THE EFFECT OF LATE PRETERM BIRTH ON EDUCATION, EXECUTIVE FUNCTION AND GRAPHOMOTOR SKILLS

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INTELLECTUAL PROPERTY AND PUBLICATIONS

I confirm that the work submitted is my own, except where work which has formed part of jointly-authored publications has been included. My contribution and the other authors to this work has been explicitly indicated below. I confirm that appropriate credit has been given within the thesis where reference has been made to the work of others.

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Abstract

The influence of prematurity has been shown to include worse neurodevelopmental outcomes, when compared to outcomes in children born at full term. However, there are far fewer studies considering the effects of late preterm birth (34 to 36 weeks' gestation), the largest preterm group, and the effects are therefore less certain. The aim of this thesis is to investigate the impact of late preterm birth on educational, executive function, and graphomotor outcomes.

Chapter Three of this thesis investigates if children born late preterm have increased odds of not reaching expected standards in overall educational achievement at ages 5, 7, and 11 years. It finds increased odds of not reaching expected levels present to age 7 in the covariate-adjusted model, and to age 11 in the unadjusted model. Chapter Four examines the trajectory of educational scores in primary education for children born late preterm, compared to children born at full term. It finds no evidence of educational "catch up" in children born late preterm. Chapter Five looks at executive function (working memory and inhibition), finding children born late preterm have poorer complex working memory than children born full term. Chapter Six examines differences in graphomotor outcomes using kinematic assessment in children born late preterm compared to full term, at age 4-5 and 7-10 years. The results suggest that children born late preterm have worse graphomotor "tracking skills" than children born full term.

This thesis contributes to the sparse literature examining outcomes for children born LPT in childhood, finding worse educational achievement; no longitudinal evidence of educational catching up; poorer complex working memory and graphomotor tracking skills, but these were consistently small effects. There is potential to follow up children born LPT using health and educational data tracking. Furthermore, greater teacher awareness of the impact of prematurity would help support such children.

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Abbreviations

ALSPAC	Avon Longitudinal Study of Parents and Children
AOR	Adjusted Odds Ratio
BIB	Born in Bradford Cohort Study
BRIEF	Behaviour Rating Inventory of Executive Function
CFA	Confirmatory Factor Analysis
CKAT	Clinical Kinematic Assessment Tool
CWM	Complex Working Memory
DAG	Directed Acyclic Graph
EGPS	English, Grammar, Punctuation, and Spelling
EYFS	Early Years Foundation Stage
EYFSP	Early Years Foundation Stage Profile
FMS	Fine Motor Skills
GCSE	General Certificate of Secondary Education
IMD	Index of Multiple Deprivation
IQ	Intelligence Quotient
KS1	Key Stage One
KS2	Key Stage Two
LPT	Late Preterm
MABC	Movement Assessment Battery for Children
MCS	Millennium Cohort Study
OECD	Organisation for Economic Cooperation and Development
OR	Odds Ratio
PCA	Principal Component Analysis
PVL	Periventricular Leukomalacia
RMSE	Root Mean Squared Error
SATs	Statutory Assessment Tests

SES	Socio-Economic Status
T1	Time 1
T2	Time 2
T3	Time 3
VMPT	Very and Moderately Preterm
VSWM	Visuospatial Working Memory
VWM	Verbal Working Memory
VZ	Ventricular Zone

Thesis Outline

This thesis is comprised of seven chapters: Chapters One and Two provide the background for the research. The first chapter defines and conceptualises the exposure of interest: gestation categorised by group (VMPT[1], LPT[2], early term and full term), and the outcomes against which it will be analysed: educational achievement; trajectory of educational scores; executive function; and graphomotor skills. It also describes the existing evidence of poorer outcomes in these areas for children born LPT and identified the current gaps in the evidence. Chapter Two provides details of the research setting (the BIB[3] Cohort); the selection of covariates used in the analyses; and the process of this selection.

