Title: Preterm birth and adult wealth: mathematics skills count

Running head: preterm birth, academic abilities and adult wealth

Authors' names and affiliations:

Maartje Basten, PhD, Department of Psychology, University of Warwick, UK

Julia Jaekel, PhD, Department of Psychology, University of Warwick, UK, and Department of Developmental Psychology, Ruhr-University Bochum, Germany

Samantha Johnson, PhD, Department of Health Sciences, University of Leicester, UK

Camilla Gilmore, PhD, Mathematics Education Centre, Loughborough University, UK

Dieter Wolke, PhD Dr rer. nat. h.c., Department of Psychology and Warwick Medical School, University of Warwick, UK

Corresponding author:

Dieter Wolke

Department of Psychology

University of Warwick

Coventry, CV4 7AL

United Kingdom

Email: D.Wolke@warwick.ac.uk

Tel: +44 (0)24 7657 3217

ABSTRACT

Each year, 15 million babies are born preterm worldwide. Preterm birth is associated with adverse neurodevelopmental outcomes across the lifespan. Recent registry-based studies suggest that preterm birth is associated with lower wealth in adulthood, but the mediating mechanisms are unknown. This study investigated whether the relationship between preterm birth and low adult wealth is mediated by poor academic abilities and educational qualifications. Participants were members of two British population-based birth cohorts born in 1958 and 1970. Results showed that preterm birth was associated with decreased wealth at 42 years of age. This association was mediated by poorer intelligence, reading and, in particular, mathematics attainment in middle childhood, and lower educational qualifications in young adulthood. Findings were similar in both cohorts, suggesting that these mechanisms may be time invariant. Special educational support in childhood may prevent preterm children from becoming less wealthy as adults.

Keywords: Preterm birth, wealth, mathematics, reading, intelligence, adulthood outcomes

INTRODUCTION

Worldwide, 11% of infants are born preterm (<37 weeks gestation), which amounts to around 15 million births per year (Blencowe et al., 2012; Goldenberg, Culhane, Iams, & Romero, 2008). Rates of preterm birth are increasing globally with an increase of 7.2% to 8.6% from 1990 to 2010 in developed countries alone (Blencowe et al., 2012). Preterm birth is a syndrome resulting from multiple causes (Goldenberg et al., 2008) and is associated with widespread brain alterations (Volpe, 2009). Prematurity is associated with adverse developmental and psychological outcomes across the lifespan (Johnson & Wolke, 2013; Moster, Lie, & Markestad, 2008; Saigal, 2014). Recent registry-based studies have documented decreased wealth in adulthood following preterm birth (Heinonen et al., 2013; Lindstrom, Winbladh, Haglund, & Hjern, 2007; Moster et al., 2008). On average, preterm born adults have lower job-related incomes and are more likely to receive social security benefits at age 20-36 years than term-born adults (Moster et al., 2008). These negative outcomes do not only apply to high risk groups such as very preterm individuals (<32 weeks gestation) but have also been found for adults born moderately (32-33 weeks gestation) and late preterm (34-36 weeks gestation; Heinonen et al., 2013; Lindstrom et al., 2007), who compromise up to 84% of all preterm births (Shapiro-Mendoza & Lackritz, 2012). These registry-based studies have important strengths, including unbiased measures and the use of large, unselected samples. However, they do not provide information on potential mechanisms leading to decreased wealth in adulthood that could aid the development of intervention strategies.

Mediators that may explain decreased wealth in preterm adults include poor academic abilities. Preterm birth is associated with low intelligence (Jaekel, Baumann, & Wolke, 2013; Kerr-Wilson, Mackay, Smith, & Pell, 2012) and learning difficulties in several domains including reading and spelling (Poulsen et al., 2013; Schneider, Wolke, Schlagmuller, & Meyer, 2004). Problems with mathematics have been found to be especially common in preterm children (Simms et al., 2014) and are associated with global cognitive deficits (Jaekel & Wolke, 2014; Simms et al., 2014). Academic difficulties in preterm children have a cascading effect on low educational success in adolescence (Schneider et al., 2004) and adulthood (Nomura et al., 2009). As such, lower educational qualifications in preterm children may result in decreased wealth in adulthood through lower-skilled occupations and lower salaries.

Understanding the mechanisms that explain decreased wealth in adulthood following preterm birth requires follow-up studies over decades. However, findings from longitudinal studies may be outdated by the time they are reported given ongoing advances in antenatal and neonatal care. Therefore, it is important to study individuals born at different times to test whether the mechanisms leading to decreased wealth are consistent over time. Identifying time-invariant predictors would have two advantages: Firstly, recent cohorts could be followed-up in relation to important childhood markers of later outcomes. Secondly, findings may help to develop interventions to improve long-term outcomes for children born preterm today.

This study examined the relationship between preterm birth and wealth in adulthood in two large population-based UK birth cohorts born in 1958 and 1970. The mediating roles of mathematics, reading and intelligence in childhood and educational qualifications in young adulthood were tested.

METHOD

Participants

Participants were members of the National Child Development Study (NCDS), born in 1958, and the British Cohort Study (BCS), born in 1970. Both longitudinal studies recruited all children born in one week in England, Scotland, and Wales and participants have been followed up in several waves through to adulthood. In the current study, we included all individuals who were born between 28 and 42 weeks gestational age and who had information on wealth at age 42 years. For the NCDS, of the 17,415 children recruited in 1958, 13,063 were born between 28 and 42 weeks gestation and 8,573 (66%) of these had information on wealth at 42 years. For the BCS, 16,568 children were recruited in 1970, 11,535 were born between 28 and 42 weeks gestation and 6,698 (58%) had information on wealth at 42 years. Data files are available from University of London, Institute of Education, Centre for Longitudinal Studies (2008-2014; 2013-2014). Baseline characteristics for both cohorts are provided in Table 1.

Table 1 Sample characteristics for NCDS (N=8,573) and BCS (N=6,698) cohorts

	NCDS cohort				BCS cohort			
	Preterm 28-36 wks	Early term 37-38 wks	Full term 39-41 wks	p-value*	Preterm 28-36 wks	Early term 37-38 wks	Full term 39-41 wks	p-value*
Characteristic	n=403 (4.7%)	n=1,406 (16.4%)	n=6,764 (78.9%)		n=320 (4.8%)	n=1,046 (15.6%)	n=5,332 (79.6%)	
Sex, % male	50.1%	52.6%	49.0%	.048	49.4%	51.5%	47.0%	.025
Multiple birth, % twins	13.2%	5.5%	1.3%	< .001	15.0%	4.7%	0.8%	< .001
Birth weight, g, mean (SD)	2,630 (619)	3,101 (492)	3,399 (468)	< .001	2,570 (655)	3,077 (466)	3,401 (457)	< .001
Gestational age, mean (SD)	35.2 (1.7)	38.2 (.5)	40.4 (.8)	< .001	35.2 (1.7)	38.2 (.5)	40.4 (.8)	< .001
Parity, % first child	42.9%	35.7%	37.2%	.030	38.2%	37.1%	39.1%	.499
Maternal age at birth, mean (SD)	27.2 (6.0)	28.2 (5.9)	27.6 (5.5)	< .001	26.4 (5.9)	26.9 (5.7)	26.1 (5.1)	< .001
Maternal smoking during pregnancy, %	40.1%	35.0%	31.8%	< .001	45.5%	40.3%	41.9%	.257
Maternal diabetes, %	1.4%	0%	.1%	< .001	2.2%	1.0%	0.5%	< .001
Antenatal care, % < 2 antenatal visits	2.5%	.4%	.4%	< .001	4.0%	1.3%	0.4%	< .001
Maternal BMI before pregnancy %**				.203				
< 18.5	3.3%	3.3%	2.3%		-	-	-	
> 30	3.9%	4.0%	3.9%		-	-	-	

