZ) twin pairs and 322 dizygotic (DZ) twin pairs; 776 females and 530 males. At age 12, the subsample included 163 monozygotic (MZ) twin pairs and 151 dizygotic (DZ) twin pairs; 376 females and 252 males. The sample included both same-sex and opposite-sex twin pairs. The mean age for participants, when data for the creativity measure was collected, was 9.00 years (SD = 0.29).

A preliminary power calculation (with 80% power) estimated a sample size as 320 MZ and 320 DZ twin pairs needed to detect genetic influences (.20) in a univariate genetic analysis.

The sample in the present study had slightly higher standardized means in comparison with the whole TEDS sample for intelligence, motivation, and educational achievement scores (see Table S6 for the comparisons of means with the complete TEDS sample). The differences may be due to the slightly higher attrition rates among lower SES status families taking part in later data collection waves (Rimfeld et al., 2019), since studies have reported that SES has a marked, lasting, and increasing impact on cognitive development (e.g., von Stumm, 2017). This is consistent with the previous findings of attrition rates in longitudinal studies (Rimfeld et al., 2019; von Stumm, 2017).

Measures

Written stories at age 9

The children were shown three coloured pictures of animals and buildings at a farm (see Figure S1). The twins were given the following instructions: 'We would like you to make up a story for us. On the next page you will see three different pictures, 1, 2 and 3. Together they make a little story about a farm. Try to think hard about what you see in the pictures. After you have looked at them carefully, write your story on the next page of this book. Have fun making your story interesting, creative or even funny!' The task was completed in family homes, with children supervised by their parents. There was no time limit for the task. All the stories were transcribed to minimize the effect of handwriting on coding.

The stories were coded for creativity and nine other dimensions using the Consensual Assessment Technique (CAT; Amabile, 1982). The CAT is a method to operationalise creativity of a product and can be used to measure creativity in common creative products, such as in written stories. The CAT is based on the principle that a creative product will be recognized as being creative in its social environment (Amabile, 1982). Since the rationale of the CAT is subjective assessment of creativity, no formal creativity definition or training is given.

The use of the CAT has demonstrated that people can recognize and agree upon creativity even though it may be difficult to define and characterize (Hennessey, 2010). In developmental samples, the CAT has been used to evaluate creativity of musical compositions, drawings and poems (Baer, 2014; Baer, Kaufman, & Gentile, 2004; Hickey, 2001; Lubart, Pacteau, Jacquet, & Caroff, 2010), as well as children's oral and written stories (Badini, Toivainen, Oliver, & Kovas, 2018; Hennessey & Amabile, 1988; Toivainen, Malanchini, Oliver, & Kovas, 2017). The use of the CAT to evaluate creativity in children's written stories was piloted in three previous studies (Badini et al., 2018; Toivainen et al., 2017, 2018).

The same rationale, as for creativity, was used with the judgements of the nine other story dimensions. As with creativity, no detailed definitions were given to evaluate the other nine dimensions. The present study replicated the coding dimensions and the procedure from an earlier study which investigated creativity in children's orally told stories (Hennessey & Amabile, 1988). Overall, the TEDS children's stories were rated with a 7-point scale on 10 dimensions: Creativity, Liking, Novelty, Imagination, Logic, Emotion, Grammar, Detail, Vocabulary, and Straightforwardness. No objective definitions of the dimensions were given to the judges; with only the following instructions given:

'Using your own subjective definition of the following dimensions, how would you assess:

1. *Creativity*: the degree to which each story is creative.
2. *Liking*: how well you like the story, using your own, subjective criteria for liking.
3. *Novelty*: the degree to which the subject/plot is novel.
4. *Imagination*: the degree to which the subject/plot is imaginative.
5. *Logic*: the degree to which story events are logical, or understandably related.
6. *Emotion*: the amount and depth of emotion the story conveys.
7. *Grammar*: the degree to which the story is grammatically correct.
8. *Detail*: the amount of detail contained in the story.
9. *Vocabulary*: the level and variety of vocabulary employed in the story.
10. *Straightforwardness:* the degree to which the story is straightforward.'