In Chapter Three, educational achievement is assessed at the ages of 5, 6, 7, and 11 years in statutory school assessment in children born early term, LPT and VMPT, compared to children born at full term. Here, educational achievement is conceptualised as whether the child did, or did not reach the age-related standards of expected development. Chapter Four examines educational score trajectory from age 5 to 11 years (and 5 to 7 years; and 7 to 11 years). It investigates if children born LPT, as well as early term and VMPT, show increased or decreased attainment change over these periods, relative to children born at full term. Chapter Five examines the executive function components of working memory and inhibition, as well as processing skills at the ages of 7 to 10 years, comparing outcomes in children born LPT, and VMPT and early term, to those born at full term. Chapter Six investigates the graphomotor outcomes of tracking, aiming and tracing in children born LPT, as well as VMPT and early term, compared to children born at full term at two time-points (ages 4 to 5 years; and 7 to 10 years).

Finally, Chapter Seven provides the discussion section of the thesis. The results from the preceding studies are revisited and the key findings are summarised. The implications of the findings for policy and practice are also outlined. Additionally, the strengths and limitations of the thesis' studies are considered, together with recommendations for the direction of future research in this area.

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[1] Very and Moderately Preterm

[2] Late Preterm

[3] Born-in-Bradford

Chapter 1 General Introduction

Preterm birth affects around 14.9 million (10.6%) births worldwide annually (Chawanpaiboon et al., 2019). Its influence has been found to stretch into adulthood, with studies finding adverse neurodevelopmental, educational and employment prospects for adults who were born preterm, when compared to their peers born at full term (Bilgin et al., 2018). There are also considerable costs involved in dealing with the health, education, and social effects of a child's preterm birth (Institute of Medicine, 2007). This thesis aims to increase our knowledge by investigating educational, cognitive and graphomotor outcomes in children born at LPT gestation (34 to 36 weeks' gestation).

This chapter provides a definition of preterm birth and the associated gestational groups; the rationale for this thesis focusing on children born LPT; examines the antecedents of preterm birth and the potential neural impact of LPT birth; and reviews a theorised risk model for children born preterm. It then assesses the suggested long-term impact of LPT birth on education achievement, followed by considering whether there is any evidence of a differing trajectory of educational scores in statutory tests for children born LPT, compared to full term. After this, it briefly examines two of the potential reasons why lower educational achievement may be seen in children born LPT: poorer executive function and worse graphomotor skills. It also identifies areas where greater knowledge in our understanding of the impact of LPT birth is required in these domains. Finally, the chapter provides an overview of each of the subsequent studies featured in this thesis.

1.1 Defining and Conceptualising Preterm Birth

Preterm birth is defined as birth before the gestation of 37 weeks (Althabe et al., 2012). This is often further classified into four preterm birth categories by gestational age: extremely preterm; very preterm; moderately preterm; and LPT, as shown in Table 1-1. It is also common for the very preterm gestational group to be examined in a combined category with the extremely preterm gestational group to form a larger "very preterm" category (Alterman et al., 2022; Chan & Quigley, 2014; Elvert et al., 2021; Quigley et al., 2012; Townley Flores et al., 2021). A greater level of adverse academic and neurodevelopmental outcomes is associated with earlier gestations, and a gestational 'dose response' effect is generally observed, with children of increased gestational age having better outcomes (Alterman et al., 2021; Boyle et al., 2012; Libuy et al., 2023).

Table 1-1

Preterm Birth Categories, Gestations and Numbers in England and Wales

Gestational Category	Gestational Age	Number and (%) of Births in England and Wales in 2022
Extremely Preterm	Less than 28 weeks	2,836 (0.47%)
Very Preterm	28 to 31 weeks	3,815 (0.63%)
Moderately Preterm	32 to 33 weeks	5,730 (0.95%)
LPT	34 to 36 weeks	34,183 (5.65%)
Early Term	37 to 38 weeks	153,105 (25.30%)
Full Term	39 to 41 weeks	392,529 (64.87%)
Late Term	42 or more weeks	9,693 (1.60%)

Note. Table adapted from Blencowe et al. (2012). Figures from Office for National Statistics (2024).

