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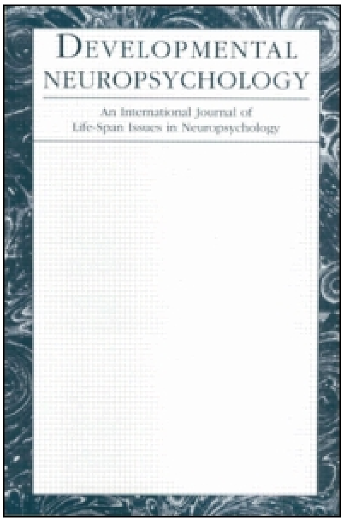

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Educational Outcomes in Extremely Preterm Children: Neuropsychological Correlates and Predictors of Attainment

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Educational Outcomes in Extremely Preterm Children: Neuropsychological Correlates and Predictors of Attainment

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This study assessed the impact of extremely preterm birth on academic attainment at 11 years of age, investigated neuropsychological antecedents of attainment in reading and mathematics, and examined early predictors of educational outcomes. Children born extremely preterm had significantly poorer academic attainment and a higher prevalence of learning difficulties than their term peers. General cognitive ability and specific deficits in visuospatial skills or phoneme deletion at 6 years were predictive of mathematics and reading attainment at 11 years in both extremely preterm and term children. Phonological processing, attention, and executive functions at 6 years were also associated with academic attainment in children born extremely preterm. Furthermore, social factors, neonatal factors (necrotizing enterocolitis, breech delivery, abnormal cerebral ultrasound, early breast milk provision), and developmental factors at 30 months (head circumference, cognitive development), were independent predictors of educational outcomes at 11 years. Neonatal complications combined with assessments of early cognitive function provide moderate prediction for educational outcomes in children born extremely preterm.

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The increase in survival rates for infants born extremely preterm (EP; <26 weeks gestational age) is associated with a burgeoning interest in long term outcomes for these survivors. The most recent population based studies of children born EP or with extremely low birthweight (ELBW) have reported up to 50% prevalence of neurodevelopmental disability throughout childhood (Farooqi, Hagglof, Sedin, Gothefors, & Serenius, 2006; Hack et al., 2005; Johnson, Fawke, et al., 2009; Marlow, Wolke, Bracewell, & Samara, 2005; Mikkola et al., 2005). While cerebral palsy and sensory impairments such as blindness and deafness continue to pose a threat, their prevalence is far exceeded by the high risk of cognitive sequelae in this population. Studies consistently report marked differences in IQ between children born EP/ELBW and their term peers (Anderson & Doyle, 2003; Hack et al., 2005; Marlow et al., 2005; Saigal et al., 2003) and up to 40% of survivors have cognitive impairment at school age (Anderson & Doyle, 2003; Farooqi et al., 2006; Marlow et al., 2005; Taylor, Klein, Minich, & Hack, 2000). The gestational age (GA) related gradient in outcome is very evident in the cognitive domain (Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Johnson, 2007) with studies showing an average decline of 2.5 IQ points for each weekly decrease in GA < 33 weeks (Marlow, 2005; Wolke, Schulz, & Meyer, 2001).

In addition to global cognitive deficits, children born EP are at increased risk for a range of more specific neurobehavioral sequelae (Aylward, 2002, 2005). Studies of school-age survivors have highlighted a significant excess of mild neuromotor dysfunction (Davis, Ford, Anderson, & Doyle, 2007; Fawke, 2007; Goyen & Lui, 2009; Wocadlo & Rieger, 2008), poor visuospatial processing (Marlow, Hennessy, Bracewell, & Wolke, 2007; Taylor, Burant, Holding, Klein, & Hack, 2002; Taylor, Klein, Minich, et al., 2000), and impairments in attention and executive functions (Aarnoudse-Moens, Smidts, Oosterlan, Duivenvoorden, & Weisglas-Kuperus, 2009; Anderson & Doyle, 2004; B. Bohm, Smedler, & Forssberg, 2004; Marlow et al., 2007; Mulder, Pitchford, Hagger, & Marlow, 2009). These deficits contribute additional morbidity in this population, with differences between EP/ELBW and term children remaining significant after adjustment for IQ (Aarnoudse-Moens, Smidts, et al., 2009; Anderson & Doyle, 2004; Marlow et al., 2007; Taylor, Klein, Minich, et al., 2000). Behavioral and psychiatric morbidity, particularly attention deficit hyperactivity disorder (ADHD) symptoms and social and emotional problems, are also common in EP/ELBW survivors (Bhutta et al., 2002; Farooqi, Hagglof, Sedin, Gothefors, & Serenius, 2007; Hack et al., 2009; Hille et al., 2001; Johnson et al., 2010; Samara, Marlow, & Wolke, 2008). It is thus not surprising that EP birth has an adverse effect on later educational attainment.

A GA-related gradient has also been observed in educational outcomes and children born EP/ELBW are more susceptible to scholastic underachievement than their more mature preterm counterparts (Klebanov, Brooks-Gunn, & McCormick, 1994; Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000; Schneider, Wolke, Schlagmuller, & Meyer, 2004). In the EP/ELBW population, the marked deficits observed in standardized reading and mathematics scores (Anderson & Doyle, 2003; Klebanov et al., 1994; Saigal et al., 2000; Schneider et al., 2004; Stjernqvist & Svenningsen, 1999; Taylor, Klein, Minich, et al., 2000) are mirrored in teacher reports of academic progress (Bowen, Gibson, & Hand, 2002; Wolke, Samara, Bracewell, & Marlow, 2008) and increased rates of specific learning difficulties for EP/ELBW children without neurocognitive disability (Bowen et al., 2002; Grunau, Whitfield, & Davis, 2002; Litt, Taylor, Klein, & Hack, 2005; Taylor, Klein, Minich, et al., 2000). The utilization of special educational needs (SEN) services is an important index of functional deficit and many studies have reported an increased prevalence of special school placement and SEN provision in this population (Bowen et al., 2002; Buck, Msall, Schisterman, Lyon, & Rogers, 2000; Hack et al., 2005; Saigal et al., 2000; Wocadlo

& Rieger, 2006). Difficulties in mathematics are particularly common with the majority of studies reporting a more pronounced deficit in this domain compared with other domains such as reading (Anderson & Doyle, 2003; Klebanov et al., 1994; Schneider et al., 2004; Taylor, Klein, Minich, et al., 2000). Further, in contrast to reading, significant effects of EP/ELBW birth persist in mathematics after adjustment for IQ (Anderson & Doyle, 2003; Botting, Powls, Cooke, & Marlow, 1998; Klebanov et al., 1994; Taylor et al., 2002; Taylor, Klein, Minich, et al., 2000) and are prevalent among children born EP with average IQ (Litt et al., 2005).

Academic attainment has been associated with attention and executive functions (Assel, Landry, Swank, Smith, & Steelman, 2003; Bull, Espy, & Wiebe, 2008; Bull & Scerif, 2001; Marlow et al., 2007; St Clair-Thompson & Gathercole, 2006), visuospatial skills (Assel et al., 2003; Rickards, Kelly, Doyle, & Callanan, 2001; Son & Meisels, 2006), and other motor abilities (Marlow et al., 2007; Sullivan & McGrath, 2003) in both term and preterm born children. The excess morbidity conferred by EP birth in these domains may underlie the specific learning difficulties observed in this population. Structural equation models have shown that neuropsychological skills mediate the relationship between preterm birth and academic attainment (Taylor et al., 2002), and therefore correlates of academic attainment may differ between EP and term children. An understanding of the causal pathways and origins of poor academic performance would provide valuable information for the development of population-specific interventions for children born EP (Taylor, Espy, & Anderson, 2009).

