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Mathematics Attainment Falls Behind Reading in the Early Primary School Years

Laura A. Outhwaite
University College London

Jake Anders
University College London

Jo Van Herwegen
University College London

Early mathematics and reading are foundational skills for later academic and life outcomes. Despite their equal value to society, previous research finds reading skills exceeded those of mathematics in the first two years of primary school in the UK. The current study conducted a conceptual replication and extension of this finding using large-scale, longitudinal data from the Millennium Cohort Study. Within the same group of nearly 12,000 children, results showed at age 2-4 years, symbolic knowledge, which underpins mathematical development was stronger than alphabetic knowledge, a key component of reading development. However, following the introduction of formal schooling, reading attainment exceeded that of mathematics at 6-8 years. These findings have important implications for educational policy and practice, which currently places a greater focus on reading development, compared to mathematics. Directions for future research to enhance the scientific understanding of mathematical development that translates to effective mathematical interventions are discussed.

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Highlights

- Reading and mathematical skills are vital for children's education and life outcomes.
- Using data from the Millenium Cohort Study, early maths was found to be stronger than early reading at age 2-4 years.
- But following the introduction of formal schooling, reading attainment exceeded that of mathematics when measured at at age 6-8 years.
- This 'maths- reading attainment gap' may be due to a greater focus on reading, compared to maths, at school and in the home learning environment.

Why does this matter?

A greater focus and awareness of mathematical development in primary-school aged children is needed in educational policy, practice, and research to raise maths attainment.

Mathematics Attainment Falls Behind Reading in the Early Primary School Years

Laura A. Outhwaite*[1], Jake Anders[1], & Jo Van Herwegen[1,2]

1. Centre for Education Policy and Equalising Opportunities, IOE- UCL's Faculty of Education and Society
2. Psychology and Human Development, IOE- UCL's Faculty of Education and Society

Abstract

Early mathematics and reading are foundational skills for later academic and life outcomes. Despite their equal value to society, previous research finds reading skills exceeded those of mathematics in the first two years of primary school in the UK. The current study conducted a conceptual replication and extension of this finding using large-scale, longitudinal data from the Millennium Cohort Study. Within the same group of nearly 12,000 children, results showed at age 2-4 years, symbolic knowledge, which underpins mathematical development was stronger than alphabetic knowledge, a key component of reading development. However, following the introduction of formal schooling, reading attainment exceeded that of mathematics at 6-8 years. These findings have important implications for educational policy and practice, which currently places a greater focus on reading development, compared to mathematics. Directions for future research to enhance the scientific understanding of mathematical development that translates to effective mathematical interventions are discussed.

1. Introduction

It is estimated that in the United Kingdom (UK), 15-17 million adults have poor mathematical skills (Department for Business Innovation and Skills, 2012). Only 22% of working-aged adults are functionally numerate, compared to 57% being functionally literate (National Numeracy, 2019).[1] Poor mathematical skills pose a significant problem in adulthood: adults with a basic level of mathematics earn 26% more, on average, than those without (Bynner & Parsons, 2006) and adults with low numeracy are at significantly greater risk of unemployment, mental and physical health issues, and involvement in the criminal justice system (Gross et al., 2009). Underachievement in mathematics is also evident during childhood. In the UK, 20% of 5-year-old children do not achieve the expected standard for mathematics (Department for Education [DfE], 2017) and the same is true by age 11 (Gross, 2007). Furthermore, children who start formal education with low mathematical skills are significantly more likely to remain low achievers throughout primary school and beyond compared to their higher attaining peers (Aubrey et al., 2006).

High-quality learning and instruction at school and at home is vital for early child development (Melhuish et al., 2013; Skwarchuk et al., 2014). Mathematics and reading are both foundational skills for later academic achievement (Golinkoff et al., 2018; Davis et al., 2014), as well as economic, employment, mental and physical health outcomes in adulthood (Goodman et al., 2015; Reyna et al., 2009). Despite the equal value of reading and mathematical skills to child development and society in general, cross-sectional data suggests early reading skills exceed those of mathematics. The difference between mathematics and reading attainment increased during the first two years of primary school in England when children were 4-6 years old (Pitchford et al., 2016). Pitchford et al. (2016) suggested that this mathematics-reading achievement gap may arise, in part, because of the provision of explicit phonics instruction in the first years of formal

[1] Functionally numerate and literate both defined as ‘equivalent to a GSCE pass (Grade4/C) or above’ (Department for Business, Innovation and Skills, 2012)

education (DfE, 2010), while a similar approach to mathematics instruction is not currently implemented.