Parental education beyond minimum school leaving age, %	28.3%	33.6%	38.5%	< .001	43.9%	48.8%	51.9%	.006
Paternal social class %				.030				.003
V unskilled	11.2%	9.3%	7.7%		5.8%	4.6%	4.4%	
IV partly skilled	12.4%	12.7%	11.9%		17.6%	15.7%	13.6%	
III skilled manual	53.6%	50.0%	49.7%		49.4%	46.4%	44.0%	
III skilled non-manual	7.6%	9.8%	10.5%		11.9%	13.9%	16.3%	
II managerial-technical	11.7%	13.5%	15.2%		12.8%	13.1%	15.1%	
I professional	3.6%	4.7%	5.1%		2.6%	6.2%	6.6%	

* Preterm, early term and full term participants were compared on baseline characteristics using analysis of variance (ANOVA) for continuous variables and χ^2 tests for categorical variables.

** Maternal BMI before pregnancy was not available for the BCS cohort.

Measures

The measures described below were used in both the NCDS and BCS cohorts unless stated otherwise. For the mathematics, reading, and intelligence variables, a more detailed description is available in Supplementary Tables S1-S3, available online.

Gestational age at birth

Gestational age was calculated based on maternal reports of the last menstrual period. We categorised gestational age into three groups: Preterm (<37 weeks), early term (37-38 weeks) and full term (39-41 weeks).

Wealth outcomes at age 42 years

A latent wealth variable was developed based on five indicators assessed during home interviews: (1) family income, (2) family social class, (3) housing tenure, (4) employment status, and (5) self-perceived financial situation. (1) Family income was assessed differently across cohorts. For the NCDS it was calculated according to Goodman, Joyce, and Smith (2011) and included participants' and partners' net income from employed work as well as other types of income, such as social benefits. Family income was log transformed and adjusted by marital status ('married or living together' or 'single'). BCS participants were asked to report on their total family income based on 18 income categories, with separate questions for couples and singles. Scores were standardized and variables were combined into one family income variable. (2) Family social class was based on the highest social class of participant and their partner and was measured by the Registrar General's Social Classes occupational classification (RGSC) scored on a 6-point scale: 1 = 'Class V, unskilled manual', 2 = 'Class IV, semi-skilled manual or non-manual', 3 = 'Class IIIM, skilled manual', 4 = 'Class IIIN, skilled non-manual', 5 = 'Class II, managerial/technical', 6 = 'Class I, professional'. (3) Housing tenure was categorized as 'rent', 'owned with mortgage', and 'owned outright'. (4) Employment status was defined as 'unemployed and looking for a job' versus 'employed or self-employed'. Participants out of labour market for other reasons were excluded. (5) Self-perceived financial situation was reported on a 5-point scale ranging from 1 'finding it very difficult' to 5 'living comfortably'.

Mathematics

For the NCDS a latent mathematics variable was constructed from four measures: (1) the Problem Arithmetic Test (Pringle, Butler, & Davie, 1966; Shepherd, 2012) at age 7, (2) teachers' ratings of participants' number work at age 7, (3) the Arithmetic/Mathematics Test (Shepherd, 2012) at age 11, and (4) teachers' ratings of participants' number work at age 11. A latent mathematics variable in the BCS was constructed from three measures at age 10 years: (1) the Friendly Maths Test (Parsons, 2014), (2) whether participants received or were in need of extra support for mathematics according to their teachers, and (3) mothers' ratings of participants' difficulties in mathematics.

Reading

In the NCDS, a latent reading variable was based on five measures: (1) the Southgate Group Reading Test (Shepherd, 2012; Southgate, 1962) completed at age 7, (2) teachers' ratings of participants' reading abilities at age 7, (3) the basic reading level of books the participants were able to read at age 7 reported by the teacher, (4) the Reading Comprehension Test (Shepherd, 2012) at age 11 and (5) teachers' ratings of participants' reading abilities at age 11. The latent reading variable in the BCS was constructed from three measures at age 10 years: (1) a shortened version of the Edinburgh Reading Test (Godfrey Thompson Unit, 1978; Parsons, 2014), (2) whether participants received or were in need of extra support for reading according to their teachers, and (3) mothers' ratings of participants' difficulties in reading.

Intelligence

In the NCDS cohort a latent intelligence variable was estimated based on a general ability test (Pigeon, 1964; Shepherd, 2012) administered at age 11, which included (1) a verbal and (2) a nonverbal component. In the BCS cohort, a latent intelligence variable was estimated from four subtests of the British Ability Scales (Elliott, Murray, & Pearson, 1978; Parsons, 2014): (1) word definitions, (2) word similarities, (3) recall of digits and (4) matrices.

Educational qualifications

At 33 years in the NCDS cohort and at 34 years in the BCS cohort, participants were asked about their highest academic or vocational qualifications. Responses were coded according to the 6-point scale of the National Vocational Qualifications (NVQ) levels ranging from ‘no education’ to ‘higher degree level’. Missing values were replaced by educational qualifications assessed at 42 years.

Covariates

The following variables were considered as potential confounders based on previous studies (Jefferis, Power, & Hertzman, 2002; Yang, Bergvall, Cnattingius, & Kramer, 2010): sex, multiple birth status, birth weight standardised per week of gestation and sex (according to Jefferis et al. (2002) and categorised into five groups: ‘< -2SD’, ‘-2 to -1 SD’, ‘-1 to +1 SD’, ‘+1 to +2 SD’, ‘> +2 SD’), maternal smoking during pregnancy, maternal diabetes, lack of antenatal care (defined as 1 or no antenatal visits), high (>30) or low (<18.5) maternal BMI before pregnancy (only available in NCDS), maternal age at birth, parity, parental education (defined as whether either the mother or the father stayed in school beyond minimum school leaving age) and paternal social class (measured by the RGSC, with categories identical to those used for participants’ social class at 42 years). In case of missing values of social class at birth, report of social class of the father or the mother at school-age was used.