1.2 Rationale for focus on Children Born at LPT Gestation

This thesis focusses on the outcomes of children born in the LPT gestational period. As shown in Table 1-1, nationally in England and Wales the numbers in the other preterm birth categories are low compared to the LPT category, with around 73% of preterm birth occurring in the LPT period (Office for National Statistics, 2024). Similarly, international comparisons show the LPT group to be by far the largest preterm group worldwide (Blencowe et al., 2012). Therefore, it is vital to consider the effects of prematurity on children born LPT, as this is a relatively substantial number of children but has been far less examined in empirical studies (Bulut et al., 2016; Cheong & Doyle, 2012; Demestre, 2017; Martínez-Nadal & Bosch, 2020).

This lack of prior attention reflects a previously held view, that children born LPT were not at increased risk relative to term births (Bulut et al., 2016; Scher et al., 2011) and the gestation period was formerly referred to as “near term” (Kinney, 2006; Sarici et al., 2004; Wang et al., 2004). However, there is increasing evidence that children born LPT have poorer outcomes in terms of morbidity (Davidoff et al., 2006; Pettinger et al., 2023), and educational achievement (Chan et al., 2016; Chan & Quigley, 2014; Quigley et al., 2012), when compared to full term births.

1.3 Risk factors for Preterm Birth

There are several social, medical and psychological factors, shown in Table 1-2, that increase the risk of premature birth. Some of these factors may themselves also have an impact on later outcomes, including on educational achievement; executive function skills; and graphomotor skills. This potential confounding effect is discussed in more detail in Chapter Two (Section 2.3).

Preterm birth can be categorised as “medically indicated” or “iatrogenic birth”, where labour is induced, or a Caesarean section performed with no premature rupture of the membrane (Ananth & Vintzileos, 2006). Alternatively, the premature birth can be as a result of spontaneous labour which includes premature rupture of the membrane or other unexplained preterm labour (Loftin et al., 2010). As seen in Table 1-2, certain conditions increase the risk of requiring a medically indicated preterm birth, e.g. chronic diabetes (Köck et al., 2010); maternal obesity (Hendler et al., 2005); preeclampsia (Li et al., 2018); multiple births (Fuchs & Senat, 2016); and assisted reproduction (R. A. Jackson et al., 2004).

1.4 Preterm Birth over Time and by Ethnicity

The preterm birth rate in England and Wales has been fairly stable over the last seven years to 2021, at just over 7% of all live births (Office for National Statistics, 2024), shown in Figure 1-1. However, as Figure 1-2 illustrates, there are wide ethnic differences within the preterm birth rate.

There was increased incidence of preterm birth in 2021 (the latest available data at time of writing) especially in the Black community, but also in the Bangladeshi, Indian, and Pakistani community, compared to the White British community. This is pertinent to this thesis, as the data used in the thesis’ studies are sourced from an area of multiple ethnicities (J. Wright et al., 2013).

It is also relevant that several of the risk factors for LPT birth are associated with lower SES[4], which is also linked to ethnicity in the UK. People of Bangladeshi and Pakistani heritage are twice as likely to be in the lowest fifth of incomes than average in the UK (Francis-Devine, 2020).

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[4]Socio-Economic Status

Table 1-2

Antecedents of Preterm Birth

Factor	Findings
Alcohol Use	Drinking 10 or more units of alcohol a week is associated with preterm birth (Kesmodel et al., 2000).
Area Based Deprivation	Systematic review by Weightman et al. (2012) found living in an area of high deprivation had increased preterm birth risk.
Assisted Reproduction	Assisted reproduction is associated with an increased risk of medically indicated preterm birth (R. A. Jackson et al., 2004).
Body Mass Index	Being overweight is a protective factor for preterm birth, being underweight increases the risk for spontaneous preterm birth. However, obesity is associated with a higher risk of medically indicated preterm birth (Hendler et al., 2005).
Cervical Length	Shortened cervical length has been found to be associated with spontaneous preterm birth (Withanawasam & Tara, 2019).
Diabetes (Chronic)	Diabetes carries an increased risk to the mother and these births are often induced. It also carries a statistically significant risk of spontaneous preterm birth (Köck et al., 2010).
Diabetes (Gestational)	Gestational diabetes carries an increased risk of spontaneous preterm birth (Hedderson, 2003).
Drug Use	Baer et al. (2019) found an increased risk of spontaneous preterm birth amongst drug users: ranging from 11.6% for cannabis users to 24.3% for cocaine users, compared to 6.7% for non-drug users.
Hypertension (Gestational)	Gestational hypertension carries increased risk of premature rupturing of the membrane (L. Liu et al., 2019).
Hypertension (Pre-existing)	Metanalysis by Bramham et al. (2014) found that women with hypertension carried a 28% increased risk of a preterm birth.