1.1. Mathematics and reading in educational policy and practice

In the first years of primary school, teachers report spending significantly less time on mathematics, (5-8% of the school day) compared to reading (21% of the school day; Early et al., 2005), thus demonstrating a "maths-practice" gap (Stacy et al., 2017). Teachers also report less confidence in engaging in early mathematics learning compared to reading (Costa et al., 2021; Gilligan-Lee et al., 2022). When mathematics activities are implemented in the early years classroom, they are typically narrow in focus (e.g., counting and cardinality), and do not represent the full range of early mathematical skills (e.g., sequences; Von Spreckelsen et al., 2019). Furthermore, research suggests early mathematics instruction often underestimates children's abilities (Engel et al., 2013; Engel et al., 2016), which may hinder development (Bodovski & Farkas, 2007). Collectively, this evidence may reflect the myths surrounding early mathematics instruction: that language and literacy are more important than mathematics, instruction on simple numbers and shape recognition is sufficient, and young children are not ready for mathematics education (Clements & Sarama, 2009).

Similarly, in the home learning environment, parents and caregivers report reading with young children five to seven days a week, which was significantly related to children's emergent literacy outcomes. In comparison, parents reported engaging in mathematics-related activities at home, on average, once a week. However, more frequent engagement with maths activities at home was significantly associated with stronger mathematical outcomes after accounting for socio-economic status (Organisation for Economic Co-Operation and Development [OECD], 2020). Research also shows early school-aged children of maths-anxious parents learnt significantly less mathematics and reported their own mathematics anxiety higher over the school year, but only when maths-anxious parents provided frequent and well-meaning help with homework. Parental mathematics anxiety was not found to affect children's reading development (Maloney et al., 2015).

1.2. Mathematical and Reading Development

Mathematical and reading development are complex and involve a range of underpinning emergent abilities, such as symbolic knowledge for mathematics and alphabetic knowledge for reading (Ehri, 2005; Merkley & Ansari, 2016). While research suggests children have an innate sense of number, which is associated with school-age mathematical abilities (Libertus et al., 2011), representations of exact number and written language are conceptual structures, invented by humans (Carey, 2009). They allow the representation and transmission of information, which children must gradually acquire during early childhood, typically through explicit instruction (Castles et al., 2018; Sarnecka, 2015).

1.3. Symbolic Knowledge

Symbolic knowledge encompasses the ability to identify exact numerical digits, as well as understanding that the last number word used when counting refers to the number of items within a set (cardinality knowledge) and how individual numbers relate to other numbers in the counting sequence (ordinal knowledge; Merkley & Ansari, 2016). The acquisition of symbolic knowledge begins prior to formal mathematics instruction and is often based on informal learning experiences (Vasilyeva et al. 2018), such as exposure to the counting sequence. Children may also acquire symbolic knowledge through targeted intervention approaches (Van Herwegen et al., 2018). Children typically demonstrate symbolic knowledge between 3-4 years of age (Sarnecka & Gelman, 2004), but children from lower socio-economic backgrounds may develop these skills at age 4 or older (Jordan & Levine, 2009). Early symbolic knowledge is a strong predictor of children's individual growth trajectories in mathematics development (Xenidou-Dervou et al., 2018), as well as concurrent and later achievement outcomes (Caviola et al., 2020; Habermann et al., 2020). Evidence suggests symbolic knowledge also mediates the relationship between informal and formal mathematical knowledge (Purpura et al., 2013).

1.4. Alphabetic Knowledge

Alphabetic knowledge is the understanding that visual symbols of the writing system (graphemes) correspond to sounds of the language (phonemes; Castles et al., 2018). Successfully acquiring the alphabetic principle is a critical starting point in learning to read as it enables children to decode most written words (Chiappe et al., 2002; Ouellette & Senechal, 2017). However, establishing the alphabetic principle does not come naturally to children; it requires explicit instruction (Castles, et al., 2018).

A strong body of research on the science of reading demonstrates that an effective means of teaching children the mapping between graphemes and phonemes is systematic phonics instruction (Ehri et al., 2001; Torgerson et al., 2006; Torgerson et al., 2019). This evidence has underpinned statutory educational policy since 2012, whereby all state-funded schools in the England must provide explicit, systematic phonics instruction when children start school at age 4 (Castles et al., 2018). Evaluations of this policy demonstrate significant positive impacts on concurrent and later reading outcomes at ages 5-7 years. Further continued benefits at age 11 years were also seen for children from low socio-economic backgrounds and children with English as an additional language, who may have started school as struggling readers (Machin et al., 2016). Similar educational policy recommendations have been made in the United States (National Reading Panel, 2000) however, it is not statutory and not all states have adopted this instructional approach, which may, in part, explain significant differences in reading outcomes across different states (U.S. Department for Education, 2015).