Data-analysis

To examine the effects of gestational age on wealth and the mediating role of childhood mathematics, reading, intelligence and later educational qualifications, structural equation modelling was performed in Mplus version 7.3. The same procedure was followed for the NCDS and BCS cohorts. We used a robust weighted least squares procedure with adjusted means and variance estimation (WLSMV; (Flora & Curran, 2004). First, latent variables of wealth, mathematics, reading and intelligence were estimated. Covariance between observed variables of mathematics, reading and intelligence that were assessed at the same time point or by the same respondent was taken into account. We examined the associations between gestational age and wealth, mathematics, reading, intelligence and educational qualifications using linear regression analyses. Gestational age groups were dummy coded with the full term group as the reference. We tested whether associations remained after adjustment for all covariates. Next, we examined the direct effect of gestational age on wealth and indirect effects via childhood mathematics, reading, intelligence and later educational qualifications in a path model. All pathways were adjusted for all covariates. Covariance among mathematics, reading and intelligence was taken into account. Model fit was based on the Root Mean Square Error of Approximation

(RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI; Hu & Bentler, 1999). For the RMSEA, values of .05 or lower indicate close fit. For CFI and TLI, values greater than .90 indicate acceptable fit. The strength of the pathways were indicated using standardized regression coefficients (betas). Coefficients less than .10 indicate a small effect, values around .30 indicate a typical or medium effect and values round .50 indicate large effects (Kline, 2005). Indirect effects were estimated by calculating the product of path coefficients and significance of indirect effects was tested using 1,000 bootstrap samples (Preacher & Hayes, 2008).
Percentages of missing data for the various mathematics, reading and intelligence assessments ranged between 8.6-13.4% for NCDS and 12.0-21.3% for BCS. For covariates missing data were all < 5%. In both cohorts, we imputed missing values in Mplus using the Markov Chain Monte Carlo technique and we generated 20 imputed data sets. The imputation model included all variables that were used for further analyses. Analyses were performed separately on each completed dataset and thereafter combined into pooled estimates.

Non-response analysis

We compared baseline characteristics of participants included in analyses with those excluded because of missing data at 42 years. For the NCDS, included participants (n=8,573) did not differ from excluded participants (n=4,490) in prevalence of preterm birth (4.7% vs. 5.3%, χ^2 =2.18, df = 1, p =140) and birth weight (mean difference 9g, F(1, 12,629) = 0.78, p > .250). Included participants were more likely than excluded participants to have parents that stayed at school beyond minimum school leaving age (37.3% vs. 32.9%, χ^2 = 24.10, df = 1, p < .001) and to come from a family with higher social class (managerial or professional 19.6% vs. 17.3%, χ^2 = 40.71, df = 5, p < .001).

In the BCS, included participants (n=6,698), compared with excluded participants (n=4,837), were less likely to be born preterm (4.8% vs. 6.1%, χ^2 = 10.30, df = 1, p = .001), but there was no difference in birth weight (mean difference 14g, F(1, 11,523) = 2.01, p = 0.156). Included participants were more likely to have parents that stayed at school beyond minimum school leaving age (51.0% vs. 44.7%, χ^2 = 44.85, df = 1, p < .001) and were more likely to come from a family with higher social class.

RESULTS

Prematurity and Wealth

Associations between gestational age and adulthood wealth, childhood mathematics, reading and intelligence and adulthood educational qualifications are shown in Table 2. Standardized regression coefficients (betas) are shown, which indicate the differences in mean score in standard deviation units between the preterm and early term born individuals and the full term born individuals. In both cohorts, preterm birth was associated with lower wealth at 42 years, lower mathematics, reading and intelligence at 7-11 years, and lower educational qualifications at 33-34 years (range β's = -.19 to -.45, all p's < .01). These associations remained after adjustment for covariates. Early term birth was not associated with lower wealth but, in the NCDS cohort, early term birth was associated with lower reading (adjusted β = -.09, p = .004) and intelligence (adjusted β = -.07 p = .031). Correlations between wealth, mathematics, reading, intelligence and educational qualifications are shown in Supplementary Table S4, available online.

Table 2 Gestational age groups and their unadjusted and adjusted associations with adulthood wealth, childhood mathematics, reading and intelligence and adulthood educational qualifications in NCDS (N=8,573) and BCS (N=6,698) cohorts

		Wealth		Mathematics		Reading		Intelligence		Educational qualifications	
		β	95%CI	β	95%CI	β	95%CI	β	95%CI	β	95%CI
NCDS cohort											
Preterm	Unadjusted	-.31***	-.43 -.19	-.41***	-.52; -.30	-.45***	-.57; -.34	-.38***	-.49; -.27	-.23***	-.33; -.13
	Adjusted[a]	-.23***	-.35; -.12	-.31***	-.42; -.20	-.34***	-.45; -.24	-.30***	-.40; -.20	-.16***	-.24; -.07
Early term	Unadjusted	-.03	-.10; .03	-.10**	-.16; -.04	-.15***	-.21; -.08	-.11**	-.17; -.04	-.06*	-.12; -.01
	Adjusted[a]	.00	-.07; .06	-.06	-.12; .00	-.09**	-.14; -.03	-.07*	-.13; -.01	-.03	-.08; .02
Full term (reference)		-		-		-		-		-	
BCS cohort											
Preterm	Unadjusted	-.24**	-.37; -.10	-.43***	-.58; -.28	-.32***	-.47; -.18	-.37***	-.52;-.22	-.19**	-.31; -.08
	Adjusted[a]	-.16*	-.29; -.02	-.34***	-.49; -.19	-.24**	-.38; -.09	-.27***	-.41; -.13	-.11*	-.22; .00
Early term	Unadjusted	-.05	-.13; .03	-.02	-.10; .07	-.06	-.14; .02	-.05	-.12; .03	-.02	-.09; .04
	Adjusted[a]	-.04	-.11; .04	.00	-.08; .09	-.03	-.11; .06	-.03	-.10; .04	-.01	-.07; .05
Full term (reference)		-		-		-		-		-	

Note: * p<.05, ** p<.01 *** p<.001

[a]Adjusted for sex, multiple birth, birth weight standardised per week of gestation and sex, maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, high and low maternal BMI before pregnancy (for NCDS only), maternal age at birth, parity, parental education beyond minimum school leaving age and paternal social class.

The differences in wealth between preterm and full term adults were as follows: in the NCDS, 32.5% (preterm) vs. 25.1% (full term) were manual workers (social class 'III skilled manual' or lower), 3.3% vs. 2.5% were unemployed, 22.3% vs. 15.5% did not own a house, 34.5% vs. 28.5% had self-reported financial difficulties, and 57.6% vs. 49.1% had below average family income. In the BCS, 26.3% (preterm) vs. 20.9% (full term) were manual workers, 4.4% vs. 2.4% were unemployed, 22.8% vs. 22.3% did not own a house, 34.7% vs. 29.8% had self-reported financial difficulties, and 55.3% vs. 47.1% had below average family income.

Mediating Role of mathematics, reading, intelligence and educational qualifications

We examined the mediating role of mathematics, reading, and intelligence in childhood, and later educational qualifications in the pathway from preterm birth to adult wealth while adjusting for possible confounders. The NCDS model is presented in Fig. 1 and the BCS model in Fig. 2. Standardized path coefficients are shown. Covariates, non-significant paths ($p > .05$), and residual variances are not presented to enhance readability. The NCDS model (Fig. 1) fit the data well (RMSEA = .032, CFI = .96, TLI = .94). Preterm birth was negatively associated with mathematics ($\beta = -.31$, $p < .001$), reading ($\beta = -.34$, $p < .001$) and intelligence ($\beta = -.30$, $p < .001$) at ages 7-11 years. Subsequently, mathematics ($\beta = .14$, $p = .004$), reading ($\beta = .33$, $p < .001$) and intelligence ($\beta = .09$, $p = .001$) predicted educational qualifications at 33 years which predicted wealth at 42 years ($\beta = .34$, $p < .001$). Additionally, there was a direct effect of mathematics on wealth ($\beta = .27$, $p < .001$).