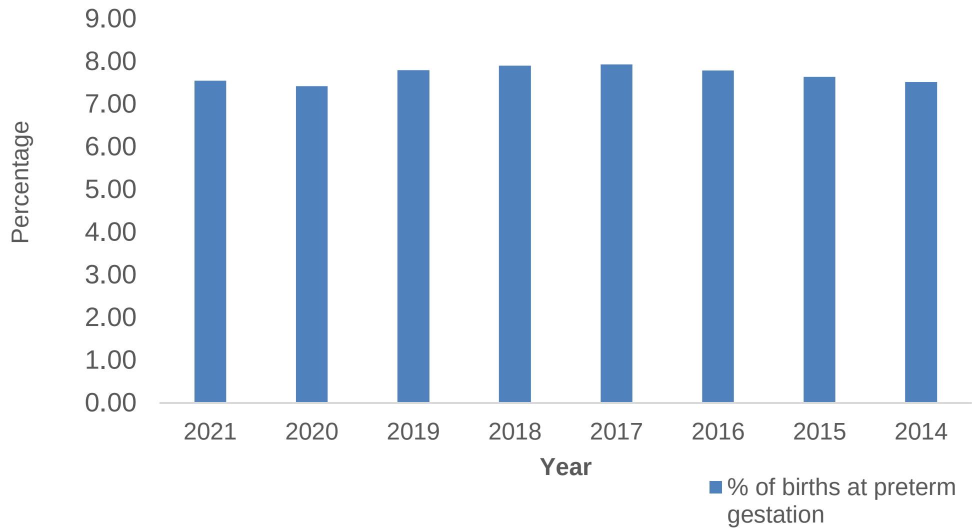
Table 1-2 continued

Factor	Findings
Maternal Education	Stacey et al. (2016) found an increase in the adjusted odds ratio of 1.22 for mothers with less education (less than 5 GCSEs [5]) of preterm birth.
Maternal Mental Health	Systematic review by Hoffman and Hatch (1996) suggested a link between stress, social support, and preterm birth.
Multiple Births	Multiple births form 15 - 20% of preterm births, however the multiple birth rate is 2 - 3% overall (Fuchs & Senat, 2016). Around one third of multiple births are medically indicated (Murray et al., 2018).
Parity	Null-parity and parity of five or more pregnancies are associated with spontaneous preterm birth (Koullali et al., 2020).
Poverty	There is an increased odds ratio of preterm birth where the mother describes herself as not managing financially (Stacey et al., 2016).
Pre-eclampsia	There is strong link between pre-eclampsia and medically indicated preterm birth: Li et al. (2018) found a preterm birth rate of 82.6% for mothers with early onset preeclampsia.
Previous Preterm Birth	This increased the risk of spontaneous preterm birth by 15 - 50% dependent on number and gestation of the previous preterm births (Goldenberg et al., 2008).
Short Gap between Pregnancies	There is increased risk of spontaneous preterm birth if the gap between pregnancies is small. A gap of less than six months provides a two-fold increase in the next pregnancy (Goldenberg et al., 2008).
Single Parent	Single mothers have been found to have a higher incidence of preterm birth (Farbu et al., 2014).
Smoking	Smoking correlates highly with spontaneous preterm birth (Kyrklund-Blomberg et al., 2005).