1.5. Current Study

While the finding that early reading development exceeded that of mathematics in the first two years of primary school, has important implications for educational policy and practice, further research using longitudinal data is required (Brown et al., 2014; Coyne et al., 2016). Specifically, Pitchford et al. (2016) used cross-sectional methods with a relatively small sample size in each age group (age 4-5 years n = 34; age 5-6 years n = 60). As cross-sectional studies provide a snapshot of attainment across different age groups, differences between these individuals may mask genuine changes over time across the whole group. For example, although all children were recruited from similar geographically areas in the UK, the socio-economic status and fine motor skills of each age group differed. These additional factors may have influenced children's mathematics and reading attainment scores (Anders et al., 2012; Cameron et al., 2016), and consequently pose a threat to the internal validity of the overall mathematics-reading achievement gap conclusion.

To address these limitations, the current study examined mathematical and reading attainment within the same group of children, using large-scale, longitudinal data. Using data from the Millennium Cohort Study (MCS), the current study first asked, how does children's mathematics attainment before (age 2-4) and during formal education (age 6-8), compare to their reading attainment? Second, to what extent do children identified as low achieving, typically achieving, or high achieving in emergent mathematics and reading skills (i.e., Symbolic Knowledge and Alphabetic Knowledge) at age 2-4, move from their original attainment group classification in school-age mathematics and reading at age 6-8?

2. Methods

2.1. The Millennium Cohort Study

The current study used data from the Millennium Cohort Study (MCS), which is a large-scale, population-based, longitudinal study of children born between September 2000 and January 2002 across the UK. The MCS sample was randomly selected using a stratified and clustered design to ensure representation of disadvantaged and ethnic minority groups and includes an over-representation of children living in smaller UK countries including Scotland, Northern Ireland, and Wales. To date, MCS has followed the same group of children with seven waves of data collection from aged 9 months to 17 years.

The current study focuses on data collected in Wave 2 (University of London, Institute of Education, Centre for Longitudinal Studies, 2017a) and Wave 4 (University of London, Institute of Education, Centre for Longitudinal Studies, 2017b), due to the availability of suitable measures of emergent and school-age mathematics and reading attainment at each time point. Wave 2 data collection was conducted between September 2003 and January 2005 when the children were 2-4 years old (n = 15,808). Wave 4 was completed between January 2008 and February 2009 when the children were 6-8 years old (n = 14,043). Ethical approval for each wave of data collection was obtained by the UCL Centre for Longitudinal Studies, who manage the MCS, from the London Multi-Centre Research Ethics Committee (Wave 2) and the Northern and Yorkshire

Multi-Centre Research Ethics Committee of the NHS (Wave 4). Ethical approval for the current study was granted by IOE ethics committee. Further details about the MCS sampling methods, attrition rates, and participation are published elsewhere (Hansen, 2012).

2.2. Measures

2.2.1. Symbolic knowledge.

Symbolic knowledge at age 2-4 years was assessed at Wave 2 using the Number/Counting subscale from the Bracken School Readiness Assessment- Revised (BSRA-R; Bracken, 1998). The Number/Counting subscale requires children to name single and double-digit numerals from a picture and count and assign a number value to a set of objects. Children are scored based on accuracy of responses and the maximum raw score available was 18. As standardised scores are not available for individual BSRA-R subscales, Number percent mastery scores were used (Connelly, 2013).

2.2.2. Alphabetic knowledge.

Alphabetic knowledge at age 2-4 years was assessed at Wave 2 using the Letter subscale from the BSRA-R (Bracken, 1998). The Letters subscale requires children to name lower- and upper-case letters from a picture. Children are scored based on accuracy of responses and the maximum raw score available was 15. As standardised scores are not available for individual BSRA-R subscales, Letters percent mastery scores were used (Connelly, 2013).

2.2.3. Mathematics.

Mathematical attainment at age 6-8 years was assessed at Wave 4 using a shortened version of the National Foundation for Educational Research Progress in Maths (PiM) test (NFER, 2004). This mathematics assessment is a standardised, age-appropriate, curriculum-based measure covering items on numbers, shapes, measurement, and data-handling. Question items are read aloud to children by the test administrator and children are required to respond by completing pen and paper calculations. Children are scored based on accuracy of responses. Age-based standardised scores for the NFER PiM test in this MCS sample were based on six-month age intervals and were calculated based on the full-length assessment normed in 2004 with a nationally representative sample ($\mu = 100$, $\sigma = 15$) (Connelly, 2013).