The model for the BCS cohort (Fig. 2) also fit the data well (RMSEA = .035, CFI = .94, TLI = .92). Again, preterm birth was negatively associated with mathematics ($\beta = -.34$, $p < .001$), reading ($\beta = -.24$, $p = .001$) and intelligence ($\beta = -.27$, $p < .001$) at age 10 years. Subsequently, mathematics ($\beta = .20$, $p < .001$) and intelligence ($\beta = .19$, $p < .001$) were associated with educational qualifications at age 34 years, but reading was not. Educational qualifications ($\beta = .28$, $p < .001$), as well as mathematics ($\beta = .28$, $p < .001$) and intelligence ($\beta = .13$, $p < .001$) predicted wealth at age 42 years.

Table 3 shows the direct, total indirect, and specific indirect effects of preterm birth on adult wealth at age 42 years. In both cohorts there was a significant total indirect effect of preterm birth on wealth (NCDS: $\beta = -.14$, $p < .001$; BCS: $\beta = -.15$, $p <.001$) which were the result of several small specific pathways. For NCDS, specific pathways were via mathematics (β = -.08, $p = .001$), via mathematics and educational qualifications (β = -.01, $p = .019$), via reading and educational qualifications (β = -.04, $p < .001$), and via intelligence and educational qualifications (β = -.01, $p = .009$). For the BCS cohort, specific indirect effects were again via mathematics (β = -.10, $p <.001$), via mathematics and educational qualifications (β = -.02, $p <.001$), via intelligence (β = -.03, $p =.012$), and via intelligence and educational qualifications (β = -.01, $p = .002$).

Fig. 1 Mathematics, reading, intelligence, and educational qualifications as mediators of the relation between preterm birth and wealth in adulthood in the NCDS cohort (N=8,573).

Note: Preterm birth and early term birth are each compared to full term. Significant standardised coefficients are shown. Correlations between school-age latent factors were: mathematics - intelligence .84, mathematics - reading .92 and intelligence - reading .82. All pathways were adjusted for sex, multiple birth, birth weight standardised per week of gestation and sex, maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, high and low maternal BMI before pregnancy, maternal age at birth, parity, parental education beyond minimum school leaving age and paternal social class. The most important covariates were parental education (direct: $\beta = .11$, $p < .001$; indirect: $\beta = .27$, $p < .001$) and paternal social class (direct: $\beta = .07$, $p < .001$; indirect: $\beta = .13$, $p < .001$). Explained variance in wealth (R^2) was 38%.

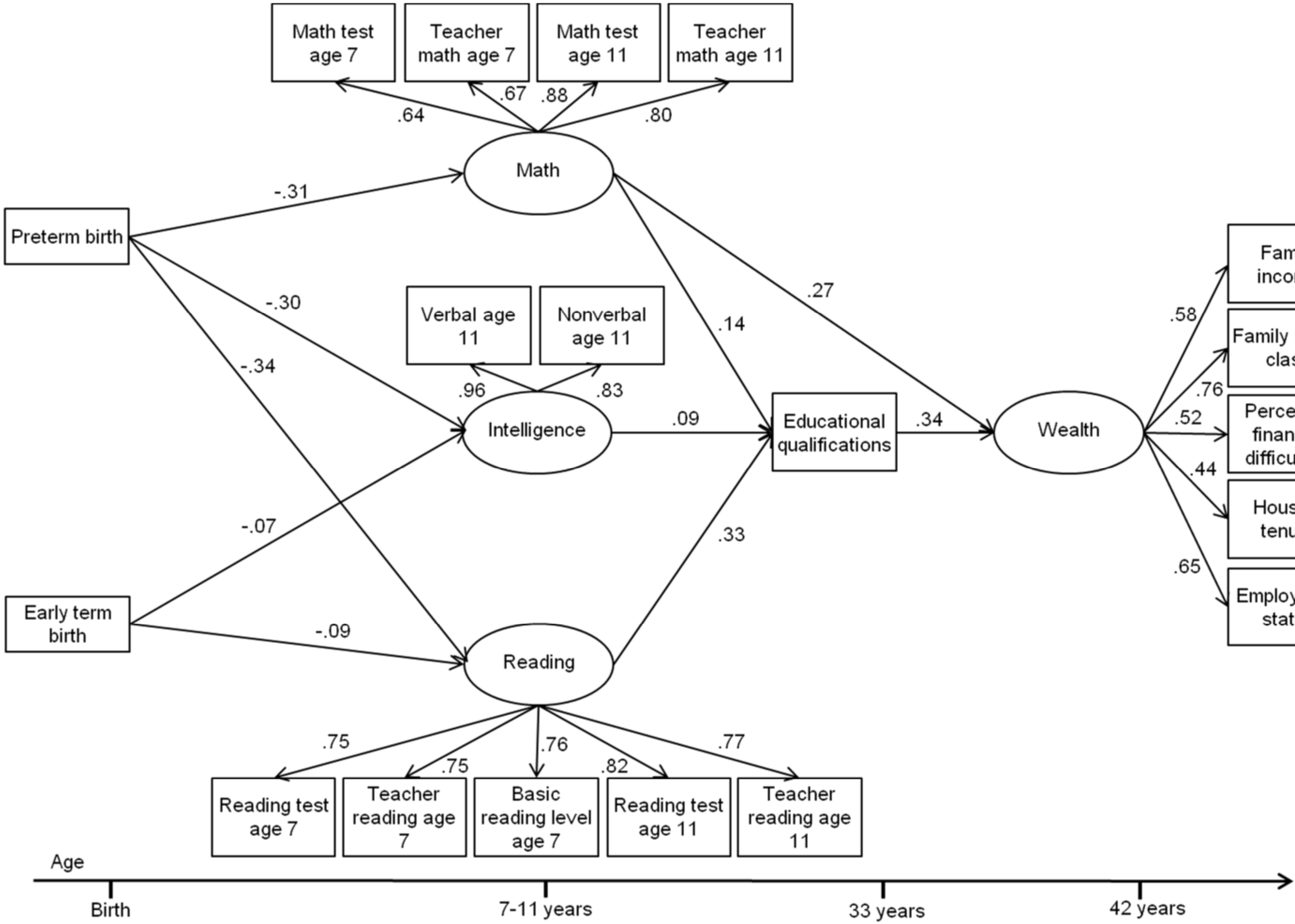
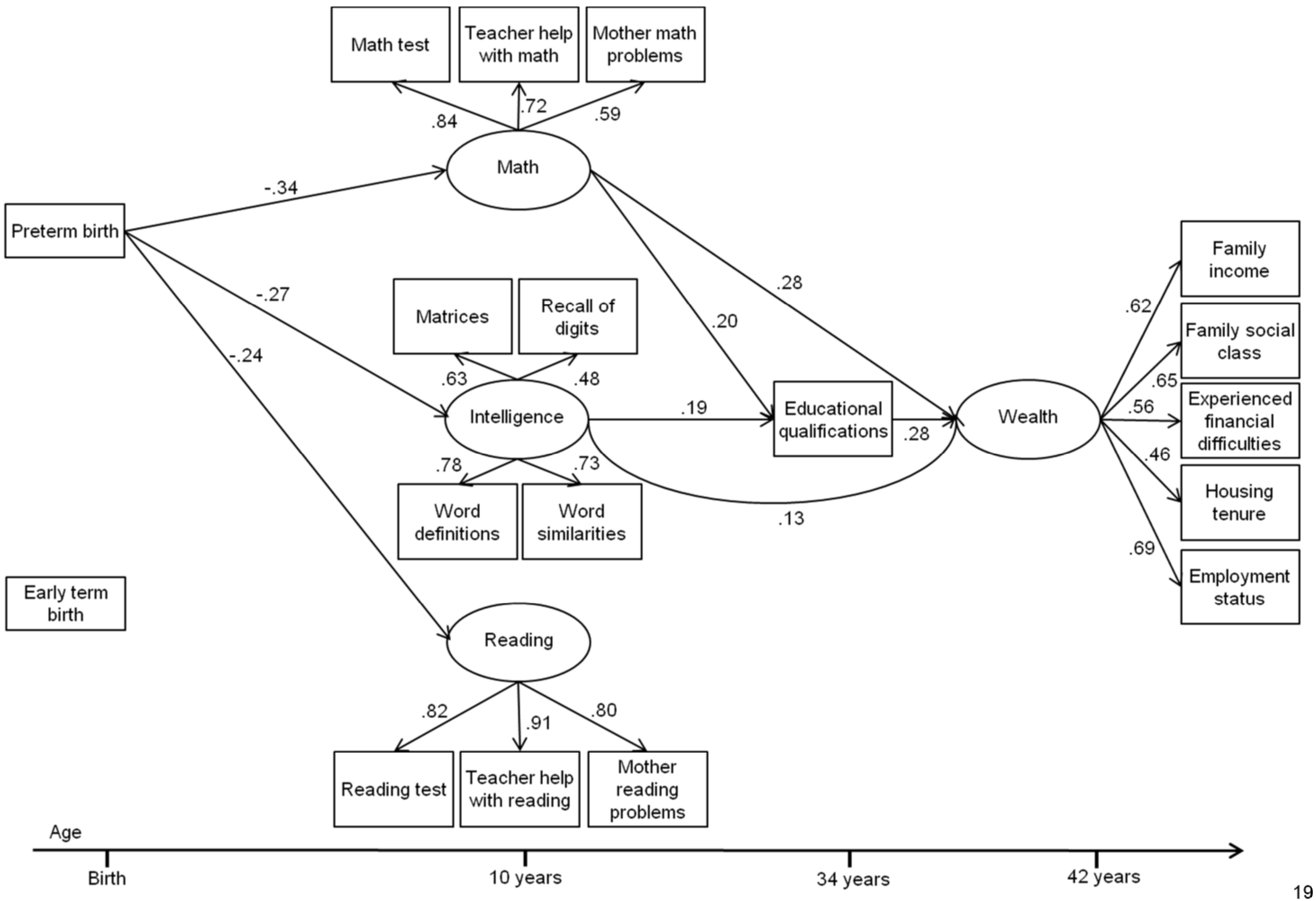