The identification of risk factors for adverse outcomes is ubiquitous in clinical research and the sphere of education is no exception. SEN provision can be notoriously expensive and improved survival rates at extremely low gestations (Costeloe, Hennessy, Myles, & Draper, 2008) will result in an increase in the number of EP children entering the education system in the coming years. Early identification and targeted intervention for those at risk is crucial in supporting the long term needs of these children. Previous investigations have identified a range of biological, medical, and socioeconomic risk factors for global cognitive impairment in EP children (Botting et al., 1998; Isaacs, Edmonds, Lucas, & Gadian, 2001; Levy-Shiff, Einat, Mogilner, Lerman, & Krikler, 1994; Peterson, Taylor, Minich, Klein, & Hack, 2006; Sullivan & McGrath, 2003; Taylor, Klein, Schatschneider, & Hack, 1998), but predictors of poor educational outcome have not been investigated in this population.

The aims of the present study were threefold. First, we investigated educational outcomes at 11 years of age in children born EP compared with term-born classmates in order to quantify the effect of EP birth on school performance in middle childhood. Second, using outcome data obtained at 6 years of age, we investigated social and neuropsychological antecedents of attainment in reading and mathematics at 11 years and examined the relative impact of these antecedents between children born EP and at term. Finally, we examined neonatal variables and early neurodevelopmental outcomes at 30 months of age as predictors of attainment in reading and mathematics and the need for SEN provision in children born EP at 11 years of age.

METHOD

Participants

All infants born <26 weeks gestation and admitted for neonatal intensive care in the United Kingdom and Ireland from March through December 1995 ($N = 811$) were recruited to the

EPICure Study (Costeloe, Hennessy, Gibson, Marlow, & Wilkinson, 2000). Of 314 children who survived to discharge, 283 (90%) were assessed at 30 months of age corrected for prematurity. Of 308 survivors at 6 years, 241 (78%) were re-assessed at a median age of 6 years 4 months chronological age. Subsequently, 219 (71%) of 307 survivors were re-assessed at 11 years chronological age (Median age: 10 years 11 months). Characteristics of the study sample at each follow-up have been described previously (Johnson et al., 2009; Marlow et al., 2005; Wood, Marlow, Costeloe, Gibson, & Wilkinson, 2000) and are summarized in Table 1.

At 6 and 11 years, a comparison group of classmates was also assessed. At 6 years, for each EP child attending mainstream school, a child born at term was selected randomly from three classmates closest in age and of the same sex and ethnicity. Of those selected, a total of 160 classmates were provided with consent to participate (Marlow et al., 2005). At 11 years of age, 110 of these children were re-assessed. Where the EP child was at a different school to the original 6-year classmate, or the original classmate declined to participate, a new classmate was selected using the same methodology resulting in 43 new comparison children. A total of 153 comparison

TABLE 1
Characteristics of Extremely Preterm Children and Classmates Assessed at 30 Months, 6 Years, and 11 Years of Age

	Extremely Preterm			*Classmates*	
Characteristic	*Assessed at 30 Months (N = 283)*	*Assessed at 6 Years (N = 241)*	*Assessed at 11 Years (N = 219)*	*Assessed at 6 Years (N = 160)*	*Assessed at 11 Years (N = 153)*
Gestation, *n* (%)					
≤23 w	26 (9.2%)	24 (10.0%)	23 (10.5%)	N/A	N/A
24 w	90 (31.8%)	73 (30.3%)	70 (32.0%)	N/A	N/A
25 w	167 (59.0%)	144 (59.8%)	126 (57.5%)	N/A	N/A
Birthweight (g), median (IQR)	740 (660, 836)	748 (660, 840)	740 (660,840)	N/A	N/A
Male, *n* (%)	135 (47.7%)	122 (50.6%)	101 (46.1%)	71 (44.4%)	64 (41.8%)
White maternal ethnicity, *n* (%)	223 (78.8%)	189 (78.2%)	179 (82.1%)	131 (84.0%)	—
Mother's education, *n* (%)					
Up to 16 years of age	195 (74.1%)	168 (76.4%)	152 (76.0%)	—	97 (65.1%)
Post-16 years of age	68 (25.9%)	52 (23.6%)	48 (24.0%)	—	52 (34.9%)
SES at 30 m, *n* (%)					
Non-manual	84 (31.0%)	73 (32.2%)	68 (32.9%)	—	—
Manual	93 (34.3%)	82 (36.1%)	78 (37.7%)	—	—
Unemployed	94 (34.7%)	72 (31.7%)	61 (29.5%)	—	—
SES at 11 y, *n* (%)					
High	—	—	79 (43.9%)	—	77 (57.0%)
Medium	—	—	44 (24.4%)	—	21 (15.6%)
Low	—	—	57 (31.7%)	—	37 (27.4%)
Age at test, mean (*SD*)	33.7 m (0.95 m)	6.3 y (0.48 y)	10.9 y (0.38 y)	6.1 y (0.50 y)	10.9 y (0.55 y)

For extremely preterm (EP) children assessed at 11 years, perinatal data were available for 218 children. Mothers' highest educational qualification was obtained at 2.5 years for EP children and at 11 years for classmates. Maternal educational level for classmates at 6 years was not obtained. Highest parental socioeconomic status (SES) obtained at 30 months for EP children was categorized as non-manual, manual, or unemployed. At 11 years SES was classified using U.K. National Statistics Socio-Economic Classification (Office for National Statistics, 2005) and was categorized as high, medium, or low. IQR = Interquartile Range.

children were thus assessed at 11 years (Table 1). There were no significant differences in age or sex between EP and comparison children.

Detailed dropout analyses have previously been published (see Johnson, Fawke, et al., 2009). EP children lost to follow-up at 11 years were more likely to be of non-white ethnic origin, have had an operation for necrotizing enterocolitis (NEC), have unemployed parents and lower cognitive test scores at both 30 months and 6 years of age. Similarly, classmates lost to follow-up between 6 and 11 years had lower cognitive test scores at 6 years. Based on the previous mean differences in IQ scores between dropouts and children assessed, it is estimated that the mean absolute difference in cognitive test scores between EP children and classmates at 11 years would be reduced by only 0.5 standardized IQ points (Mean = 100, *SD* = 15) had there been no dropouts in either group after 6 years of age.

Procedure

Each follow-up was approved by the relevant NHS research ethics committees and parents provided informed consent for their child's participation. At 30 months, children were assessed in hospital by a pediatrician. At both 6 and 11 years, children were assessed at school by a pediatrician and psychologist blind to group allocation. Examiners received training in administration of standardized tests and achieved a high criterion of inter-rater reliability (>95% agreement across test items) prior to commencing study assessments.