2.2.4. Reading.

Reading attainment at age 6-8 years was also assessed at Wave 4 using the Word Reading subscale from the BAS-II (Elliott et al., 1996). This standardised and age-appropriate measure of educational knowledge of reading abilities requires children to read aloud written words presented on cards. Children are scored based on accuracy of responses. Age-based standardised scores for the BAS-II Word Reading sub-scale are based on three-month age intervals with reference to a representative norming sample in 1995 ($\mu = 100$, $\sigma = 15$) (Connelly, 2013; Elliott et al., 1996).

2.3. Participants

There were 19,244 children born between 2000 and 2002 across the UK in the initial MCS sample (Wave 1). For the purposes of the current study, participants with missing data on any of the emergent and school-age mathematics and reading attainment measures Wave 2 and Wave 4 were excluded from the sample. Table 1 summarises the unweighted and weighted (whole UK MCS weights; WEIGHT2) descriptive data for the final sample of 11,749 children. As shown in Table 1, there are more white participants compared to all other ethnic groups within this final sample. There are also fewer participants from low-income households compared to the other equivalised household income quintiles. Demographic details of the excluded sample compared to the included sample are reported in the Appendix.

Table 1. Descriptive statistics summarising the final sample of children in the current study. All demographic data collected at Wave 4 unless otherwise stated.

Demographic Measure	**Unweighted (*n* = 11,749)**		**Weighted (*n* = 12,672)**	
	Total *n*	**Total %**	**Total *n***	**Total %**
Gender				
Male	5,880	50.0	6,356	50.2
Female	5,869	50.0	6,316	49.8
OECD equivalised household income quintiles				
Lowest	2,160	18.4	1,771	14.0
Second	2,333	19.9	2,219	16.7
Third	2,419	20.6	2,564	20.2
Fourth	2,415	20.6	2,958	23.3
Highest	2,409	20.5	3,250	25.6
Missing	13	.1	10	.1
Ethnicity group				
White	10,297	87.6	11,617	91.7
Mixed	95	.8	86	.7
Indian	282	2.4	219	1.7
Pakistani & Bangladeshi	594	5.1	365	2.9
Black or Black British	323	2.7	255	2.0
Other Ethnic group	156	1.3	128	1.0
Missing	2	.0	2	.0
Age (months)	**Mean (SD)**	**Min – Max**	**Mean (SD)**	**Min – Max**
Wave 2	37.57 (2.34)	31.84- 54.77	37.44 (2.23)	31.84- 54.77
Wave 4	86.77 (2.95)	76.41- 97.77	86.75 (2.96)	76.41- 97.77

2.4. Analysis Strategy

Statistical analyses were conducted in IBM SPSS Statistics Version 26. To account for the stratified design of the MCS sample, whole UK MCS weights (WEIGHT2) were applied for all reported analyses. Initial descriptive statistics and a Pearson's correlation matrix were calculated for measures of emergent and school-aged mathematics and reading attainment.

To compare children's symbolic knowledge and letter knowledge at age 2-4 (Wave 2) and children's mathematics and reading attainment at age 6-8 years (Wave 4), separate parametric paired samples t-test were conducted comparing percent correct and standardised attainment scores, respectively. As Kolmogorov-Smirnov tests identified all measures to deviate significantly from normality (p <.001), more conservative non-parametric, Wilcoxon signed ranks tests were also conducted to ensure the robustness of the findings. Additional non-parametric results are reported in footnotes. Between-group Cohen's d with 95% confidence intervals (CIs) were calculated to indicate standardised differences between mathematics and reading attainment at each time point and afford comparisons with previous research (Pitchford et al., 2016). Effects sizes summarising standardised differences below .20 are typically considered small, .50 medium and .80 or above as large (Cohen, 1988).

Next, the distribution of attainment scores at Wave 2 (age 2-4) and Wave 4 (age 6-8) were examined. At Wave 2 (age 2-4) standardised scores were not available. As such, the distribution of percent correct scores on the BSRA-R Number and Letter sub-scales were categorised into three attainment groups based on percentage correct scores: low attainment (percentage correct 9% or below; equivalent to 0-1 correct items), average attainment (percentage correct 10%- 90%; equivalent to 2-16 correct items on the Numbers sub-scale and 2-13 correct items on the Letters sub-scale), and high attainment (percentage correct 91% or above; equivalent to 17-18 correct items on the Numbers sub-scale and 14-15 correct items on the Letters sub-scale).

At Wave 4 (age 6-8), the distribution of standardised scores in NFER Mathematics and BAS-II Word Reading were also categorised into three attainment groups: low attainment (standardised score 79 or below), average attainment (standardised score between 80-119), and high attainment (standardised score 120 or above). These attainment groups were defined based on theoretically and statistically relevant cut-off points within a standard distribution, which are typically used to classify scores on standardised assessments of cognitive and scholastic attainment (e.g., Snowling, 2013; Peng et al., 2016). Separate 2 x 3 chi squared tests were conducted to examine whether the proportion of children in each attainment group significantly differed across the two skill domains at each time point.