All stories were coded for creativity first (1 = not very creative; 7 = very creative). The order for the following nine dimensions was randomized to avoid potential order effect in the coding. Additionally, stories were randomly coded such that coders did not score two stories from the members of the same twin pair consecutively.

Due to the large sample size, the stories were divided into 5 blocks of 248–306 stories each (in total 1,306 stories). The stories in each block were coded for all 10 dimensions by five independent undergraduate-student judges. In total, 25 students worked on the coding. A pilot study (Toivainen et al., 2017) tested whether expertise in children's writing influenced the creativity coding (n = 59). The study compared ratings by primary school teachers, who have experience assessing children's writing with ratings of undergraduate students, who do not have such experience. The groups did not differ in their evaluations of all 10 story dimensions, including creativity. Based on this finding, the coding in the present study was done by students.

Another study established that five coders were sufficient to reach acceptable inter-rater reliabilities for all dimensions (Toivainen et al., 2018). The inter-rater reliabilities are presented in the Table S1. For seven of the ten dimensions, the inter-rater reliabilities were acceptable (e.g., for creativity dimension .81 to .90). However, the inter-rater reliabilities were lower for Straightforwardness (.55 to .75) and Logic (.48 to .75). The total score for each dimension was created by averaging the sum of the standardized scores from the 5 coders.

The present study reported a similar two-componential structure among the coded dimensions as was found in three previous studies that were based partly on the same sample as the present study. The earlier studies utilized a smaller number of participants (n = 59–306) and did not include any genetically sensitive analyses (Badini et al., 2018; Toivainen et al., 2017, 2018). The two components were named *Creative Expressiveness* and *Logic*. The first component – *Creative Expressiveness* – included Creativity, Liking, Novelty, Imagination, Emotion and Detail. The second component – *Logic* – included Logic, Grammar and Straightforwardness. The Vocabulary dimension had similar loadings on both components (.57 and .71) and was therefore excluded when the component scores were computed.

The component scores for *Creative Expressiveness* and *Logic,* which were used in the analyses, were based on six (*Creative Expressiveness*) and three (*Logic*) story dimensions. The component scores were calculated using the regression method. The component loadings are presented in the Table S2.

Intelligence at age 9

A composite of two non-verbal and two verbal tests was used. The test booklets were completed at home. The verbal tests were age-appropriate versions of Vocabulary and General Knowledge tests from the WISC-III (Kaplan, Fein, Kramer, Delis, & Morris, 1999; Wechsler, 1992). The non-verbal tests were Figure Classification and Shapes tests from the Cognitive Abilities Test 3 (Smith, Fernandes, & Strand, 2001).

Motivation to write at age 9

Twins and their parents responded to two questions. Children were asked 'How much do you like writing' (1–5) and parents 'How much does your child like writing' (1–5). The items were developed by the TEDS research team (Spinath, Spinath, Harlaar, & Plomin, 2006).

Educational achievement at age 9

Teachers commented on twins' 'current level of attainment' in writing in terms of the National Curriculum (NC). The assessment criteria were based on grammar, punctuation, and spelling (NC level KS2). English writing at age 9 was teacher evaluated, based on the NC scale 1 to 5, in which level 5 represents exceptional achievement and 1 represents achievement well below the expected standard for most 9-year-olds.

Educational achievement at age 12

English writing was teacher reported, based on the NC scale 1 to 9, in which 9 represents exceptional achievement. In addition to the assessment criteria applied at age 9, the following was also assessed: accuracy, fluency, planning, drafting, editing, and the effectiveness of writing (NC level KS3).