11-Year Assessment

Academic attainment was assessed using the Wechsler Individual Achievement Test–II (WIAT–II^{UK})(Wechsler, 2004) from which standardized scores (Mean = 100, *SD* = 15) were obtained for Word Reading, Reading Comprehension, Pseudo-word Decoding, Numerical Operations, Mathematical Reasoning and the composite scales of Reading and Mathematics. For children in whom severe cognitive deficit precluded testing ($n = 18$), a score 1-point below the basal score for the Reading and Mathematics composite scales was substituted (score = 39). Composite scores were not substituted for children who failed to complete the test for other reasons (e.g., communication difficulties, behavior problems during testing). Learning impairment was classified as scores <2 *SD* below the mean of the comparison group of classmates on each scale (Reading <74; Mathematics <69) to account for the secular drift in test scores over time (Flynn, 1987, 1999; Johnson et al., 2008; Wolke, Ratschinski, Ohrt, & Riegel, 1994).

Classroom teachers of children in mainstream schools who followed a standard national curriculum completed the Teachers Academic Attainment Scale (TAAS) (Wolke, Rizzo, & Woods, 2002). The child's performance was rated in relation to the national average expected for the child's age. Each child's performance in seven classroom subjects was rated on a 5-point Likert scale with scores ranging from 1 (very below average) to 5 (very above average). Attainment was classified as below the expected range if the average TAAS score across all seven subjects was <2.5. Teachers also completed a questionnaire to elicit information detailing whether SEN provision was utilized by the child and, if so, what type of SEN services were utilized.

General cognitive ability was assessed using the Kaufman Assessment Battery for Children (KABC) (Kaufman & Kaufman, 1983) from which standardized scores (Mean = 100, *SD* = 15) were obtained for sequential and simultaneous information processing and for the Mental Processing Composite (MPC). A nominal MPC score (score = 39), 1-point below the basal test score was assigned for children who were unable to participate in testing due to severe cognitive impairment.

Parental socioeconomic status (SES) at 11 years of age was classified into three categories corresponding to high, medium and low (I—Professional/Managerial; II—Intermediate; III—Routine/Manual/Unemployed) using U.K. National Statistics (Office for National Statistics, 2005). Mother's highest educational qualification was dichotomized using education up to 16 years of age versus education beyond 16 (i.e., no/basic school education vs. further education).

Longitudinal Predictors of Educational Outcomes

Outcome data obtained at 6 years of age for both EP and term children were used to investigate neuropsychological antecedents of educational outcomes at 11 years. At 6 years, general cognitive ability was assessed using the KABC as described earlier. The Developmental Neuropsychological Assessment (NEPSY) (Korkman, Kirk, & Kemp, 1998) was used to assess neuropsychological abilities from which standardized domain scores (Mean = 100, *SD* = 15) were derived for visuospatial processing and sensorimotor skills and scaled scores (Mean = 10, *SD* = 3) for the subtests of Visual Attention (selective attention) and Tower (executive functions of planning, monitoring, and self-regulation). The Phonological Abilities Test (PAT) (Muter, Hulme, & Snowling, 1997) was used to screen for phonological processing deficits from which percentile scores (0, 10, 25, 50, 75) were derived for subtests assessing phoneme deletion (beginning and end sounds) and letter knowledge. The analysis of the relationship between 6-year antecedents and 11-year reading and mathematics scores was restricted to children with a measurable MPC score at 6 years (i.e., MPC >39) because of the very high predictive value of a substituted MPC score at this age. Those excluded from these analyses comprised 15 children with a substituted MPC at 6 years, irrespective of their reading and mathematics scores, and one further child with an MPC >39 but for whom reading and mathematics scores at 11 years were not obtained.

In EP children only, perinatal information and outcome data obtained at 30 months corrected age were used as early predictors of educational outcomes at 11 years. Information relating to maternal and infant characteristics, obstetric complications, birth, and neonatal course were collected at discharge from hospital (see Table 5 for a list of variables). At 30 months, cognitive and motor skills were assessed using the Mental Development Index (MDI) and the Psychomotor Development Index (PDI) of the Bayley Scales of Infant Development II (BSID–II) (Bayley, 1993). Scores < 2 *SD* below test norms (scores < 70) were used to classify developmental impairment as a local comparison group was not available. Hearing, vision and neuromotor impairment (none, other, severe) were also identified and occipitofrontal circumference (OFC) measured. Parental ratings of behavioral problems were obtained using the Child Behavior Checklist (CBCL) (Achenbach & Rescorla, 2000) from which borderline and clinically significant problems were identified for internalizing and externalizing behavior problems. For the purposes of assessing the effects of social and economic factors as predictors of outcome, SES according to parental employment was classified at 30 months into three categories (non-manual, manual, unemployed).

STATISTICAL ANALYSES

Data were double entered, verified, and analyzed using SPSS17 (SPSS Inc., 2008) and STATA10 (StataCorp, 2007). Group differences in standardized test scores were analyzed using independent *t*-tests. To compare group differences across outcomes, standardized effect sizes were calculated with Cohen's d using pooled variance with effect sizes of 0.2, 0.5, and 0.8 classified as small, medium, and large, respectively (Cohen, 1992). Rates of impairment were cross-tabulated and the risks of adverse outcomes are presented as odds ratios (OR) with 95% confidence intervals (95% CI). As adjustment for SES and maternal education reduced group differences by 1 MPC point or less for all comparisons, and there was more missing data for these variables than other predictors, the results presented are unadjusted unless otherwise stated. All p values are two sided. No adjustments were made for multiple comparisons. Multivariate stepwise linear regression was performed for the two groups combined in order to investigate the impact of social and neuropsychological variables assessed at 6 years on reading and mathematics scores at 11 years. The independent variables tested were MPC, NEPSY visuospatial processing, sensorimotor skills, visual attention and tower scores, PAT phoneme deletion, and letter knowledge percentiles at 6 years of age, and SES and highest maternal educational level obtained at 11 years along with their interaction terms with group. This was done in order to identify whether any of these variables had significantly different effects in EP children and classmates. As some of the interactions were significant and others had non-significant but sizeable effects, multivariate models were also produced separately for the EP and classmate groups for comparison. For EP children only, univariate and then multivariate linear regression were used to examine the associations among neonatal factors, outcomes at 30 months of age, and reading and mathematics scores at 11 years. Logistic regression was used to investigate the associations among neonatal factors, outcomes at 30 months of age and the need for SEN provision. Results are presented as unstandardized beta coefficients (95% CI) for reading and mathematics scores and as OR (95% CI) for SEN provision.