Finally, the frequency of movement across the three attainment groups (low attainment, average attainment, high attainment) from Wave 2 (age 3-4) to Wave 4 (age 7-8) were considered (Conti-Ramsden & Botting, 1999). Movement across attainment groups were categorised as: upwards mobility (i.e., moving from low attainment at Wave 2 to average attainment or high attainment at Wave 4, or from average attainment at Wave 2 to high attainment at Wave 4), stable (i.e., no movement across attainment groups across time), and downwards mobility (i.e., moving from high attainment at Wave 2 to average attainment or low attainment at Wave 4, or from average attainment at Wave 2 to low attainment at Wave 4). To assess mobility rates in mathematics compared to reading, separate one-way t-tests between percentages with Bonferroni-corrected significance levels (α = .05/3= .017) were conducted. A crosstabs frequency and Pearson's correlation were also conducted to examine the relationship between attainment group movement in mathematics compared to reading.

3. Results

Descriptive statistics and a correlation matrix for the measures of emergent and school-aged mathematics and reading attainment in the same group of children aged 2-4 years (Wave 2) and 6-8 years (Wave 4) are summarised in Table 2 and Table 3, respectively.

Table 2. Whole sample descriptive statistics for emergent (Wave 2; age 2-4) and school-aged (Wave 4; age 6-8) mathematics and reading attainment (weighted).

Wave	Assessment	Mean (SD)	Median	Min - Max
Two	BSRA-R Number Sub-Scale % Correct	16.62 (20.24)	10.53	0- 100
	BSRA-R Letter Sub-Scale % Correct	11.42 (16.90)	6.25	0- 100
Four	NFER Mathematics Standardised Score	99.10 (15.28)	99.00	69- 136
	BAS-II Word Reading Standardised Score	113.55 (17.40)	114.00	55- 145

BAS-II = British Ability Scales II; BSRA-R = Bracken School Readiness Assessment- Revised; NFER = National Foundation for Educational Research.

Table 3. Correlation matrix between emergent (Wave 2; age 2-4) and school-aged (Wave 4; age 6-8) mathematics and reading skills (weighted).

Wave	Assessment	Correlation (*r*)			
		1	2	3	4
Two	1. BSRA-R Number Sub-Scale % Correct	-			
	2. BSRA-R Letter Sub-Scale % Correct	.50**	-		
Four	3. NFER Mathematics Standardised Score	.26**	.15**	-	
	4. BAS-II Word Reading Standardised Score	.31**	.21**	.53**	-

*** $p < .001$.*

3.1. Emergent Mathematics and Reading Attainment

A paired samples t-test showed, at the group level, children's emergent mathematical skills at age 2-4 years, significantly exceeded their emergent reading attainment, $t(12671) = 30.94$, $p < .001$.[2] This difference between emergent mathematics and reading was equivalent to a small standardised difference effect size, Cohen's $d = .28$ (95% CI = .24- .31). Table 4 summarises the proportion of children in the three attainment groups (low attainment, average attainment, high attainment) based on percentage correct scores in symbolic knowledge and alphabetic knowledge, respectively. A 2 x 3 chi-squared test showed these differences were significant, $\chi(4)= 1497.74$, $p < .001$.

Table 4. Proportion of children in the three attainment groups for emergent (Wave 2; age 3-4) and school-aged (Wave 4; age 7-8) mathematics and reading skills (weighted).

Wave	**Assessment**	**Attainment Group Total *n* (Total %)**		
		Low attainment	**Average attainment**	**High attainment**
Two	BSRA-R Number	5572 (44.0)	7007 (55.3)	93 (.7)
	BSRA-R Letter	7781 (61.4)	4774 (37.7)	117 (.9)
Four	NFER Mathematics	1478 (11.7)	9793 (77.3)	1401 (11.1)
	BAS-II Word Reading	320 (2.5)	7543 (59.5)	4809 (38.0)

[2] A non-parametric Wilcoxon signed ranks test showed the same significant pattern of results, $Z= 29.69$, $p <.001$, $r = .27$.

3.2. School-Aged Mathematics and Reading Skills

A paired samples t-test showed, at the group level, children's reading attainment at age 6-8 years, significantly exceeded their mathematics, $t(12671) = 101.56$, $p < .001$.[3] This difference between mathematics and reading standardised scores was equivalent to a large standardised difference effect size, Cohen's $d = .88$ (95% CI = .85- .92). Table 4 summarises the proportion of children in the three attainment groups (low attainment, average attainment, high attainment) based on standardised scores in mathematics and reading attainment. A 2 x 3 chi squared test showed these differences were significant, $\chi(4)= 1846.57$, $p < .001$.