Educational achievement at age 16

A composite grade score was created as the mean of General Certificate of Secondary Education (GCSE) examination grades for English language and English literature. If only one examination was sat, the score was based on that grade (n = 137). The GCSE is a nationwide examination taken at the end of compulsory education in England and Wales, generally at the age 16. English is a compulsory subject. The grades were coded for the present study from 11 (the highest grade, A*) to 4 (the lowest pass grade, G). Two participants who did not have a grade (e.g. due to failure) were coded as missing.

Statistical analyses

For the non-genetically sensitive analyses, one twin per pair was randomly selected. This eliminated the confound of genetic and environmental influences shared by the twins from the same pair. This procedure creates two 'singleton' samples, allowing for the replication of results with the other half of the sample (the regression results for the second half of the sample are presented in the Tables S3-S5).

For univariate and multivariate genetic model fitting, age and sex were added as covariates. A univariate ACE model was fitted to each of the variables. Nested models (i.e., AE, CE, E) were also fitted to examine whether one (or two) components could be dropped without a significant decrease in model fit. The fit of the different models and sub-models was checked using the likelihood-ratio chi-square test and the Akaike's information criterion (AIC; (Akaike, 1987). Assumptions of twin models were checked in the saturated models in order to check for differences in means and variances between the different groups: MZ/DZ twins and twin1/twin2 (randomly selected within each pair).

Multivariate genetic analyses allow the estimation of aetiological correlations between variables, that is the extent to which the latent variables (A, C, and E) correlate across two traits. These correlations (i.e., rA rC, rE) vary from −1 to +1, with 0 indicating entirely separate aetiologies; and +1 indicating a complete overlap in aetiologies of the two measures. Bivariate heritability, based on the multivariate correlations, is the proportion of the phenotypic covariance explained by A, C, and E. Bivariate heritability indicates the strength of genetic mediation between two variables. The same procedure also enables the estimation of the contributions of shared and non-shared environmental influences on the correlations between two study measures.

Twin analyses were conducted using the package OpenMx (2.13.2) in R (Neale et al., 2016) Requests to access the data should be directed to the TEDS study. Please visit www.teds.ac.uk for further information on the TEDS data access policy. The analysis script can be requested from the authors.

Results

Phenotypic analyses

Descriptive statistics (for the whole group as well as separated by gender) and intercorrelations between the study variables are presented in Table S6. All variables were normally distributed. All study measures were positively correlated (ranging from $r = .15$ to .57), with the exception of no significant correlation between writing motivation and intelligence at age 9. Age (measured in years and months) was not associated with study variables. Regarding sex differences, girls outperformed boys in *Creative Expressiveness* at age 9 ($d = 0.45$); *Logic* at age 9 ($d = 0.29$); motivation to write at age 9 ($d = 0.62$); and in English writing grade at ages 9 ($d = 0.19$); and 16 ($d = 0.20$). No sex differences were found in intelligence at age 9 and English writing grade at age 12.

Three regressions were run to establish whether *Creative Expressiveness* and *Logic* scores measured at age 9 were independently related to educational achievement at ages 9, 12, and 16 over and above intelligence and motivation.

Table 1 presents regression results for the English writing grade at age 9. Both *Creative Expressiveness* and *Logic* were significant predictors, beyond writing motivation and intelligence at the same age (which were also significant). All variables had similar beta weights (0.10–0.16) predicting the variance in English writing grade at age 9.

Table 2 presents the regression results for English writing at age 12. Out of 5 variables entered in the same model, *Creative Expressiveness* and writing motivation at age 9 were not significant predictors, whereas *Logic*, intelligence, and English writing grade at age 9 were all significant predictors. However, the finding of *Logic* at age 9 being a statistically significant predictor of English writing at age 12 did not replicate in the second half of the sample (see Table S4). Due to a failed replication, *Logic* at age 9 is not found to be a predictor of English writing at age 12.

Table 3 presents the regression results for English GCSE grade at age 16. *Creative Expressiveness* at age 9 explained additional variance to that explained by intelligence at age 9, as well as English writing grades at ages 9 and 12. *Logic* and motivation to write at age 9 were not significant predictors of educational achievement at age 16 with all other variables included in the model.