RESULTS

Educational Outcomes at 11 Years: Standardized Measures

EP children had significantly lower reading ($t = 10.0$, $p < .0001$) and mathematics ($t = 13.8$, $p < .0001$) scores than classmates. Effect sizes were large for all comparisons with the greatest effect for mathematics (Table 2). While there was no sex difference among classmates, EP boys had significantly lower reading scores than girls (7.00 points, 95% CI 1.45 to 12.56) but this difference was not significant for mathematics (4.40 points, 95% CI 1.28 to 10.08). The Group x Sex interaction was not significant for reading ($F(1,365) = 3.02$, $p = .083$) or mathematics ($F(1,365) = 2.17$, $p = .142$). After adjustment for MPC at 11 years, children in the EP group had significantly poorer attainment in mathematics (9.3 points, 95% CI 21.4 to 1.2, $p < .001$) but not in reading (1.8 points, 95% CI 4.7 to 1.1, $p = .215$). Exclusion of children with serious neurocognitive impairment reduced the group difference in reading to 7.7 points ($t = 5.0$, $p < .0001$) and in mathematics to 14.8 points ($t = 8.0$, $p < .0001$); the effect size for mathematics remained large ($d = 1.0$). EP children were more likely to have impairment in reading than classmates with

TABLE 2
Academic Attainment in Extremely Preterm Children (N = 219) and Classmates (N = 153) at 11 Years of Age

	Standardized Test Performance								Rates of Learning Impairment (Scores <−2 SD)				
	Classmates			Preterm					Classmates		Preterm		
Outcome Assessment	*n*	*Mean*	*(SD)*	*n*	*Mean*	*(SD)*	*Mean difference (95% CI)*	*Cohen's d*†	*n*	*(%)*	*n*	*(%)*	*OR (95% CI)*
							Full Cohort						
Reading composite	**153**	**98.5**	**(11.6)**	**212**	**80.2**	**(20.3)**	**−18 (−21 to −15)**	**1.1**	**3**	**(2.0%)**	**64**	**(30.2%)**	**21.6 (6.6 to 70.4)**
Word Reading	153	99.6	(12.1)	199	86.3	(17.3)	−13 (−16 to −10)	0.9					
Reading comprehension	153	100.6	(11.6)	195	85.9	(18.3)	−15 (−18 to −12)	1.0					
Pseudoword decoding	153	99.7	(11.3)	199	86.7	(15.6)	−13 (−16 to −10)	1.0					
Mathematics composite	**153**	**98.5**	**(15.0)**	**215**	**71.2**	**(20.9)**	**−27 (−31 to −24)**	**1.5**	**2**	**(1.3%)**	**94**	**(43.7%)**	**58.7 (14.2 to 242.9)**
Numerical operations	153	98.0	(15.5)	199	75.6	(18.4)	−22 (−26 to −19)	1.5					
Mathematical reasoning	153	99.7	(12.0)	198	78.2	(18.1)	−21 (−25 to −18)	1.3					
							*Excluding Children with Serious Neuro-Cognitive Impairment**						
Reading Composite	**151**	**98.7**	**(11.5)**	**119**	**91.0**	**(13.4)**	**−7.7 (−10 .7 to −4.7)**	**0.6**	**3**	**(2.0%)**	**12**	**(10.1%)**	**5.5 (1.5 to 20.1)**
Word Reading	151	99.8	(12.0)	120	93.9	(13.1)	−5.9 (−8.9 to −2.9)	0.5					
Reading comprehension	151	100.9	(11.5)	119	93.9	(14.1)	−7.0 (−10.2 to −3.9)	0.5					
Pseudoword decoding	151	99.8	(11.1)	120	92.3	(13.9)	−7.5 (−10.6 to −4.5)	0.6					
Mathematics Composite	**151**	**98.8**	**(14.8)**	**119**	**84.0**	**(15.6)**	**−14.8 (−18.5 to −11.1)**	**1.0**	**2**	**(1.3%)**	**20**	**(16.8%)**	**15.1 (3.4 to 65.8)**
Numerical operations	151	98.4	(15.2)	120	84.2	(16.2)	−14.2 (−18.0 to −10.4)	0.9					
Mathematical reasoning	151	99.9	(11.9)	118	87.7	(13.6)	−12.2 (−15.3 to −9.2)	1.0					

All scores are standardized scores (Mean 100, *SD* 15) obtained using the Wechsler Individual Achievement Test 2nd UK Edition (WIAT–II^{UK}). Composite scores were substituted with a nominal value 1-point below the basal test score (score = 39) for children unable to participate in testing due to severe cognitive impairment. Sub-scale scores were not substituted. Impairment was defined as scores <−2 *SD* using classmate Mean (*SD*) as reference data for each scale. *Children with serious composite functional disability defined as one or more serious impairment in the domain of hearing, vision, motor, and/or cognitive ability were excluded. This includes children with IQ scores <−2 *SD* using classmate reference ranges. †Cohen's d calculated using pooled variance.

an even greater risk for impairment in mathematics (odds ratio: 22 and 59, respectively). Rates of learning impairment remained significantly increased after excluding children with neurocognitive impairment (Table 2).

Educational Outcomes at 11 Years: Teacher-Based Assessment

Teachers rated EP children in mainstream schools with significantly lower attainment than classmates in all subjects assessed, with the greatest deficit in mathematics (Table 3). Overall, 49.7% of EP children had attainment below the national average range compared with 5.1% of classmates. Twenty-nine EP children (13%) were educated in special schools. Among the EP cohort, 62.3% were identified by teachers as having some degree of SEN and almost the same number had SEN severe enough to require special educational provision (OR 13, 95% CI 7 to 23). The prevalence of SEN remained significantly increased in EP children without neurocognitive impairment (42.7%). SEN provision has been described in detail previously (Johnson, Hennessy, et al., 2009).

TABLE 3
Teacher-Rated Academic Attainment and SEN Provision in Extremely Preterm Children and Classmates at 11 Years of Age

	Classmates			*Preterm*				
Outcome	*[n]*	*Mean*	*(SD)*	*[n]*	*Mean*	*(SD)*	*Mean difference (95% CI)*	*Cohen's d*[†]
Teacher-rated attainment: Mainstream schools only*								
Literacy	[145]	3.43	0.91	[171]	2.39	1.07	−1.0 (−1.3 to −0.8)	1.0
Maths	[144]	3.50	0.89	[169]	2.17	1.06	−1.3 (−1.5 to −1.1)	1.4
Science	[144]	3.47	0.73	[169]	2.57	0.92	−0.9 (−1.1 to −0.7)	1.1
Geography	[145]	3.36	0.63	[167]	2.53	0.83	−0.8 (−1.0 to −0.7)	1.1
History	[144]	3.38	0.62	[168]	2.54	0.84	−0.8 (−1.0 to −0.7)	1.1
Information Technology	[144]	3.43	0.63	[165]	2.65	0.79	−0.8 (−0.9 to −0.6)	1.1
Design & Technology	[139]	3.33	0.60	[159]	2.59	0.82	−0.7 (−0.9 to −0.6)	1.0
Composite TAAS*	[136]	3.41	0.59	[155]	2.49	0.78	−0.9 (−1.1 to −0.8)	1.3
	[n]	*n*	*(%)*	*[n]*	*n*	*(%)*	*OR (95% CI)*	
Below average TAAS	[136]	7	(5.1%)	[155]	77	(49.7%)	18.2 (8.0 to 41.4)	—
Special Educational Needs (SEN): Mainstream schools only								
Identified SEN	[152]	17	(11.2%)	[186]	105	(56.5%)	10.3 (5.8 to 18.4)	—
SEN Provision	[152]	17	(11.2%)	[186]	105	(55.4%)	9.9 (5.5 to 17.6)	—
Special Educational Needs (SEN): Full cohort excluding children with serious neuro-cognitive impairment								
Identified SEN	[150]	16	(10.7%)	[117]	50	(42.7%)	6.3 (3.3 to 11.8)	—
SEN Provision	[150]	15	(10.0%)	[117]	46	(39.3%)	5.8 (3.1 to 11.2)	—
Special Educational Needs (SEN): Full cohort								
Identified SEN	[152]	17	(11.2%)	[215]	134	(62.3%)	13.1 (7.4 to 23.3)	—
SEN Provision	[153]	17	(11.2%)	[215]	132	(61.4%)	12.6 (7.1 to 22.4)	—

*TAAS refers to Teacher Academic Attainment Scale, a composite measure of rating across all 7 subjects. Below average TAAS is classified using an average TAAS score across all seven subjects < 2.5. SEN = special educational needs.