[5] General Certificate of Secondary Education

Figure 1-1

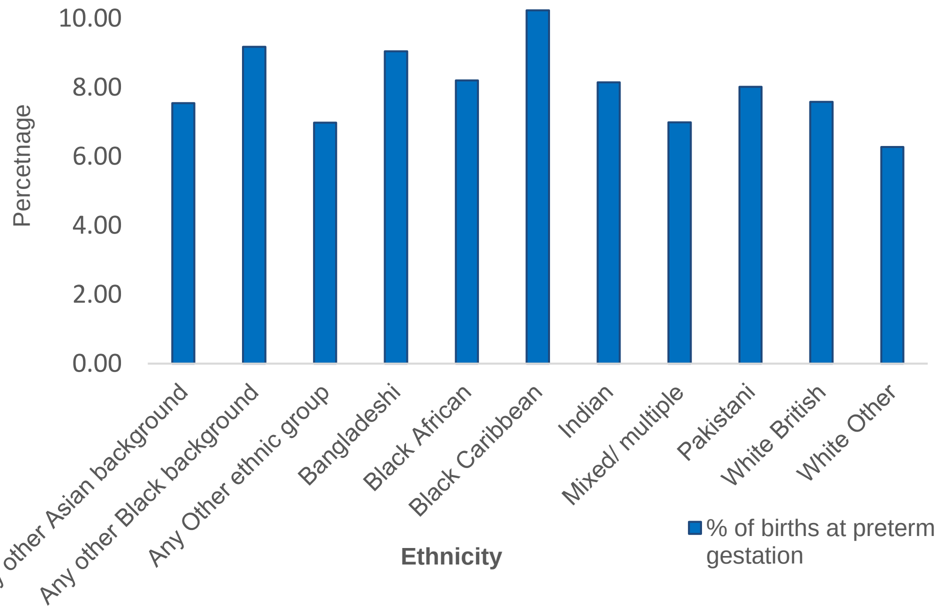
Percentage of Births at Preterm Gestation by Year in England and Wales



Note. Figures taken from Office for National Statistics (2024).

Figure 1-2

Preterm Births by Ethnicity in 2021 in England and Wales



Note. Figures taken from Office for National Statistics (2024)

It is suggested that differences in SES is at least contributory to the higher incidence of preterm birth in many ethnic minority groups (Institute of Medicine, 2007). However, differences remain in rates of prematurity by ethnicity even when efforts are made to control for SES (Collins & Hawkes, 1997).

1.5 The Premature Brain

1.5.1 Brief Overview of the Brain

As a result of shorter gestation and early extra-uterine development, the ‘normal’ pattern of brain development can be altered by preterm birth, potentially resulting in neurodevelopmental deficits (Degnan et al., 2015; Inder et al., 2005; Volpe, 2019, 2022). As this, and subsequent chapter studies refer to structures within the brain sometimes affected by premature birth, the current section provides a rudimentary overview of features of the brain to provide some background explanation.

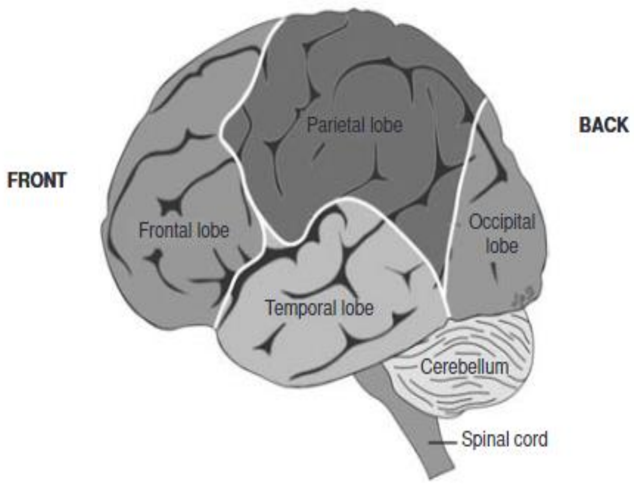
The brain comprises of neurons which transmit and receive information (M. M. Shah, 2014), and glia cells (Herculano-Houzel, 2009). These glia cells include “oligodendrocytes” that are involved in myelination (Purves et al., 2001). This myelination insulates the axon of the neuron and increases the speed and effectiveness of information transmission (Hughes & Appel, 2016). The brain consists of three parts: the cerebrum which is the majority of the brain; the cerebellum at the back of the brain; and the brain stem at the lower part of the brain (Morin et al., 2017).