The results of the three regression analyses for the second half of the sample are presented in the Supporting Information. The strength of the predictors was similar to the findings from the first half of the sample, except *Logic* at age 9 explaining variance in English writing at age 12.

In addition, the results showed that the moderate correlation coefficient between Logic at age 9 and English at age 16 reduced to a negligible beta coefficient in the regression model (Table 3). This indicates that the effect is mediated via other study variables. Similar result was also seen for Creative Expressiveness predicting English at 12. Two additional stepwise regressions confirmed the reduction in the associations when additional predictors are added to the models (Tables S7 and S8).

Quantitative genetic analyses

All the twin–cotwin phenotypic correlations were higher in MZ than DZ pairs. Intraclass correlations and univariate model fitting results are presented in Table S9. The results from seven univariate genetic analyses, based on the best fitting models (either ACE, CE, or AE) are summarized in Figure 1.

Table 1. Regression results using English writing at 9 as the criterion (n = 653)

Predictor	*b*	*b* 95% CI [LL, UL]	β	β 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	*r*	Fit
(Intercept)	1.12	[−0.39, 2.63]						
age	0.16	[−0.00, 0.33]	.07	[−0.00, 0.14]	.00	[−0.00, 0.01]	.11**	
sex	−0.03	[−0.13, 0.07]	−.02	[−0.09, 0.05]	.00	[−0.00, 0.00]	−.11**	
Intelligence 9	0.16**	[0.10, 0.21]	.20	[0.13, 0.28]	.04	[0.01, 0.06]	.32**	
Motivation to write 9	0.10**	[0.04, 0.16]	.12	[0.05, 0.19]	.01	[−0.00, 0.03]	.20**	
Logic 9	0.15**	[0.10, 0.21]	.22	[0.14, 0.30]	.04	[0.01, 0.06]	.39**	
Creative expressiveness 9	0.12**	[0.07, 0.17]	.17	[0.09, 0.25]	.02	[0.00, 0.04]	.34**	R^2 =.241**

Notes. The analysis is based on one randomly selected member from each twin pair. A significant *b*-weight indicates that the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. β indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.
$^*p < .05$; $^{**}p < .01$.

Table 2. Regression results using English writing at 12 as the criterion (n = 325)

Predictor	b	b 95% CI [LL, UL]	β	β 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	r	Fit
(Intercept)	4.39**	[1.69, 7.10]						
age	−0.16	[−0.45, 0.13]	−0.05	[−0.15, 0.04]	.00	[−0.01, 0.01]	.00	
sex	0.03	[−0.15, 0.22]	0.02	[−0.08, 0.12]	.00	[−0.00, 0.00]	−.00	
Intelligence 9	0.18**	[0.08, 0.28]	0.19	[0.09, 0.29]	.03	[−0.00, 0.06]	.35**	
Motivation to write 9	0.07	[−0.04, 0.18]	0.06	[−0.04, 0.16]	.00	[−0.01, 0.01]	.16**	
English 9	0.50**	[0.35, 0.64]	0.38	[0.27, 0.49]	.11	[0.05, 0.16]	.51**	
Logic 9	0.15**	[0.04, 0.26]	0.16	[0.04, 0.27]	.02	[−0.01, 0.04]	.39**	
Creative expressiveness 9	0.02	[−0.08, 0.12]	0.02	[−0.08, 0.13]	.00	[−0.00, 0.00]	.25**	R^2 = .334**

Notes. The analysis is based on one randomly selected member from each twin pair. A significant *b*-weight indicates that the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. β indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.
*$p < .05$; **$p < .01$.