3.3. Movement Across Attainment Groups

Table 5 summarises the movement of children between the three attainment groups (low attainment, average attainment, high attainment) in emergent mathematics and reading at Wave 2 (age 2-4), to school-aged mathematics and reading at Wave Four (age 6-8). Significantly more children (51.1%) remained in the same attainment group classifications for mathematics, compared to reading (23.0%), $t(12671)= 38.88$, $p <.001$. Of the children that moved attainment group classifications from Wave 2 (age 3-4) to Wave 4 (age 7-8), significantly more experienced upwards mobility in reading (76.0%), compared to mathematics (44.0%), $t(12671)= 34.84$, $p <.001$. In contrast, significantly more children experienced downwards mobility in mathematics (4.8%) compared to reading (.8%), $t(12,671)= 19.31$, $p <.001$.

Table 6 summarises the relationship between attainment group movement in mathematics and reading. A positive, significant, but weak correlation was observed between movement in mathematics and movement in reading from Wave 2 (age 3-4) and Wave 4 (age 7-8), $r = .13$, $p < .001$.

[3] A non-parametric Wilcoxon signed ranks test showed the same significant pattern of results, $Z= 75.81$, $p <.001$, $r = .70$.

Table 5. Frequency of movement across attainment groups from Wave 2 (age 3-4) to Wave 4 (age 7-8) (weighted).

		Wave 4 Attainment Group Total *n* (Total %)		
		Low attainment	**Average attainment**	**High attainment**
	Mathematics			
	Low attainment	*930 (7.3)*	4210 (33.2)	432 (3.4)
	Average attainment	546 (4.3)	*5519 (43.6)*	942 (7.4)
Wave Two	High attainment	2 (.02)	64 (.5)	*27 (.2)*
	Reading			
	Low attainment	*248 (2.0)*	4936 (39.0)	2597 (20.5)
	Average attainment	72 (.6)	*2581 (20.4)*	2121 (16.7)
	High attainment	0 (.0)	26 (.2)	*91 (.7)*

Table 6. Crosstab relationship between attainment group movement in mathematics and reading from Wave 2 (age 3-4) to Wave 4 (age 7-8) (weighted).

		Reading Total *n* (Total %)		
		Upwards Mobility	**Stable**	**Downwards Mobility**
	Upwards Mobility	4547 (35.9)	1014 (8.0)	24 (.2)
Mathematics	Stable	4752 (37.5)	1671 (13.2)	53 (.4)
	Downwards Mobility	356 (2.8)	235 (1.9)	21 (.2)

4. Discussion

The current study examined, for the first time, differences in emergent (age 2-4) and school-aged (age 6-8) mathematics and reading abilities within the same group of nearly 12,000 children. Using more rigorous large-scale, longitudinal data from the MCS, the current study conceptually replicated and extended previous small-scale, cross-sectional research, which also showed early reading attainment exceeded that of mathematics in the first two years of formal education in England (Pitchford et al., 2016). The current evidence is significant for educational policy and practice surrounding the provision of early mathematics instruction in school and at home. It highlights the need to raise standards and awareness of early mathematics development to ensure children have the foundational skills necessary for later academic attainment and other life outcomes. Directions for future research to enhance the scientific understanding of mathematical development that translates to effective mathematical interventions are discussed.

4.1. Mathematics and Reading Attainment

The current study found at age 6-8 years, children's reading skills were, on average, significantly stronger than their mathematical skills. This was characterised by a large, standardised difference effect size (Cohen's d = .88). When examining the distribution of mathematics and reading scores, 11.7% of children were identified to have low attainment in mathematics (standardised score 79 or below), compared to only 2.5% of these same children for reading. In contrast, 38.0% of children were identified to have high attainment in reading (standardised score 120 or above), compared to 11.1% for mathematics.

This evidence corroborates previous research that shows the difference between mathematics and reading attainment increases during the first two years of formal schooling (Pitchford et al., 2016). Specifically, the modest standardised difference effect size (Cohen's d) previously observed in the group of 4-5-year-old children increased from .45 to .58 in the group of children aged 5-6 years. Pitchford et al. (2016) suggested this difference in reading and mathematics attainment may arise, in part, because of the provision of explicit phonics instruction (DfE, 2010). Whereas a similar targeted approach to mathematics instruction is not currently implemented. The current study extended previous work by examining this claim using longitudinal data within a large sample of children.