1.5.1.1 The Cerebrum

The cerebrum is divided into two hemispheres, known as the right and left hemisphere, which are connected by the corpus callosum (Bui & Das, 2023). The cerebrum also has four lobes within each hemisphere: the frontal lobe; the parietal lobe; the temporal lobe; and the occipital lobe, as shown in Figure 1-3. The frontal lobe is mainly associated with self-regulation and reasoning (Bui & Das, 2023). The parietal lobe is principally involved in visual-spatial processing and sensory processing (Bui & Das, 2023). The temporal lobe processes auditory information (Bui & Das, 2023), and together with the hippocampus and amygdala which lie within this lobe, is involved in memory formation and retention (Jeneson & Squire, 2012). The occipital lobe is involved with the processing of visual information and distances (Bui & Das, 2023).

Figure 1-3

The Lobes of the Brain



Note. Drawing by Jean-Pierre Souteyrand taken from the OECD[6] (2002, p. 45).

1.5.1.2 Brain Development

Brain development starts at around three weeks' gestation with "gastrulation". This process transforms the embryo from a one-dimensional layer of epithelial cells to a three-dimensional structure (Muhr et al., 2024). The upper layer of this resulting structure has epiblast cells that produce neural stem cells that yield neurons. The stem cells in the mid-line of the upper structural layer lie in a region known as the "neural plate" (Ortinau & Neil, 2015). Either side of this neural plate the ridges fold in, forming the neural tube, at around three weeks' gestation. This neural tube closes off at around four weeks' gestation (Stiles & Jernigan, 2010). Immediately prior to this closure, the rudimentary forebrain, which later forms most of the cerebrum; midbrain (brain stem); and hindbrain (cerebellum) are formed. The anterior of the neural tube forms the anterior neuropore; the hollow sections of this develop into the two ventricles of the brain (Ortinau & Neil, 2015). This region is known as the VZ[7] and high numbers of stems cells lie within it, these stem cells are present in order to commence the process of neuronal proliferation (Stiles & Jernigan, 2010).

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[6] Organisation for Economic Co-operation and Development

[7] Ventricular Zone

1.5.1.3 Neuronal Proliferation

Neuronal proliferation starts in the first gestational month and peaks at around four months' gestation (Stiles & Jernigan, 2010). Due to this expansion in cells, the VZ increases in volume and surface area. The VZ diminishes from around 15 weeks' gestation to be a single layered structure at 25 to 27 gestational weeks (Budday et al., 2015). Neurogenesis within the VZ continues into the third trimester of pregnancy (28 weeks' gestation) (Ortinau & Neil, 2015). This process is therefore continuing within the very preterm birth gestational period.

Additionally, the VZ contains a bed of immature endothelial layer: the "germinal matrix". This produces neurons and glial cells and is present between 8 to 36 weeks of gestation but is in a reduced form after 25 weeks. This germinal matrix is very vulnerable to rupture during birth in preterm infants (Ortinau & Neil, 2015). Rupture of the germinal matrix is a frequent cause of intraventricular haemorrhage within very to moderately preterm births (Jones et al., 2018). This rupturing carries an elevated risk of both mortality and morbidity to the preterm infant (Choi et al., 2023).

Neurons move from the VZ to their end location, chiefly during 3 to 5 months' gestation but continuing to 9 months' gestation. These projecting neurons are also a frequent pathway for white matter brain injury in preterm infants (Ortinau & Neil, 2015).

1.5.1.4 Cortical Plate Development

As the size of the VZ develops, neurons migrate to the "pial" (the top layer of the developing brain) and form a pre-plate which then forms the cortex (Ortinau & Neil, 2015). The developing cortex is made up of six layers which are all developed by seven months' gestation (Ortinau & Neil, 2015). Neural axons move to the cortex at 32 to 36 weeks' gestation (Kostović & Judaš, 2010). Therefore, the timing of these events is a key factor in preterm brain injury, as preterm birth results in this neural development taking place ex-utero (Ortinau & Neil, 2015).