Table 3. Regression results using English GCSE at 16 as the criterion ($n = 653$)

Predictor	b	b 95% CI [LL, UL]	β	β 95% CI [LL, UL]	sr^2	sr^2 95% CI [LL, UL]	r	Fit
(Intercept)	4.56**	[1.71, 7.40]						
Age	0.15	[−0.16, 0.45]	0.04	[−0.04, 0.12]	.00	[−.00, 0.01]	.07	
Sex	−0.19	[−0.39, 0.00]	−0.08	[−0.17, 0.00]	.01	[−0.01, 0.02]	−.12*	
Intelligence 9	0.25**	[0.14, 0.36]	0.21	[0.12, 0.30]	.03	[0.00, 0.05]	.49**	
Motivation to write 9	0.06	[−0.06, 0.19]	0.04	[−0.04, 0.13]	.00	[−0.01, 0.01]	.25**	
English 9	0.39**	[0.21, 0.56]	0.24	[0.13, 0.34]	.03	[0.00, 0.06]	.58**	
English 12	0.40**	[0.27, 0.53]	0.29	[0.20, 0.39]	.06	[0.02, 0.09]	.57**	
Logic 9	0.01	[−0.09, 0.12]	0.01	[−0.08, 0.11]	.00	[−0.00, 0.00]	.40**	
Creative expressiveness 9	0.17**	[0.07, 0.28]	0.15	[0.06, 0.24]	.02	[−0.00, 0.04]	.43**	$R^2 = .502$**

Note. The analysis is based on one randomly selected member from each twin pair. A significant *b*-weight indicates that the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. β indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. *LL* and *UL* indicate the lower and upper limits of a confidence interval, respectively.
*$p < .05$; **$p < .01$.

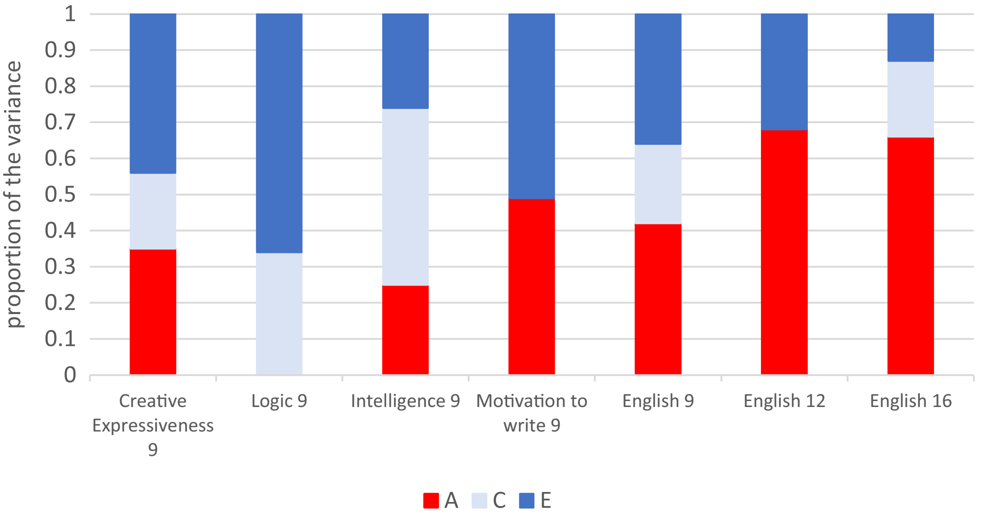

Figure 1. Model fitting results for additive genetic (A), shared environment (C), and non-shared environment (E) components of variance for *Creative Expressiveness* and six other study variables.

Genetic factors accounted for a substantial proportion of the variance in *Creative Expressiveness* (35%; 95% CI: 0.13–0.57). Shared environmental factors also accounted for a significant proportion of the variance in creativity (20%; 95% CI: 0.01–0.39). The remaining variance in *Creative Expressiveness* was explained by non-shared environmental influences (45%; 95% CI: 0.38–0.52). Intelligence, motivation, English at 9, English at 12, and English at 16 were influenced by genetic factors ranging from 25% to 68%. *Logic* at 9 did not show a significant genetic influence. For *Logic*, a CE model indicated that shared environment explained 34% (95% CI: 0.27–0.41) of the variance.