Neuropsychological Antecedents of Reading and Mathematics Scores at 11 Years

The results of functional assessments at 6 years have been reported previously (Marlow et al., 2007; Marlow et al., 2005; Wolke et al., 2008). Multivariate stepwise linear regression analyses revealed different patterns of neuropsychological antecedents at 6 years of age on reading and mathematics attainment at 11 years between EP children and classmates (Table 4). Overall, MPC, visuospatial processing, visual attention, phoneme deletion, and letter knowledge were significant antecedents of attainment in reading for all children combined. In both groups, MPC and phoneme deletion were strong predictors of reading scores. The effect of visual attention and letter knowledge were stronger in EP children than classmates but this interaction was not significant. However, the interaction term was significant for visuospatial processing, indicating that the impact of these skills on reading at 11 years differed between groups and was an independent predictor for EP children only.

MPC, visuospatial, tower, letter knowledge, and phoneme deletion scores were significant functional predictors of mathematics scores across all children. In both groups, MPC and visuospatial processing skills were strong predictors of mathematics scores. The between-group interaction was significant for phoneme deletion and letter knowledge, indicating significant differences in the impact of these scores between EP children and classmates: both skills contributed significantly to mathematics scores for EP children only. Tower scores also had a stronger impact on mathematics in EP children than classmates but the between group interaction was not significant. SES and maternal education were not significant after adjustment for other factors in any model.

Prediction of Educational Outcomes: Univariate Associations

Results of univariate analyses are shown in Table 5. Indices of lower SES and maternal education, adverse neonatal outcome, and poorer neurodevelopmental function at 30 months were significantly associated with lower reading scores. Similar associations were observed for mathematics with the addition of smaller weight at birth, an admission temperature less than 35°C and postnatal steroid use. With the exception of maternal education, the same pattern of associations was found between neurodevelopmental outcomes and SEN provision (Table 5).

Prediction of Educational Outcomes: Multivariate Models

Multivariate linear stepwise regression analyses of neonatal variables and neurodevelopmental outcomes at 30 months accounted for up to 43% of the variance in academic attainment (reading $r^2 = 0.31$; mathematics $r^2 = 0.43$; Table 6). The neonatal factors of male sex, lower GA, vaginal breech delivery, and indices of neonatal illness including abnormal cerebral ultrasound scan, NEC requiring surgery or drainage and postnatal steroid use were associated with lower reading scores. Higher SES and having received breast milk during the neonatal period were associated with higher scores. When outcomes at 30 months were included in step 2 of the regression analysis, higher SES and breast milk received during the neonatal period remained significant predictors. New independent associations emerged between higher cognitive scores,

TABLE 4
Extremely Preterm Birth and Neuropsychological Abilities at 6 Years of Age Independently Associated With Attainment in Reading and Mathematics in Extremely Preterm Children and Classmates at 11 Years of Age From Multivariable Stepwise Regression Analyses (in Children With Measurable MPC at 6 Years)

Neuropsychological Variables at 6 Years	*Coefficient*	*(95% CI)*	*p*
Dependent Variable: READING SCORES ($N = 275$): $r^2 = 0.60$			
EP birth	1.37	(−1.79 to 4.54)	.39
Mental Processing Composite (MPC)	0.33	(0.21 to 0.46)	<.001
Visuospatial processing: interaction with group	0.29	(0.13 to 0.44)	<.001
Phoneme deletion*	0.15	(0.10 to 0.20)	<.001
Visual attention	1.38	(0.39 to 2.38)	.007
Letter knowledge*	0.08	(0.03 to 0.13)	.002
Dependent Variable: READING SCORES—EP CHILDREN ONLY ($N = 167$): $r^2 = 0.56$			
Mental Processing Composite (MPC)	0.21	(0.03 to 0.40)	.025
Phoneme deletion	0.17	(0.10 to 0.24)	<.001
Visuospatial processing	0.33	(0.14 to 0.51)	.001
Letter knowledge	0.10	(0.03 to 0.17)	.004
Visual attention	1.7	(0.42 to 2.99)	.01
Dependent Variable: READING SCORES—CLASSMATES ONLY ($N = 109$): $r^2 = 0.39$			
Mental Processing Composite (MPC)	0.51	(0.35 to 0.66)	<.001
Phoneme deletion	0.13	(0.07 to 0.19)	<.001
Dependent Variable: MATHEMATICS SCORES ($N = 280$): $r^2 = 0.62$			
EP birth	−3.39	(−7.62 to 0.83)	.12
Mental Processing Composite (MPC)	0.38	(0.22 to 0.55)	<.001
Visuospatial processing	0.35	(0.19 to 0.51)	<.001
Letter knowledge: interaction with group	0.14	(0.06 to 0.22)	.001
Phoneme deletion: interaction with group	0.11	(0.03 to 0.19)	.009
Tower	0.81	(0.15 to 1.46)	.016
Dependent Variable: MATHEMATICS SCORES—EP CHILDREN ONLY ($N = 171$): $r^2 = 0.52$			
Mental Processing Composite (MPC)	0.41	(0.18 to 0.64)	.001
Visuospatial processing	0.32	(0.09 to 0.55)	.006
Letter knowledge	0.14	(0.05 to 0.22)	.001
Phoneme deletion	0.11	(0.02 to 0.19)	.014
Tower	0.9	(0.04 to 1.76)	.039
Dependent Variable: MATHEMATICS SCORES—CLASSMATES ONLY ($N = 110$): $r^2 = 0.26$			
Mental Processing Composite (MPC)	0.39	(0.16 to 0.62)	.001
Visuospatial processing	0.41	(0.18 to 0.64)	.001

*Letter Knowledge and Phoneme Deletion are categorical variables for increase in percentiles (0, 10, 25, 50, 75) derived from the Phonological Abilities Test (PAT). In each case phoneme deletion refers to Phoneme Deletion Beginning. Mental Processing Composite scores (Mean 100, *SD* 15) are derived from the Kaufman Assessment Battery for Children. Visuospatial Processing (Mean 100, *SD* 10), visual attention (Mean 10, *SD* 3), and tower (Mean 10, *SD* 3) scores are derived from the NEPSY (Developmental Neuropsychological Assessment). The interaction with group variables are centered on 100 for visuospatial processing and 50 for PAT scores. EP = extremely preterm.

larger OFC at 30 months and higher reading scores. Similar associations were found with mathematics scores. In addition, higher maternal education and the effect of NEC were significant independent predictors of mathematics. Higher psychomotor development (PDI) scores at 30 months were also associated with increased mathematics scores (Table 6).