1.5.1.5 Neuronal Organisation

The development of neural axons and dendrites takes place within the third gestational trimester and continues into the early post-natal period (Haynes et al., 2005). This growth in dendrites and axons is partly responsible for a four-fold increase in cortical grey matter volume between 30 to 40 gestational weeks (Hüppi et al., 1998). Synaptic connections between axons and dendrites mainly occurs in the third trimester of pregnancy and into infancy, peaking at around age 2 years (Huttenlocher & Dabholkar, 1997).

The last stage to commence in organisation is glial proliferation. Here, glial cells from the VZ develop astrocytes and oligodendrocytes (Billiards et al., 2006). A further division of glial: microglia (part of the immune system) move from the germinal zones to white matter at 23 to 35 weeks' gestation (Billiards et al., 2006). Again, this is at in critical point in terms of preterm birth, including LPT birth.

Additionally, 32 to 40 gestational weeks have been suggested to be a critical period (defined in Section 1.5.3) for the network in the brain known as the "default mode network" (Degnan et al., 2015). This is a "resting state network," where a correlated signal occurs in related areas of the brain at times when there are no stimuli (Biswal, 2015). The default mode network is posited to have a role in introspective thought and integrating associated information (Pfefferbaum et al., 2011).

1.5.1.6 Myelination of Neurons

Myelination is thought to commence in the fifth month of gestation and is largely complete by age 2 years (Morell & Quarles, 1999). Pre-oligodendrocytes are cells that generate myelination (Kuhn et al., 2019). These pre-oligodendrocytes are prone to damage due to hypoxic ischemic encephalopathy, a brain injury due to lack of oxygen at time of birth, which is very associated with preterm birth and subsequent increased neurological disorders (Gopagondanahalli et al., 2016).

1.5.2 Known Impact of LPT on the Brain in Childhood

Rice and Barone (2000) suggest that adverse brain development may be the result of two factors: firstly, whether an agent reaches the developing nervous system and subsequently damages it and, secondly, the timing of any adverse exposure. They suggest that such exposure on the developing brain can interfere with the developmental process, and that organs such as the brain are less vulnerable to damage if the exposure occurs before or after the development phase. As preterm birth, including LPT birth, happens at a time when many areas of the brain are still developing, this increases the brain's vulnerability.

The latter half of gestation is argued to be a "critical period" for brain development due to the neural changes that occur at this time (Kinney, 2006; Matthews et al., 2018; Volpe, 2022). Critical periods are time sensitive, irreversible developmental phases where disruption cannot be remedied (Kinney, 2006; Rice & Barone, 2000). Therefore, birth at this time may fundamentally change the course of neural development: it is notable that the volume of the brain at 34 weeks' gestation is only around 65% of the brain's volume at full term, illustrating the amount of neural development yet to occur (Kinney, 2006). The prefrontal cortex also experiences many organisational changes at 32 to 34 weeks' gestation (Mrzljak et al., 1988). Similarly, Hüppi et al. (1998) found myelination increased fivefold after 34 weeks' gestation.

1.5.2.1 Impact of PVL and Cerebral Palsy

A notable adverse outcome for children born very preterm is PVL[8] which affects white matter brain structures. However, even children born LPT are at increased risk of PVL compared to term births (Haynes et al., 2013; Karnati et al., 2020). This illness has a notable effect on brain development, as PVL results in softening of the brain's white matter. The oligodendrocytes, the pre-myelinating cells of the brain, are highly affected by PVL. This often results in cerebral white matter injury, but this may also damage the thalamus, basal ganglia, cerebral cortex, brain stem and cerebellum (Volpe, 2009).

Additionally, children who have had PVL have a much higher incidence of cerebral palsy (Back et al., 2001; Kinney, 2006). There is an increased risk from cerebral palsy for all preterm gestations compared to full term, with children born LPT at around three times the risk of full term births (Pettinger et al., 2023).

1.5.2.2 Differences in Brain Matter between Children Born LPT and Full Term

Difference in the brain between children born LPT and full term have been seen from birth and into later childhood. White matter injury and increased number of glial cells have been found immediately post-birth in autopsy studies of children born LPT (Haynes et al., 2013). Similarly, Zhang et al. (2024) found lower neural response and functional connectivity in babies born LPT at age one month, compared to babies born at term.