Figure 2 presents the results of six bivariate models on the aetiology of the phenotypic correlations between *Creative Expressiveness* and the other 6 variables (see Table S9 for

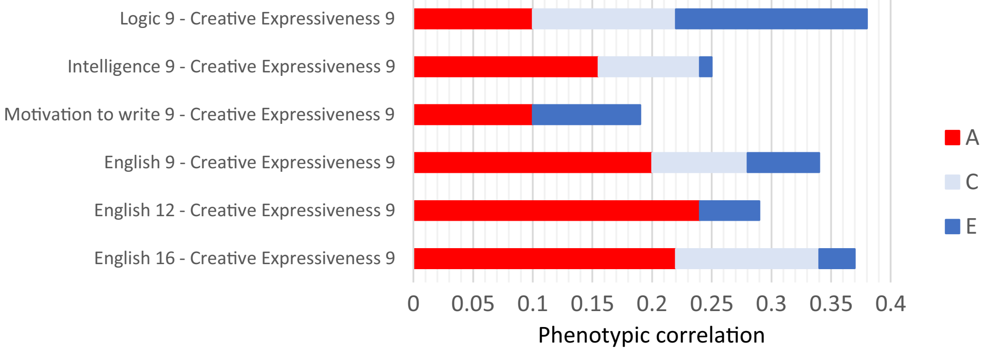

Figure 2. Bivariate estimates for additive genetic (A), shared environmental (C), and non-shared environmental (E) contributions to the correlations between *Creative Expressiveness* at age 9 and the six other variables. The total length of the bar indicates the phenotypic correlations.

bivariate heritability estimates). The figure shows the proportion of additive genetic (A), shared environmental (C), and non-shared environmental (E) influences on the phenotypic correlations between *Creative Expressiveness* and the other six study variables (bivariate correlations). An ACE model provided the best fit for associations between *Creative Expressiveness* and *Logic* at 9, intelligence at 9, English at 9, and English at 12. An AE model provided the best fit for the associations between *Creative Expressiveness* and motivation at 9 and English at 12. The genetic influences explained 26% to 84% of the total covariance between each of six pairs of variables. Shared environmental effects mediated correlations between *Creative Expressiveness* and *Logic* (31%), intelligence (35%), English at age 9 (23%), and English at age 16 (31%). Non-shared environmental influences also contributed to the observed overlap between *Creative Expressiveness* and all other measures.

All the genetic correlations between creativity and the other variables were significant ranging from 0.19 (motivation) to 0.54 (intelligence; see Table S10). The genetic correlation for *Creative Expressiveness* and *Logic* at age 9, based on the ACE model, was 1. However, the confidence interval included zero, probably due to negligible genetic influences on the *Logic* score at age 9 for which the univariate CE model provided the best model fit. The shared and non-shared environmental correlations were generally of lower magnitude than the genetic correlations and not always significant.

Discussion

The present study investigated creativity in relation to educational achievement, intelligence, and motivation. Creativity, operationalised as a *Creative Expressiveness* component score, based on written stories at age 9, was associated with tests of intelligence and self-reported motivation at the same age. *Creative Expressiveness* also explained variance in English grades over and above intelligence and motivation, including longitudinally. Furthermore, the study indicated modest genetic and moderate environmental (shared and non-shared) influences on creativity in writing at age 9. The associations between creativity and other study variables were mainly mediated genetically.

As the present study shows, creative content in writing can be detected in primary education. As was reported in three previous studies, based partly on the same sample as the present study, a two-componential structure emerged among the ten story dimensions (Badini et al., 2018; Toivainen et al., 2018; Toivainen et al., 2017). Five dimensions (Liking, Novelty, Imagination, Emotion, and Detail) loaded highly on the *Creative Expressiveness* component with creativity. This indicates that creativity in childhood storytelling is not a discriminant unitary dimension. For children's stories, it is conceptually viable that creativity would load with other items. For example, imagination is regarded to be an element of creative childhood writing. Additionally, a reader is likely to view a text written by a child as creative if it is novel, filled with detail, and has a strong emotional content.