First, emergent mathematics and reading skills, namely symbolic knowledge, and alphabetic knowledge, at age 2-4 years, before children started primary school were compared. Results showed children's symbolic knowledge (i.e., recognition of single and double-digit numbers, and counting skills) were significantly stronger than their alphabetic knowledge (i.e., recognition of letters). This was characterised by a small, standardised difference effect size (Cohen's d = .28). Furthermore, 61.4% of children were within the low attainment group (percentage correct score 9% or below) in alphabetic knowledge at Wave 2 (age 2-4), compared to 44.0% for symbolic knowledge.

Second, the current study examined children's movement across the three attainment groups from Wave 2 (age 2-4) to Wave 4 (age 6-8). Results showed 76.0% of children experienced upwards mobility over time in reading, compared to 44.0% in mathematics. While, in general a smaller proportion of children experienced downwards mobility, compared to upwards mobility, or remaining stable, significantly more children experienced downwards mobility over time in mathematics (4.8%), compared to reading (less than 1.0%).

Furthermore, a positive, significant correlation was observed between children's mobility in mathematics and reading, which suggests that children who experienced upwards mobility in in reading, also experienced upwards mobility in mathematics. This may reflect evidence indicating a close relationship between mathematics and reading development (Cameron et al., 2019; Erberli et al., 2020; Purpura et al., 2019). Research shows a large overlapping of latent skills of mathematics and reading (Bailey et al., 2020), as well as a substantial and shared genetic component, which affects both abilities (Davis et al., 2014). However, the strength of the correlation was weak (r = .13), which combined with the higher rates of upwards mobility in reading (76.0%), compared to mathematics (44.0%), suggests that overall, early educational policy and practices are influential on the observed differences between children's mathematics and reading attainment.

4.2. Policy and Practice Implications

Collectively, the current study suggests that emergent mathematics skills are stronger than emergent reading skills when children are 2-4 years old. This may reflect children's innate disposition towards number (Libertus et al., 2011) and research suggesting children typically acquire symbolic knowledge around this age (Sarnecka & Gelman, 2004), through informal learning experiences (Vasilyeva et al., 2018). In contrast, establishing alphabetic knowledge does not come naturally to young children and may require further explicit instruction (Castles et al., 2018). However, following the introduction of formal schooling, which places a greater focus on early reading development in classroom practice (Early et al., 2015) and at home (OCED, 2020), reading attainment goes on to exceed that of mathematics when measured at 6-8 years. The significance of the current findings has important implications for educational policy and practice.

Since the introduction of the systematic phonics policy in 2012, the percentage of 4-5-year-old children achieving at least the expected level of reading has gradually increased from 61% in 2013 to 77% in 2019 before the Covid-19 pandemic (DfE, 2013; 2019). It is also viewed particularly beneficial for children from low socio-economic backgrounds and children with English as an Additional Language, who may start school as struggling readers (Machin et al., 2016). Early reading and language skills are also received additional support through government campaigns in the UK, such as Hungry Little Minds, which aimed to encourage parental engagement with young children's early development at home from 0-5 years (DfE, 2020). A similar focus and attention are needed for early mathematical development, particularly as estimates suggest that children's maths attainment has been significantly impacted by the disruptions caused by Covid-19, much more so than reading (DfE, 2022).

To develop and implement effective early mathematics instruction, a strong scientific understanding of mathematics is required (Alcock et al., 2016; Clark et al., 2020). For example, reading research consistently demonstrates that early language and code-based skills underpin later reading abilities (Muter et al, 2004; Storch & Whitehurst, 2002) and a strong understanding exists of how and when reading skills develop in young children (Grant et al., 2012; Lonigan et al., 2013). These insights have informed targeted language and literacy interventions, including explicit phonics instruction (Castles et al., 2018; West et al., 2021), as well as best practice models for classroom instruction to promote reading development (Dickinson & Porche, 2001). While similar research in early childhood mathematics is growing, efforts are still behind that of reading development (Dowker & Sigley, 2010; Litkowski et al., 2020). Further longitudinal research in mathematical development is vital in building the evidence base required to meaningfully inform educational policy and practice.

4.3. Limitations and Future Directions

The large-scale, longitudinal data available within the MCS dataset, affords mathematics and reading development to be examined over time within the same group of children. However, there are three important methodological limitations to consider in the current study, which can help guide future longitudinal research in mathematical development.