Math test age 7
Teacher math age 7
Math test age 11
Teacher math age 11
.64
.67
.88
.80
Math
-.31
Preterm birth
-.30
-.34
Verbal age 11
Nonverbal age 11
.96
.83
Intelligence
.09
.14
.27
Educational qualifications
.34
Wealth
.58
.76
.52
.44
.65
Family income
Family social class
Perceived financial difficulties
Housing tenure
Employment status
-.07
Early term birth
-.09
Reading
.33
.75
.75
.76
.82
.77
Reading test age 7
Teacher reading age 7
Basic reading level age 7
Reading test age 11
Teacher reading age 11
Age
Birth
7-11 years
33 years
42 years

Fig. 2 Mathematics, reading, intelligence, and educational qualifications as mediators of the relation between preterm birth and wealth in adulthood in the BCS cohort (N=6,698).

Note: Preterm birth and early term birth are each compared to full term. Significant standardised coefficients are shown. Correlations between school-age latent factors were: mathematics - intelligence .70, mathematics - reading .78 and intelligence - reading .71. All pathways were adjusted for sex, multiple birth, birth weight standardised per week of gestation and sex, maternal smoking during pregnancy, maternal diabetes, lack of antenatal care, maternal age at birth, parity, parental education beyond minimum school leaving age and paternal social class. The most important covariates were parental education (direct: $\beta = .09$, $p = .003$; indirect: $\beta = .25$, $p < .001$) and paternal social class (direct: $\beta = .07$, $p < .001$; indirect: $\beta = .12$, $p < .001$). Explained variance in wealth (R^2) was 35%.



Math test
Teacher help with math
Mother math problems
.84
.72
.59
Math
-.34
Preterm birth
-.27
-.24
Matrices
Recall of digits
.63
.48
Intelligence
.19
.20
.28
Educational qualifications
.28
Wealth
.13
.78
.73
Word definitions
Word similarities
Early term birth
Reading
.82
.91
.80
Reading test
Teacher help with reading
Mother reading problems
Family income
Family social class
Experienced financial difficulties
Housing tenure
Employment status
.62
.65
.56
.46
.69
Age
Birth
10 years
34 years
42 years

Table 3 Direct, indirect and total effects of preterm birth on wealth at 42 years of age for NCDS cohort (N=8,573) and BCS cohort (N=6,698)

	Wealth age 42 years			
	NCDS cohort		BCS cohort	
Preterm birth	β	*p*	β	*p*
Total effect	-.23	<.001	-.16	.039
Total direct effect	-.09	.099	-.01	>.250
Total indirect effect	-.14	<.001	-.15	<.001
via mathematics	-.08	.001	-.10	<.001
via reading	-.02	>.250	.02	.206
via intelligence	.01	.231	-.03	.012
via mathematics and educational qualifications	-.01	.019	-.02	<.001
via reading and educational qualifications	-.04	<.001	.00	>.250
via intelligence and educational qualifications	-.01	.009	-.01	.002

DISCUSSION

This study examined the associations between preterm birth and wealth at 42 years of age in two large population-based cohorts, and tested the mediating roles of mathematics, reading and intelligence in childhood as well as educational qualifications in adulthood. As a group, preterm children had lower mathematics and reading achievement and lower intelligence in primary school compared with term-born peers. These decreased academic abilities predicted decreased educational qualifications and subsequent lower wealth in adulthood. Notably, mathematics achievement in primary school was also directly associated with wealth in adulthood independent of later educational qualifications. The indirect effects of preterm birth on adult wealth were found despite controlling for the well-known effects of socio-economic status at birth and were replicated in both the 1958 and 1970 birth cohorts.

The findings that individuals born preterm are at risk for decreased wealth in adulthood are consistent with previous Scandinavian registry-based studies on outcomes such as income, occupational attainment, and receipt of social security benefits (Heinonen et al., 2013; Lindstrom et al., 2007; Moster et al., 2008). Similar to these studies, effect sizes are small but should be interpreted in light of the 42 year time span. This study provides new evidence of a developmental cascade in which decreased academic abilities following preterm birth lead to lower educational qualifications, which subsequently decrease wealth in adulthood. A similar developmental cascade from decreased mathematics and reading achievement to shorter full-time education and lower socio-economic attainment has been described in the general population (Ritchie & Bates, 2013). Brain injury in preterm children, which includes a combination of destructive and developmental disturbances (Volpe, 2009), is likely to result in cognitive deficits which may impact on the development of learning difficulties and subsequently puts these children at risk of following this pathway of underachievement.