Our measure of creativity, *Creative Expressiveness*, was positively associated with intelligence and motivation. This relationship has been widely reported within adult samples (e.g. Kim, 2005; Neves de Jesus et al., 2013). The present study has shown that these relationships are also evident in childhood, as are relationships between creativity and educational achievement. *Creative Expressiveness*, as well as *Logic*, intelligence, and motivation were all associated with English writing grade at age 9. However, the association between motivation at age 9 and educational achievement disappeared when investigated longitudinally in relation to English writing grade at age 12 and English end-of-school examination grade at age 16. The finding that writing motivation at 9 is not linked to English writing grades at age 12 may suggest that writing differs from other literacy skills. For example, a study reported a correlation of $r = .26$ between reading motivation at age 9 and reading achievement at 12 (Malanchini et al., 2017). The difference in this finding with the present study may be due to differences between reading and writing. Reading is more commonly practised, everyday skill in comparison with writing, which may be limited only to school hours among nine-year-olds.

This study also indicated some interesting sex differences. At age 9, girls, on average, scored higher than boys in both Creative Expressiveness and Logic measures. This is likely to reflect the fact girls also scored higher in their motivation for writing and English writing grade at this age. In adult samples, no consistent patterns of sex differences have emerged in creative cognition (review by Baer & Kaufman, 2008).

The results showed that *Creative Expressiveness* at age 9 was a significant predictor of English grades at ages 9 and 16, beyond intelligence, motivation, and prior English grades. A smaller, non-significant, effect of creativity was found on English at age 12. However, the results at age 9 did not account for any earlier grades that may have explained some of the variance in the English writing grade at age 9. It could be that the effect of *Creative Expressiveness* on English at age 9 would have reduced if an earlier measure for English writing could have been added into the model. Effect sizes for creativity predicting educational achievement at ages 9 and 16 were small ($sr^2 = .02$). However, the effect of Creative Expressiveness on English at age 16 was similar in magnitude to that of intelligence or English writing grade, both measured at age 9 (both $sr^2 = .03$). The results indicate that creativity in childhood writing can be associated with educational achievement, even later in adolescence.

Also, interestingly, the variance accounted by *Logic* was shared substantially with English grades, which lead *Logic* being a negligible predictor of English writing at 16 when previous writing grades were added to the model. The addition of the previous writing grades did not reduce the effect of *Creative Expressiveness* predicting English writing at 16. These results are consistent with previous research demonstrating that variance in academic achievement is explained by variance in many characteristics, including intelligence, motivation, and behavioural problems. These characteristics have partly shared genetic and environmental aetiology, and therefore, adding them in the same model reduces the contribution of each one to the overall variance (Krapohl et al., 2014).

Establishing the positive associations between Creative Expressiveness and educational achievement at different points of education is important. Firstly, since creativity, intrinsic motivation and achievement are intertwined, undervaluing creativity and emphasizing only technical aspects of writing may decrease the motivation to write creatively and, furthermore, writing in general. Secondly, National Curriculum criteria differ at different ages, as indicated by the predictive value of creativity: creativity was associated with English grade at age 16 even after variance that was attributable to English grades at younger ages (9 and 12) was taken into account. This highlights the fact that a set of skills, relevant for specific educational subjects, may not be equally taught/emphasized across school. Technical skills are valued from the early school years onwards, but creative expressiveness in writing may be emphasized only some years later.

Genetically sensitive analyses were run to investigate the proportion of variance explained by genetic and environmental factors in *Creative Expressiveness*. Univariate analysis showed that 35% of the variance in *Creative Expressiveness* is explained by genetic factors; with 20% attributable to shared and 45% to non-shared environments. The proportion of genetic influences in the present study is somewhat lower in comparison with previous twin studies on creativity (e.g., 42% in Vinkhuyzen et al., 2009; and 70% in Roeling et al., 2017). However, these previous studies utilized different creativity measures and (mostly) adult samples. The results from the present study are therefore in line with the finding that heritability estimates for many cognitive abilities increase during development (e.g., Plomin, DeFries, Knopik, & Neiderhiser, 2016). It is possible, that as children grow older and have more autonomy, their genetic propensities contribute to seeking environments where creative activities are encouraged.