First, the correlation between symbolic knowledge (at age 2-4) and mathematics (at age 6-8), while significant, was relatively weak ($r = .26$). The same pattern of results was also observed between alphabetic knowledge (at age 2-4) and reading (at age 6-8; $r = .21$). The strength of these relationships may reflect that, although symbolic and alphabetic knowledge are key skills for mathematics and reading development, respectively (Ehri, 2005; Merkley & Ansari, 2016), they are not the only emergent skills involved. For mathematical development, there is a strong body of evidence highlighting the role of spatial and executive function skills, including short-term and working memory, as well as mathematical language, processing speed, and motor skills (Cameron et al., 2016; Hawes et al., 2019; Gilligan et al., 2017; Purpura et al., 2019; Mulder et al., 2010). Mathematical development is also affected by other non-cognitive factors, such as mathematics anxiety (Maloney et al., 2015). Many of these domain-general cognitive factors (Chu et al., 2016; Pitchford et al., 2016), as well as phonological awareness, fluency, and comprehension (Grant et al., 2012) underpin reading development. Assessments of these other vital factors, at time points consistent with the current study, are not available within the MCS dataset.

Second, there is the possibility that the comparisons between mathematics and reading attainment from different assessment batteries, which have been standardised with different sample populations at different times, poses a risk to the internal validity of the current findings.

In the current study, the NFER Mathematics assessment was standardised in 2004, whereas the BAS-II Word Reading assessment was standardised in 1996. As such, the large, standardised difference effect size between mathematics and reading attainment at age 6-8 years (d = .88), may be inflated. This is because there has been more time for improvement in reading attainment scores (i.e., the Flynn effect) in the additional eight years since the BAS-II Word Reading standardisation point compared to the NFER mathematics assessment (Wasserman & Bracken, 2003). While this is an important caveat to consider, the current evidence fits the pattern of standardised difference effect sizes observed in previous research (from d = .45 to .58; Pitchford et al., 2016), which also used standardised measures of mathematics and reading from the same assessment battery in both age groups; Wechsler Individual Achievement Test-Second Edition (WIAT-II; Wechsler, 2005). Furthermore, a positive, significant, but modest correlation is observed in the current study between the NFER Mathematics assessment and the BAS-II Word Reading assessment (r = .53). The strength of this correlation was also consistent with the relationship observed between the Number and Letter sub-scales from the same BSRA-R test battery (r = .50).

Third, there are risks that differential regression towards the mean (Jerrim & Vignoles, 2012) caused by differences in measurement error in the assessment of emergent mathematics and reading skills, could affect interpretation of the relative mobility rates between mathematics and reading over time. Consequently, caution should be taken not to over-interpret the absolute mobility rates. However, the possibility of this phenomenon in the current study would not be consistent with the overall finding of both more upward mobility in reading and more downward mobility in mathematics, even if it could be exaggerating the former and attenuating the latter.

Overall, mathematical development requires the complex acquisition of different component skills and is underpinned by several domain-specific and domain-general cognitive skills (Geary, 2004; LeFevre et al., 2010). To enhance our scientific understanding of mathematical development, more detailed and consistent measurements in longitudinal studies are required. In general, the cognitive skills and processes involved in mathematical development are not well represented in other UK based large-scale, longitudinal datasets, including the British Cohort Study and the Avon Longitudinal Study of Parents and Children. Research, across a broad range of methodologies that can address the methodological flaws of the current study, are much needed to enhance the evidence base within mathematical development. This will support the design, evaluation, and implementation of effective mathematical interventions and help address underachievement in mathematics (Litkowski et al., 2020).

4.4. Conclusion

In conclusion, this study shows the difference between mathematics and reading attainment emerges during childhood, with reading attainment exceeding that of mathematics, following the introduction of formal schooling. This may be attributed, in part, to the greater focus on reading compared to mathematics in educational polices, classroom practices, and the home learning environment. This may have lasting impacts on mathematics attainment relative to reading into adulthood (National Numeracy, 2019). To close this attainment gap and ensure children have these foundational skills for life, mathematics needs to receive greater attention in educational research, policy, and practice.

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Appendix 1. Demographic details of the excluded sample compared to the included sample (unweighted).

Demographic Measure	**Included**		**Excluded**	
	Unweighted (*n* = 11,749)		**Unweighted (*n* = 5,276)**	
	Total *n*	**Total %**	**Total *n***	**Total %**
Gender (Wave 2 & 4)				
Male	5,880	50.0	2,803	53.1
Female	5,869	50.0	2,473	46.9
OECD equivalised household income quintiles (Wave 4 only)				
Lowest	2,160	18.4	725	13.7
Second	2,333	19.9	552	10.5
Third	2,419	20.6	404	7.7
Fourth	2,415	20.6	323	6.1
Highest	2,409	20.5	244	4.6
Missing	13	.1	3,028	42.6
Ethnicity group (Wave 2 & 4)				
White	10,297	87.6	3,790	71.8
Mixed	95	.8	67	1.3
Indian	282	2.4	151	2.9
Pakistani & Bangladeshi	594	5.1	515	9.8
Black or Black British	323	2.7	262	5.0
Other Ethnic group	156	1.3	124	2.4
Missing	2	.0	367	7.0