Notably, we found for both cohorts a medium direct effect of mathematics achievement in childhood on adult wealth, independent of later educational qualifications (see also Ritchie & Bates, 2013). This may be explained by findings of recent studies, showing that preterm born individuals are at risk to continue to have decreased cognitive functioning in multiple domains in adulthood (Eryigit Madzwamuse, Baumann, Jaekel, Bartmann, & Wolke, 2014; Pyhala et al., 2011). Preterm individuals may be employed in lower status jobs based on their educational qualifications, but their lower mathematical skills and problems in dealing with increased memory workload (Jaekel et al., 2013) may make them less successful in their work. This may result in a lower job-related income, as has been found previously by Moster et al. (2008), and decreased chances of achieving promotion. In addition, numerical ability is important for financial judgements and decision making which in turn have been linked to wealth outcomes (Banks & Oldfield, 2007; Peters et al., 2006). Numerical ability has, for example, been related to mortgage default (Gerardi, Goette, & Meier, 2013). Preterm born individuals who have difficulties in mathematics may thus be less able to manage their personal finances adequately.

The importance of mathematics achievement compared to reading for adult economic outcomes has been previously reported in the NCDS and BCS cohorts by Parsons and Bynner (2005). The authors suggest that basic mathematical skills have become more important in modern jobs. However, apart from mathematics, reading and intelligence may also play a significant role in the pathway from preterm birth to decreased wealth in adulthood. Preterm birth had comparable negative effects on mathematics, reading and intelligence, reflecting that these children have global aberrant neurodevelopment leading to deficits in multiple general cognitive domains. The smaller and less consistently found paths of reading and intelligence to educational qualifications and wealth in our study should be interpreted carefully since mediators were highly correlated and the effects of reading and intelligence on educational qualifications and wealth may therefore have been over adjusted in our models.

In the NCDS cohort we found that individuals born early term, that is at 37 or 38 weeks of gestation, were not at risk for decreased wealth in adulthood, but showed decreased academic abilities, while this relation was not found in the BCS cohort 12 years later. Improvements in medical care or in the educational system over the years may have resulted in better outcomes among early term born individuals. However, findings regarding early term birth and learning abilities in more recent cohorts are mixed (MacKay, Smith, Dobbie, & Pell, 2010; Poulsen et al., 2013; Yang et al., 2010). Clarification is needed, since early term birth compromises around 30% of all births (Ananth, Friedman, & Gyamfi-Bannerman, 2013) and may account for a substantial proportion of children experiencing difficulties in school (MacKay et al., 2010).

To predict the long term outcomes of children born preterm today we need to rely on data from earlier cohorts. Similar findings for individuals born in 1958 and in 1970 suggest that the mechanisms from preterm birth to reduced adult wealth may be consistent over time. If these mechanisms are time invariant they may also affect children born preterm today. Even though neonatal care has improved enormously over the years, more recent datasets such as the Millennium Cohort Study including children born in 2000-2002 still show that preterm children are at risk for decreased cognitive functioning (Poulsen et al., 2013). A meta-analysis on the relation between preterm birth and intelligence also found no change in effects across cohorts (Kerr-Wilson et al., 2012). In 1958 and 1970 the prevalence of very preterm birth was however substantially lower than today, with only a very small number of individuals being born before 32 weeks of gestation (0.2-0.3% in our study samples). The increasing number of preterm births and the higher survival of extremely preterm children born as early as 23 or 24 weeks, who have the highest risk for cognitive problems, has led to more children being at risk for decreased academic abilities in the community (Blencowe et al., 2012). Our findings suggest that cognitive deficits experienced by preterm children born today may have negative effects on their future wealth, affecting both individual success and societal productivity.

Our study has important strengths, including the use of two large population-based studies and the long term follow-up over 42 years. Also, we used achievement tests as well as teacher and parent reports of children’s mathematics and reading skills, and we included multiple indicators of wealth. There are also limitations. Even though response was very high given the long follow-up period, a positive selection occurred towards individuals born at term and with higher socio-economic family background. While selective dropout reduces statistical power, it may have little biasing influence on estimates in regressions in prospective studies (Wolke et al., 2009). Second, our studies were performed in the United Kingdom. Findings need replication in other countries. Third, gestational age was based on mother report of last menstrual period. Misclassification of gestational age may have led to an underestimation of prematurity effects. Finally, we adjusted our analyses for a wide range of confounders, including several indicators of socio economic background, prenatal lifestyle and maternal health. We were not able to adjust for other possible confounders such as alcohol and drug exposure during pregnancy. Therefore residual confounding cannot be excluded.

In conclusion, this study showed that decreased academic abilities in preterm children have long-lasting consequences on their educational qualifications and their attained wealth in adulthood. Decision makers should be aware that the economic costs of preterm birth are not limited to costs for neonatal intensive and ongoing health care and educational support in childhood (Petrou, Sach, & Davidson, 2001), but extend into adulthood. Recent cohorts could be studied in relation to these early predictors in childhood as markers of the cascade to later wealth. Extra educational support that aims to improve children's mathematics and reading skills may prevent these children from becoming less wealthy than their term born peers and reduce the economic and societal costs of preterm birth. We recently found that there is a large gap in knowledge about the long-term effects of preterm birth among school teachers and educational psychologists compared with neonatal clinicians in the UK (Johnson, Gilmore, Gallimore, Jaekel, & Wolke, 2015). Communicating information about the learning needs of preterm children to educational professionals may be an important way towards improving the life chances of the growing population of children born preterm.

AUTHOR CONTRIBUTIONS

All authors contributed to the study concept. M. Basten performed the data analysis and interpretation under the supervision of J. Jaekel and D. Wolke. M. Basten drafted the manuscript and J. Jaekel, D. Wolke, S. Johnson and C. Gilmore provided critical revisions. All authors approved the final version of the manuscript for submission.

ACKNOWLEDGEMENTS

We are grateful to the Centre for Longitudinal Studies (CLS), Institute of Education, University of London and UK Data Archive for the use of these data. This study was funded by the Nuffield Foundation (Grant number: EDU/40442).

REFERENCES

Ananth, C. V., Friedman, A. M., & Gyamfi-Bannerman, C. (2013). Epidemiology of moderate preterm, late preterm and early term delivery. *Clinics in Perinatology, 40*, 601-610. doi: 10.1016/j.clp.2013.07.001

Banks, J., & Oldfield, Z. (2007). Understanding pensions: Cognitive function, numerical ability and retirement saving. *Fiscal Studies, 28*, 143-170. doi:10.1111/j.1475-5890.2007.00052.x

Blencowe, H., Cousens, S., Oestergaard, M. Z., Chou, D., Moller, A. B., Narwal, R., . . . Lawn, J. E. (2012). National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet, 379*, 2162-2172. doi: 10.1016/S0140-6736(12)60820-4

Elliott, C., Murray, D., & Pearson, L. (1978). *British ability scales*. Windsor: National Foundation for Educational Research.

Eryigit Madzwamuse, S., Baumann, N., Jaekel, J., Bartmann, P., & Wolke, D. (2014). Neuro-cognitive performance of very preterm or very low birth weight adults at 26 years. *Journal of Child Psychology and Psychiatry and Allied Disciplines*. Advance online publication. doi: 10.1111/jcpp.12358

Flora, D. B., & Curran, P. J. (2004). An empirical evaluation of alternative methods of estimation for confirmatory factor analysis with ordinal data. *Psychological Methods, 9*, 466-491. doi: 10.1037/1082-989X.9.4.466

Gerardi, K., Goette, L., & Meier, S. (2013). Numerical ability predicts mortgage default. *Proceedings of the National Academy of Sciences of the United States of America, 110*, 11267-11271. doi: 10.1073/pnas.1220568110

Godfrey Thompson Unit, U. o. E. (1978). *Edinburgh Reading Test*. Sevenoaks, UK: Hodder and Stoughton.