TABLE 5
Univariate Associations With Reading and Mathematics Scores (Linear Regression) and Utilization of SEN Provision (Logistic Regression) at 11 Years of Age in Extremely Preterm Children

	Reading Scores				*Mathematics Scores*				*SEN Provision*			
Neonatal Variables	*(n)*	*Coefficient*	*(95% CI)*	*p*	*(n)*	*Coefficient*	*(95% CI)*	*p*	*(n)*	*OR*	*(95% CI)*	*p*
Male	212	−7.00	(−12.46 to −1.55)	**.012**	215	−4.4	(−10.02 to 1.22)	.12	215	2.71	(1.52 to 4.83)	**.001**
Gestational age (per week)	212	3.56	(−0.30 to 7.42)	.071	215	3.66	(−0.15 to 7.48)	.06	215	0.86	(0.59 to 1.25)	.43
Birthweight SDS	210	2.54	(−0.96 to 6.05)	.15	212	3.94	(0.37 to 7.50)	**.031**	212	0.68	(0.48 to 0.97)	**.034**
OFC SDS at birth	139	−0.57	(−3.75 to 2.60)	.72	141	0.17	(−3.14 to 3.47)	.92	141	1.06	(0.76 to 1.49)	.73
White maternal ethnic origin	211	5.77	(−1.45 to 12.99)	.12	214	6.93	(−0.41 to 14.27)	.06	214	0.77	(0.37 to 1.60)	.48
Maternal age (per 10 years)	210	2.16	(−2.61 to 6.94)	.37	213	1.17	(−3.74 to 6.07)	.64	213	1.02	(0.63 to 1.65)	.92
Maternal education post-16 years	208	8.33	(2.48 to 14.18)	**.005**	211	10.21	(4.21 to 16.22)	**.001**	210	0.71	(0.39 to 1.29)	.26
SES (at 30 months)$	201	−5.99	(−9.44 to −2.55)	**.001**	204	−8.42	(−11.89 to −4.95)	<**.001**	203	1.54	(1.07 to 2.22)	**.022**
Any antenatal steroids	211	4.85	(−2.30 to 12.0)	.18	214	7.83	(0.59 to 15.08)	**.034**	213	0.68	(0.32 to 1.42)	.30
Preterm premature rupture of membranes	209	5.60	(−0.68 to 11.88)	.08	212	3.68	(−2.76 to 10.12)	.26	213	0.67	(0.36 to 1.24)	.20
Vaginal Breech delivery	211	−3.35	(−9.66 to 2.96)	.30	214	−2.66	(−9.16 to 3.83)	.42	214	1.08	(0.57 to 2.03)	.82
Chorioamnionitis (suspected or proven)	209	6.05	(−0.74 to 12.83)	.08	212	5.61	(−1.31 to 12.53)	.11	213	0.64	(0.33 to 1.24)	.19
Fetal heart rate >100 bpm @ 5mins	208	0.7	(−9.76 to 11.16)	.90	211	0.63	(−10.12 to 11.38)	.91	211	1.44	(0.50 to 4.14)	.50
Admission temperature <35°C	202	−5.31	(−11.95 to 1.33)	.12	205	−6.82	(−13.47 to −0.17)	**.045**	205	1.46	(0.73 to 2.89)	.29
CRIB score (per point)	211	−0.98	(−1.76 to −0.19)	**.015**	214	−1.24	(−2.05 to −0.44)	**.003**	214	1.06	(0.97 to 1.14)	.18
Abnormal last cranial ultrasound scan	211	−14.41	(−21.65 to −7.16)	<**.001**	214	−14.01	(−21.42 to −6.61)	<**.001**	214	3.73	(1.48 to 9.40)	**.005**
Necrotizing Enterocolitis (NEC)	205	−21.46	(−37.81 to −5.12)	**.01**	205	−26.44	(−43.14 to −9.74)	**.002**	205	—	—	.085
Any postnatal steroids for CLD	211	−7.79	(−13.91 to −1.67)	**.013**	214	−5.02	(−11.31 to 1.27)	.12	214	1.19	(0.64 to 2.21)	.58
Postnatal steroids (per week) for CLD	208	−1.90	(−2.72 to −1.07)	<**.001**	211	−1.34	(−2.19 to −0.49)	**.002**	211	1.11	(1.01 to 1.23)	**.039**
Any breast milk given	210	13.48	(5.79 to 21.16)	**.001**	213	10.99	(2.99 to 18.98)	**.007**	213	0.55	(0.23 to 1.30)	.17
Duration of NICU admission (per week)	161	−1.36	(−1.91 to −0.81)	<**.001**	164	−1.2	(−1.74 to −0.67)	<**.001**	165	1.15	(1.06 to 1.25)	**.001**

(*Continued*)

TABLE 5
(Continued)

Neonatal Variables	Reading Scores (n)	Coefficient	(95% CI)	p	Mathematics Scores (n)	Coefficient	(95% CI)	p	SEN Provision (n)	OR	(95% CI)	p
Outcome at 30 months												
BSID–II MDI score	190	0.74	(0.58 to 0.90)	<**.001**	192	0.75	(0.57 to 0.92)	<**001**	190	0.93	(0.90 to 0.96)	<**.001**
BSID–II PDI score	186	0.50	(0.35 to 0.65)	<**.001**	188	0.58	(0.42 to 0.74)	<**.001**	186	0.92	(0.89 to 0.95)	<**.001**
Serious cognitive impairment‡	190	−22.39	(−29.45 to −15.32)	<**.001**	192	−21.16	(−28.90 to −13.42)	<**.001**	190	7.16	(2.07 to 24.73)	**.002**
Functional disability (per category)‡‡	207	−15.22	(−18.12 to −12.32)	<**.001**	210	−13.96	(−17.07 to −10.86)	<**.001**	209	4.42	(2.63 to 7.44)	<**.001**
OFC SDS at 30 months	206	6.06	(4.37 to 7.76)	<**.001**	208	6.45	(4.71 to 8.18)	<**.001**	207	0.57	(0.45 to 0.72)	<**.001**
Internalizing behavior problems*	201	−3.79	(−7.41 to −0.17)	**.04**	204	−3.38	(−7.10 to 0.34)	.074	203	1.49	(1.01 to 2.20)	**.047**
Externalizing behavior problems*	201	−3.14	(−7.13 to 0.85)	.12	204	−3.91	(−8.05 to 0.24)	.064	203	1.48	(0.95 to 2.28)	.08

NEC is necrotising enterocolitis requiring surgery or drainage. CRIB: Clinical Risk Index for Babies; NICU: Neonatal Intensive Care Unit; SDS: Standard Deviation Score. CLD: Chronic Lung Disease. Birthweight and occipitofrontal circumference (OFC) *SD* Score calculated using Child Growth Foundation standards (Cole, Freeman, & Preece, 1998) for age and sex. $socioeconomic status (SES) was classified into 3 categories at 30 months corresponding to non-manual, manual, unemployed. ‡at 30 months Bayley Scales of Infant Development 2nd Edition, Mental Development Index score <–2 *SD* (scores <70). ‡‡Functional disability per category is for none, other, severe. *Assessed with Child Behavior Checklist (CBCL). Regression for internalizing and externalizing problems are for 3 categories: none, borderline, clinically significant problems defined using published cutoffs. #IQ <–2 *SD* of classmates. Phonological Abilities Test (PAT) scores are percentile scores (0, 10, 25, 50, 75). *p* values in bold denote significance at .05 level. OR for NEC were not applicable as all 6 children with NEC had special educational needs (SEN) provision at 11 years.