Interestingly, the variation in the *Logic* component score showed negligible genetic effects. This could be due to lower inter-rater reliabilities among Logic and Straightforwardness dimension judgments which, together with the Grammar dimension, formed the *Logic* factor score. This is further supported by the fact that the non-shared environmental estimate (which includes measurement error) was the highest for *Logic*, out of all study measures. In comparison, a previous study, also based on the TEDS sample, when the twins were 4.5-year-olds, showed that genetic influences explained 26% of the variance, shared environmental 22%, and non-shared environmental 52% in a grammar score (Hayiou-Thomas et al., 2006). The grammar score in the previous study was based on a cognitive test, whereas in the present study it was evaluated subjectively in comparison with the other stories.

Genetic investigation of the sources of covariance between the measures, utilizing multivariate genetic analyses, showed that a large proportion of all phenotypic correlations is mediated genetically. Genetic influences explained 26–84% of the covariance between creativity and other study measures. This finding is in line with previous findings that differences between children in many educationally relevant constructs are partly influenced by the same genetic effects (Plomin & Kovas, 2005).

Our findings are limited as they were coded by judges with no special expertise in creative writing. Further research is needed to test whether the results would be similar if ratings were done by experts from the creative industries such as creative writers or literary agents. Indeed, previous research has shown that the level of expertise influences creativity assessment, for example, in visual artwork and music compositions (Hickey, 2001; Runco, Mccarthy, & Svenson, 1994). Another possible future direction for research would be to consider how children rate the creativity of their own work and that of their peers.

Our results indicate that creativity can be detected already in childhood writing. Furthermore, creativity plays a role in educational achievement, albeit with a small effect. Currently, creativity in primary education, such as creative content of childhood writing, may be undervalued. The somewhat low heritability of creativity at age 9 may reflect the lack of environments that promote creativity enabling expression of genetic potential. It is important to recognize and encourage of creativity in primary education. Opportunities to express and develop creativity can open new directions for students' educational and future professional development.

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Conflicts of interest

All authors declare no conflict of interest.

Author contributions

T.T. developed the study concept. The data collection based on the written stories was initiated by B.R.O. Data collection was performed by the TEDS research team, managed by A.M. T.T. performed the data analyses with the guidance from J.J.M.V. Y.K. supervised all aspects of the study. All authors contributed to the preparation of the manuscript and approved the final version of the manuscript for submission.

Data Availability Statement

Requests to access the data should be directed to the TEDS study. Please visit www.teds.ac.uk for further information on the TEDS data access policy. The analysis script can be requested from the authors.

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Supporting Information

The following supporting information may be found in the online edition of the article:

Figure S1. Instructions for the story writing.
Table S1. Inter-rater reliabilities (intraclass correlation coefficient) for 10 story dimensions.
Table S2. The rotated principal component loadings, with Varimax rotation, for 10 story dimensions.
Table S3. Regression results using English writing at 9 as the criterion for Twin 2.
Table S4. Regression results using English writing at 12 as the criterion for Twin 2 (n = 325).
Table S5. Regression results using English GCSE at 16 as the criterion for Twin 2.
Table S6. Means, standard deviations, skewness, kurtosis and correlations with confidence intervals for the study variables.
Table S7. Stepwise regression of Logic at 9 (Step 1); and with other predictors (Step 2); explaining English at 16.
Table S8. Stepwise regression of Creative Expressiveness at 9 (Step 1); and with other predictors (Step 2); explaining English at 12.
Table S9. Intraclass correlations and univariate model fitting results.
Table S10. Bivariate models for Creative Expressiveness at age 9 with the other study variables.