Goldenberg, R. L., Culhane, J. F., Iams, J. D., & Romero, R. (2008). Epidemiology and causes of preterm birth. *Lancet, 371*, 75-84. doi: 10.1016/S0140-6736(08)60074-4

Goodman, A., Joyce, R., & Smith, J. P. (2011). The long shadow cast by childhood physical and mental problems on adult life. *Proceedings of the National Academy of Sciences of the United States of America, 108*, 6032-6037. doi: 10.1073/pnas.1016970108

Heinonen, K., Eriksson, J. G., Kajantie, E., Pesonen, A. K., Barker, D. J., Osmond, C., & Raikkonen, K. (2013). Late-preterm birth and lifetime socioeconomic attainments: the Helsinki birth cohort study. *Pediatrics, 132*, 647-655. doi: 10.1542/peds.2013-0951

Hu, L. t., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*, 1-55. doi: 10.1080/10705519909540118

Jaekel, J., Baumann, N., & Wolke, D. (2013). Effects of Gestational Age at Birth on Cognitive Performance: A Function of Cognitive Workload Demands. *PloS One, 8*. doi: 10.1371/journal.pone.0065219

Jaekel, J., & Wolke, D. (2014). Preterm Birth and Dyscalculia. *Journal of Pediatrics, 164*, 1327-1332. doi: 10.1016/j.jpeds.2014.01.069

Jefferis, B. J., Power, C., & Hertzman, C. (2002). Birth weight, childhood socioeconomic environment, and cognitive development in the 1958 British birth cohort study. *BMJ, 325*, 305.

Johnson, S., Gilmore, C., Gallimore, I., Jaekel, J., & Wolke, D. (2015). The long term consequences of preterm birth: What do teachers know? *Developmental Medicine and Child Neurology*. Advance online publication doi: 10.1111/dmcn.12683

Johnson, S., & Wolke, D. (2013). Behavioural outcomes and psychopathology during adolescence. *Early Human Development, 89*, 199-207. doi: 10.1016/j.earlhumdev.2013.01.014

Kerr-Wilson, C. O., Mackay, D. F., Smith, G. C., & Pell, J. P. (2012). Meta-analysis of the association between preterm delivery and intelligence. *Journal of Public Health, 34*, 209-216. doi: 10.1093/pubmed/fdr024

Kline, R. B. (2005). *Principles and practice of structural equation modeling* (second ed.). New York: The Guilford Press.

Lindstrom, K., Winbladh, B., Haglund, B., & Hjern, A. (2007). Preterm infants as young adults: a Swedish national cohort study. *Pediatrics, 120*, 70-77. doi: 10.1542/peds.2006-3260

MacKay, D. F., Smith, G. C., Dobbie, R., & Pell, J. P. (2010). Gestational age at delivery and special educational need: retrospective cohort study of 407,503 schoolchildren. *PLoS Medicine, 7*, e1000289. doi: 10.1371/journal.pmed.1000289

Moster, D., Lie, R. T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *New England Journal of Medicine, 359*, 262-273. doi: 10.1056/NEJMoa0706475

Nomura, Y., Halperin, J. M., Newcorn, J. H., Davey, C., Fifer, W. P., Savitz, D. A., & Brooks-Gunn, J. (2009). The risk for impaired learning-related abilities in childhood and educational attainment among adults born near-term. *Journal of Pediatric Psychology, 34*, 406-418. doi: 10.1093/jpepsy/jsn092

Parsons, S. (2014). *Childhood cognition in the 1970 British Cohort Study.* London: Centre for Longitudinal Studies, Institute of Education, University of London.

Parsons, S., & Bynner, J. (2005). *Does numeracy matter more?* London: National Research and Development Centre for Adult Literacy and Numeracy.

Peters, E., Vastfjall, D., Slovic, P., Mertz, C. K., Mazzocco, K., & Dickert, S. (2006). Numeracy and decision making. *Psychological Science, 17,* 407-413. doi: 10.1111/j.1467-9280.2006.01720.x

Petrou, S., Sach, T., & Davidson, L. (2001). The long-term costs of preterm birth and low birth weight: results of a systematic review. *Child Care Health and Development, 27*, 97-115. doi: 10.1046/j.1365-2214.2001.00203.x

Pigeon, D. A. (1964). Details of the fifteen years test. Appendix 1. In J. W. B. Douglas (Ed.), *The Home and the School*. London: MacGibbon and Kee.

Poulsen, G., Wolke, D., Kurinczuk, J. J., Boyle, E. M., Field, D., Alfirevic, Z., & Quigley, M. A. (2013). Gestational Age and Cognitive Ability in Early Childhood: a Population-based Cohort Study. *Paediatric and Perinatal Epidemiology, 27*, 371-379. doi: 10.1111/ppe.12058

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods, 40*(3), 879-891.

Pringle, M. K., Butler, N., & Davie, R. (1966). *11,000 Seven Year Olds.* London: Longman.

Pyhala, R., Lahti, J., Heinonen, K., Pesonen, A. K., Strang-Karlsson, S., Hovi, P., . . . Raikkonen, K. (2011). Neurocognitive abilities in young adults with very low birth weight. *Neurology, 77*, 2052-2060. doi: 10.1212/WNL.0b013e31823b473e

Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science, 24*, 1301-1308. doi: 10.1177/0956797612466268

Saigal, S. (2014). Functional outcomes of very premature infants into adulthood. *Seminars in Fetal & Neonatal Medicine, 19*, 125-130. doi: 10.1016/j.siny.2013.11.001

Schneider, W., Wolke, D., Schlagmuller, M., & Meyer, R. (2004). Pathways to school achievement in very preterm and full term children. *European Journal of Psychology of Education, 19*, 385-406.

Shapiro-Mendoza, C. K., & Lackritz, E. M. (2012). Epidemiology of late and moderate preterm birth. *Seminars in Fetal & Neonatal Medicine, 17*, 120-125. doi: 10.1016/j.siny.2012.01.007

Shepherd, P. (2012). *1958 National Child Development Study user guide: Measures of ability at ages 7 to 16.* London: Centre for Longitudinal Studies, Institute of Education, University of London.

Simms, V., Gilmore, C., Cragg, L., Clayton, S., Marlow, N., & Johnson, S. (2014). The nature and origins of mathematics difficulties in very preterm children: A different etiology than Developmental Dyscalculia. *Pediatric Research*. Advance online publication. doi: 10.1038/pr.2014.184

Southgate, V. (1962). *Southgate Group Reading Tests: Manual of instructions*. London: University of London Press.

University of London. Institute of Education. Centre for Longitudinal Studies, *1970 British Cohort Study: Birth and 22-Month Subsample 1970-1972, Ten-Year Follow-Up 1980, Thirty-Four-Year Follow-Up 2004-2005*, *Forty-Two-Year Follow-Up 2012* [computer files] 2013-2014. Colchester, Essex: UK Data Archive [distributor], 2012-2014. SNs: 2666, 3723, 5585, 7473.