TABLE 6
Factors Independently Associated With Reading Scores and Mathematics Scores in Extremely Preterm Children at 11 Years of Age in Stepwise Multivariate Regression, and With SEN Provision in Multivariate Logistic Regression.

Variable	*Coefficient*	*(95% CI)*	*p*
Reading Scores			
Step 1: Neonatal: (N = 193) $r^2 = 0.29$			
Gestational age (per week)	3.9	(0.2 to 7.6)	.037
Abnormal last cerebral ultrasound	−12.5	(−19.0 to −5.9)	<.001
NEC	−18.0	(−32.7*to* − 3.4)	.016
Postnatal steroids (per week)	−1.5	(−2.4 to −068)	.001
Any breast milk received	12.6	(5.3 to 19.9)	.001
Male	−7.2	(−12.1 to −2.3)	.004
SES	−4.8	(−7.9 to −1.7)	.003
Vaginal breech delivery	−8.7	(−14.4 to −3.1)	.002
Step 2: Neonatal & outcome at 30 months: (N = 181) $r^2 = 0.31$			
BSID–II MDI	0.6	(0.5 to 0.8)	<.001
OFC SDS at 30 months	2.7	(1.0 to 4.4)	.002
Any breast milk received	7.3	(1.3 to 13.3)	.018
Premature rupture of membranes	6.2	1.6 to 10.9)	.009
SES	−3.7	(−6.3 to −1.0)	.007
Mathematics Scores			
Step 1: Neonatal: (N = 149) $r^2 = 0.25$			
Abnormal last cerebral ultrasound	−10.7	(−18.6 to −2.8)	.008
NEC	−24.2	(−39.4 to −9.1)	.002
Vaginal breech delivery	−8.1	(014.9 to −1.3)	.02
Maternal qualification post 16-years	7.2	(0.4 to 14.1)	.039
Duration in NNU (per week)	−0.9	(−1.4 to −0.3)	.004
SES	−5.0	(−8.9 to −1.1)	.012
Step 2: Neonatal & outcome at 30 months: (N = 175) $r^2 = 0.43$			
NEC	−18.3	(−31.5 to −5.1)	.007
BSID–II MDI	0.4	(0.2 to 0.6)	<.001
BSID–II PDI	0.2	(0.0 to 0.4)	.015
OFC SDS at 30 months	3.9	(2.1 to 5.6)	<.001
SES	−6.7	(−9.5 to −3.8)	<.001
Variable	*OR*	*(95% CI)*	*p*
SEN Provision			
Step 1: Neonatal: (N = 165) $r^2 = 0.14$			
Abnormal last cerebral ultrasound	3.72	(1.16 to 11.91)	.027
Male	3.08	(1.48 to 6.40)	.003
Duration in NNU (per week)	1.12	(1.03 to 1.22)	.007
Step 2: Neonatal & Outcome at 30 months: (N = 184) $r^2 = 0.25$			
BSID–II MDI (per 10-point increase)	0.67	(0.45 to 0.99)	.047
BSID–II PDI (per 10-point increase)	0.50	(0.34 to 0.73)	<.001
OFC SDS at 30 months	0.55	(0.40 to 0.75)	<.001

NEC is necrotising enterocolitis requiring surgery or drainage. OFC SDS: occipitofrontal circumference Standard Deviation Score using Child Growth Foundation standards for age and sex. Socioeconomic status (SES) was classified into 3 categories at 30 months corresponding to non-manual, manual, unemployed. Association is for each change in SES category from non-manual to manual to unemployed. BSID–II MDI: Bayley Scales of Infant Development 2nd Edition, Mental Development Index score (Mean 100, *SD* 15). NNU: Neonatal Unit. Duration of stay in NNU (i.e., from birth to discharge home) was poorly recorded and there is much missing data.

Multivariate logistic regression models of utilization of SEN provision were relatively less predictive with up to 25% of the pseudo variance accounted for at 30 months corrected age. Neonatally, male sex, abnormal cerebral ultrasound, and longer neonatal intensive care unit (NICU) admission were associated with increased risk for SEN. Neonatal variables were no longer significant once 30 month function was considered. Only BSID–II scores and smaller OFC were significant independent predictors of the need for SEN provision (Table 6).

DISCUSSION

Educational Outcomes in Children Born EP

The results of this large population-based study indicate a profound effect of EP birth on educational outcomes in middle childhood. Children born EP were rated by their teachers as having significantly poorer attainment than their term peers across all school subjects with half of the children assessed as having attainment below the national average. EP birth was associated with odd ratios up to 59 for learning difficulties and a markedly greater reliance on SEN provision. Academic deficits were significantly increased even among those who were free of neurocognitive impairment.

These results mirror the findings of previous studies in which poorer academic attainment has been reported on both standardized tests (Anderson & Doyle, 2003; Johnson et al., 2003; Litt et al., 2005; Saigal et al., 2003; Saigal, Szatmari, Rosembaum, Campbell, & King, 1991; Stjernqvist & Svenningsen, 1999; Taylor, Klein, Minich, et al., 2000) and teacher-based assessments (Anderson & Doyle, 2003; Bowen et al., 2002; Wolke et al., 2008) in VLBW/ELBW children. The rates of impairment and observed effect sizes are larger than typically reported in VP/VLBW samples (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlan, 2009) but were anticipated given the GA-related gradient in outcomes (Johnson, 2007; Klebanov et al., 1994; Saigal et al., 2000; Schneider et al., 2004; Wolke et al., 2001). Further, impairment was classified using reference data obtained from classmates to account for the secular drift in scores over time (Flynn, 1999). This typically yields a higher prevalence of impairment (Johnson et al., 2008; Marlow et al., 2005) but reflects reality as children are judged against their peers with whom they must compete in the classroom. The prevalence of special school placements was lower than in other EP/ELBW cohorts (Davies, Corbett, McGurk, & Jerrett, 1994; Hack et al., 1994; Saigal et al., 2000) but reflects the UK policy for integration of children with complex SEN into mainstream education.

Commensurate with other studies, the largest effect of EP birth was observed on poor attainment in mathematics (Anderson & Doyle, 2003; Schneider et al., 2004; Taylor, Klein, Minich, et al., 2000). In contrast to reading, the group difference remained significant after adjustment for IQ as has been shown previously (Botting et al., 1998; Klebanov et al., 1994; Taylor et al., 2002) and, compared with term-born counterparts, the prevalence of impairment in mathematics remained significantly increased after exclusion of children with serious neurocognitive impairment. These results suggest that mathematics is a particular area of difficultly in children born EP.