University of London. Institute of Education. Centre for Longitudinal Studies, *National Child Development Study: Childhood Data Sweeps 0-3 1958-1974, Sweep 5 1991, Sweep 6 1999-2000* [computer files]. Colchester, Essex: UK Data Archive [distributor], 2008-2014. SNs: 5565, 5567, 5578.

Volpe, J. J. (2009). Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *Lancet Neurology, 8*(1), 110-124. doi: 10.1016/S1474-4422(08)70294-1

Wolke, D., Waylen, A., Samara, M., Steer, C., Goodman, R., Ford, T., & Lamberts, K. (2009). Selective drop-out in longitudinal studies and non-biased prediction of behaviour disorders. *British Journal of Psychiatry, 195*, 249-256. doi: 10.1192/bjp.bp.108.053751

Yang, S., Bergvall, N., Cnattingius, S., & Kramer, M. S. (2010). Gestational age differences in health and development among young Swedish men born at term. *International Journal of Epidemiology, 39*, 1240-1249. doi: 10.1093/ije/dyq070

Supplementary Table S1: Description of indicators used for the estimation of a latent mathematics variable in the NCDS and BCS cohorts

Cohort	Measure	Age	Description
NCDS	Problem Arithmetic Test (Pringle, Butler, & Davie, 1966; Shepherd, 2012)	7	- Arithmetic test including 10 items - Administered by teachers
	Teacher rating I	7	- Teachers rated the number work of the child in relation to all children of this age on a 5-point scale, from 1 'extremely good facility with number and/or mathematical concepts' to 5 'little, if any, ability in this sphere'; reverse coded for analyses
	Arithmetic/Mathematics Test (Shepherd, 2012)	11	- Arithmetic test compromising 40 items involving numerical and geometric work - Developed by the National Foundation for Educational Research in England and Wales (NFER) - Reliability coefficient = 0.94 - Administered by teachers
	Teacher rating II	11	- Teachers rated the number work of the child in relation to all children of this age on a 5-point scale, from 1 'extremely good facility with number and with mathematical concepts' to 5 'little, if any, ability in this sphere'; reverse coded for analyses
BCS	Friendly Maths Test (Parsons, 2014)	10	- Multiple choice test including 72 items that covered arithmetic, number skills, fractions, algebra, geometry and statistics - Developed specifically for use in the BCS cohort - Administered by teachers
	Extra educational support	10	- Teachers were asked 1) whether the child received remedial group work or other type of help inside the school for mathematics, and 2) whether this child would benefit from special educational help - A dichotomous variable was created with participants divided in those who did not receive and did not need any support versus those who received or would benefit from special educational help in mathematics
	Mother report	10	- Mothers were asked whether their child had difficulty at school with mathematics by choosing from 3 answer categories: 'No difficulty', 'Some difficulty', 'Great difficulty'; reverse coded for analyses

Supplementary Table S2: Description of indicators used for the estimation of a latent reading variable in the NCDS and BCS cohorts

Cohort	Measure	Age	Description
NCDS	Southgate Group Reading Test (Shepherd, 2012; Southgate, 1962)	7	- Test of word recognition and comprehension including 30 items - Particularly suited to identifying problems with reading in young children - Administered by teachers
	Teacher rating I	7	- Teachers rated the reading ability of the child in relation to all children of this age on a 5-point scale, from 1 'avid reader: reads fluently and widely in relation to his age' to 5 'non-reader, or recognizes very few words'; reverse coded for analyses
	Basic reading level	7	- Teachers reported on the present reading standard of the child on a six point scale: 1 'beyond basic reading scheme, 2 'at present on Book 4', 3 'at present on Book 3', 4 'at present on Book 2', 5 'at present on Book 1 or introductory book' and 6 'on pre-reading activities only'; reverse coded for analyses
	Reading comprehension test (Shepherd, 2012)	11	- Test of reading comprehension, including 35 items - Developed by the National Foundation for Educational Research in England and Wales (NFER) - Reliability coefficient = 0.82 - Administered by teachers
	Teacher rating II	11	- Teachers were asked to rate the use of books of the child in relation to all children of this age on a 5-point scale, from 1 'exceptional, reads very widely for pleasure and information', to 5 'very poor or non-reader because of poor skill' - reverse coded for analyses
BCS	Shortened Edinburgh Reading Test (Godfrey Thompson Unit, 1978; Parsons, 2014)	10	- A word recognition test examining vocabulary, syntax, sequencing, comprehension and retention - A shortened version appropriate for 10-year olds was created including 67 questions (Parsons, 2014) - Administered by teachers
	Extra educational support	10	- Teachers were asked 1) whether the child received remedial group work or other type of help inside the school for reading, and 2) whether this child would benefit from special educational help - A dichotomous variable was created with participants divided in those who did not receive and did not need any support versus those who received or would benefit from special educational help in reading.
	Mother report	10	- Mothers were asked whether their child had difficulty at school with reading by choosing from 3 answer categories: 'No difficulty', 'Some difficulty', 'Great difficulty'; reverse coded for analyses

Supplementary Table S3: Description of indicators used for the estimation of a latent intelligence variable in the NCDS and BCS cohorts

Cohort	Measure	Age	Description
NCDS	General Ability Test (Pigeon, 1964; Shepherd, 2012)	11	- Mental ability test, consisting of a verbal and a nonverbal component of each 40 items - Reliability coefficient = 0.94 - Administered by teachers
BCS	British Ability Scales (Elliott, Murray, & Pearson, 1978; Parsons, 2014)	10	- Four sub-scales: Word Definitions (37 items), Word Similarities (21 items), Recall of Digits (34 items) and Matrices (28 items) - Administered by teachers

Supplementary Table S4: Correlations among the latent variables of Mathematics, Reading, Intelligence and Wealth, and the observed variable educational qualifications for NCDS cohort (above the diagonal) and BCS cohort (*cursive*, below the diagonal).

	Mathematics	Reading	Intelligence	Educational qualifications	Wealth
Mathematics	-	.92	.86	.58	.52
Reading	*.78*	-	.86	.59	.51
Intelligence	*.74*	*.74*	-	.55	.47
Educational Qualifications	*.42*	*.39*	*.44*	-	.55
Wealth	*.49*	*.41*	*.47*	*.47*	-

Note: Unadjusted Pearson's correlation coefficients are presented. All correlations were significant at p<.001. Correlations are based on N=8,573 for the NCDS cohort and N=6,698 for the BCS cohort.

References Supplementary Tables 1-3

Elliott, C., Murray, D., & Pearson, L. (1978). *British ability scales*. Windsor: National Foundation for Educational Research.

Godfrey Thompson Unit, U. o. E. (1978). *Edinburgh Reading Test*. Sevenoaks, UK: Hodder and Stoughton.

Parsons, S. (2014). *Childhood cognition in the 1970 British Cohort Study.* London: Centre for Longitudinal Studies, Institute of Education, University of London.

Pigeon, D. A. (1964). Details of the fifteen years test. Appendix 1. In J. W. B. Douglas (Ed.), *The Home and the School*. London: MacGibbon and Kee.

Pringle, M. K., Butler, N., & Davie, R. (1966). *11,000 Seven Year Olds.* London: Longman.

Shepherd, P. (2012). *1958 National Child Development Study user guide: Measures of ability at ages 7 to 16*. London: Centre for Longitudinal Studies, Institute of Education, University of London.

Southgate, V. (1962). *Southgate Group Reading Tests: Manual of instructions*. London: University of London Press.