Neuropsychological Antecedents of Academic Attainment

As learning difficulties may be associated with deficits in visuomotor and executive functions, we examined the relative contribution of neuropsychological abilities at early school age to attainment in reading and mathematics at the end of primary schooling. The prediction from early to later school attainment was stronger in children born EP compared to classmates and a different pattern of antecedents was observed between groups suggestive of a different neuropsychological basis for academic difficulties in children born EP. Visuospatial processing was found to be a significant correlate of reading scores in the EP group only. Significant deficits in visuospatial processing associated with EP birth (Marlow et al., 2007; Taylor, Klein, Minich, et al., 2000) thus account for some of the learning difficulties observed. Furthermore, the high rate of mild visual impairments in this population (Johnson, Fawke, et al., 2009), such as problems with visual acuity or visual field restrictions (O'Connor & Fielder, 2007), may contribute to poor visuospatial processing among those who are otherwise free of neurocognitive disability (Bohm, Katz-Salamon, Smedler, Lagercrantz, & Forssberg, 2002); however, this requires further investigation.

Similarly, attainment in mathematics was associated with a different pattern of antecedents between EP and term children. Measures of letter knowledge, phoneme deletion (measures of phonological awareness), and the NEPSY Tower task (a non-verbal problem- solving task requiring planning, similar to the classic Tower of Hanoi or Tower of London tasks) accounted for additional variance in scores after adjustment for general cognitive ability in children born EP only. Specific deficits in phonological processing have been documented in VP/EP children (Wolke & Meyer, 1999; Wolke et al., 2008) and such difficulties have been associated with attainment in both reading and mathematics after adjustment for IQ in children born at term and preterm (Breslau, Paneth, & Lucia, 2004; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Wocadlo & Rieger, 2007). The association between phonological abilities and mathematics found by Wocadlo and Rieger was largely accounted for by rapid naming (Wocadlo & Rieger, 2007) and others have identified a significant association between rapid naming and academic attainment in term children (Schatschneider et al., 2004; van der Sluis, de Jong, & van der Leij, 2007). Thus, the association with phonological abilities observed in this study may be indicative of the fundamental role of processing speed or a non-executive automatization deficit in the educational outcomes of children born EP (van der Sluis et al., 2007; Wocadlo & Rieger, 2007). Indeed, studies of typically developing children have documented significant associations between processing speed and academic outcomes (Berg, 2008; Bull & Johnston, 1997; Gathercole, Pickering, Knight, & Stegman, 2004; Schatschneider et al., 2004; St Clair-Thompson & Gathercole, 2006). Moreover, these processes have shown to be impaired in children born VP and could contribute to the learning difficulties observed in EP populations (Aarnoudse-Moens, Smidts, et al., 2009; Mulder, Pitchford, & Marlow, 2010; Taylor et al., 2002).

Predicting Educational Outcomes in Children Born EP

Provision of long term support for children born EP has significant financial implications and we have recently shown that the costs associated with EP birth are greatest for educational provision compared with other health and social care services in middle childhood (Petrou, Abangma, Johnson, Wolke, & Marlow, 2009). The early identification of those at risk is thus crucial in instigating intervention and reducing the need for later remediation.

Indices of severe neonatal outcome, including longer NICU admission, postnatal steroids, NEC, and an abnormal cerebral ultrasound scan were independent predictors of lower scores in both reading and mathematics. Such factors have previously been shown to be associated with academic achievement in children born VLBW/VP (Botting et al., 1998; Taylor et al., 1998; Wocadlo & Rieger, 2007). NEC was a strong predictor of attainment accounting for up to a 24-point deficit in standardized scores. However, only six children had NEC requiring surgery or drainage, all of whom received SEN provision and had serious impairment in mathematics; five of these children also had impairment in reading. While this limited range may contribute to the strong association, it is evident that NEC is an important risk factor for later school failure. Having received any breast milk during NICU admission was a protective factor for reading scores. This association is complex as only a few children did not receive breast milk and it is impossible to determine whether this is a marker of neurological difficulties, parental aspiration, other proximal social factors, or an indication of the critical role of breast milk in neuronal development. A normal cerebral ultrasound scan and larger OFC at 30 months corrected age were both associated with higher reading and mathematics scores. This may reflect perinatal insults to the developing brain or the impact of EP birth on normal brain growth and development (Kapellou et al., 2006; Peterson et al., 2000, 2006).

By 30 months of age, delayed cognitive development (scores <-2 *SD*) was an independent predictor of all educational outcomes. In addition, impairment in motor development was also independently associated with mathematics and SEN provision. The predictive value of motor skills for later mathematics skills has previously been documented (Botting et al., 1998; Sullivan & McGrath, 2003). SES exerted a significant impact for almost all models with higher SES associated with higher reading and mathematics scores. The relationship between SES and academic achievement is well documented in both preterm and term populations (Schneider et al., 2004; Taylor, Klein, & Hack, 2000; Wolke & Meyer, 1999).

As expected, we found that the accuracy of prediction increased with age and more functional measures of ability. The influence of social and environmental factors over time was also increasingly captured with later assessments. To make a reasonable prediction of later academic attainment, knowledge of neonatal complications needs to be combined with early functional measures.

Strengths and Limitations

The strengths of this study lie in the collection of validated outcomes from birth for a whole GA-defined population of children born EP. Standardized outcome measures were used at each follow-up and longitudinal contemporary reference data were collected from term-born classmates. However, this study is not without its limitations. The prevalence of impairment is predicted to be underestimated by approximately 5% given the selective dropout of EP children at higher risk for disability (Johnson, Fawke, et al., 2009). However, despite selective dropout, prediction of academic attainment may not have been adversely affected (Wolke et al., 2009). In addition, only one measure of educational attainment was administered and future studies would benefit from inclusion of a wider battery of academic assessments to further our understanding of the nature of learning difficulties in this population. It would also be advantageous to explore other educational outcomes in this population in more detail including self esteem and academic self concept, as these are also affected in children with VLBW (Rickards et al., 2001; Schneider et al., 2004).

The present study capitalized on longitudinal data collected as part of the EPICure study. However, the range of neuropsychological abilities assessed at school entry was limited. Associations between academic attainment and other executive functions, such as shifting, inhibition, and working memory, which were not examined in this study have also been found (Bull et al., 2008; Bull & Scerif, 2001; Litt et al., 2005; Mulder et al., 2009; St Clair-Thompson & Gathercole, 2006). Future studies that encompass a more comprehensive battery of neuropsychological assessments would be advantageous in exploring the origins of learning difficulties in this population. In addition, an examination of parenting factors may prove fruitful in this population. The impact of parenting and the home environment on executive functions and mathematical abilities has been demonstrated in both term (Assel et al., 2003; Melhuish et al., 2008) and preterm children (Breslau et al., 2009). Elucidation of factors underpinning school failure in this population has important implications for screening for those at risk for learning difficulties and for the development population-specific intervention strategies.

CONCLUSIONS

EP birth has a profound effect on educational outcomes in middle childhood. This is manifest in poorer academic attainment, specific difficulties in mathematics, and a markedly higher reliance on SEN support. Neonatal complications (NEC, abnormal neonatal cerebral ultrasound) combined with functional assessment early in the preschool period (neurodevelopmental tests) allow some prediction of later academic attainment. IQ, visuospatial processing, executive functions, and phonological abilities at early school age were significantly associated with later academic abilities and thus may provide potential targets for the content of early intervention programs for this population. The implications are, firstly, in EP and full term children, deficits in these functions are early indicators for academic problems; secondly, they can be used for the early identification of those requiring special educational support. The results of this study thus emphasize the need for long term outcome monitoring for the early identification of EP children at risk for later school failure.

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