Walsh et al. (2014) investigated the neural impact in children born moderately/LPT at full term equivalent gestation, i.e. the time when the child would have been at 40 weeks' gestation. They found that children born moderately/LPT had smaller brains, including smaller corpus callosum and cerebellum, with less advanced myelination and

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[8] Periventricular Leukomalacia

gyral formation than children born at full term gestation. Similarly, Kelly et al. (2016) found that at full term equivalent gestation, children born LPT had differing white matter microstructure, including in the corpus callosum, to children born at full term. Thus suggesting delayed or disrupted development when compared to full term births. Additionally, grey matter volume has been found to be reduced at full term equivalent gestation for children born LPT, compared to children born at full term (Munakata et al., 2013).

Some of these neural differences are still apparent in childhood. Rogers et al. (2014) found decreased total grey matter; cranial volume; smaller right temporal volume; and reduced parietal grey matter volume, as well as less right parietal lobe cortical surface area, in children born LPT relative to full term, at age 6 to 12 years. Degnan et al. (2015) found that children born LPT, relative to children born full term, at age 9 to 13 years had increased connectivity in several resting state networks and altered functional connectivity to the parietal cortex. Similarly, Brumbaugh et al. (2016) found that between age 6 and 13 years, children born LPT compared to children born at full term had increased cerebrospinal fluid; less intracranial tissue; cerebrum tissue; subcortical tissue; a smaller amount of cortical surface areas; and a smaller thalamus. Therefore, there is evidence of subtle brain differences in children born LPT in later childhood that may be implicated in neurodevelopmental issues.

1.6 Immediate Health Risks Following LPT Birth

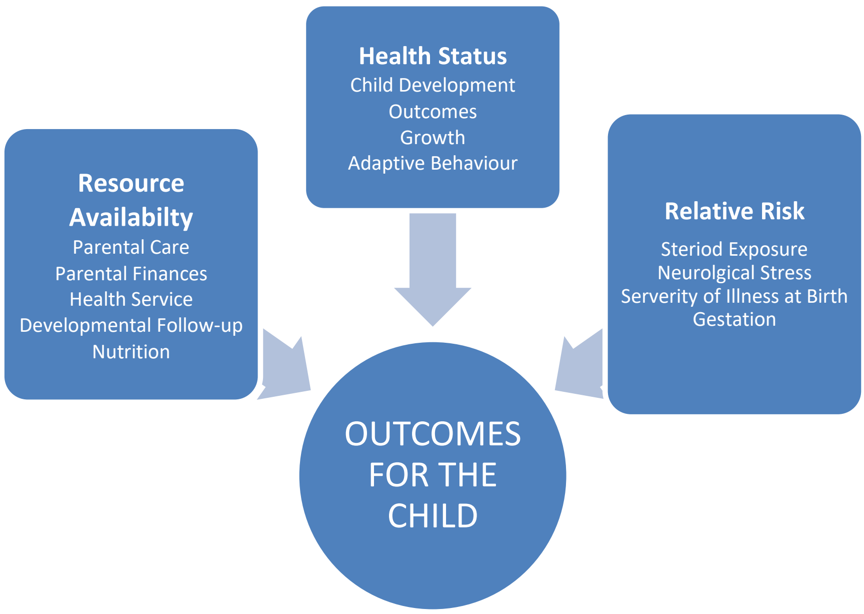
Immediately following birth, LPT birth carries an increased risk of infant mortality compared to term births, together with an increased hospitalisation risk (Bulut et al., 2016; McIntire & Levono, 2008; Shapiro-Mendoza et al., 2008; Tomashek et al., 2006). Children born LPT are at a heightened risk for respiratory distress (Wang et al., 2004); central nervous system problems (Mekic et al., 2023); infections; jaundice (Sarici et al., 2004; Wang et al., 2004); temperature instability and hypoglycaemia (Wang et al., 2004), compared to full term births. Therefore, children born LPT have an increased health risk which may also impact on their later development (D. Field et al., 2016; Pettinger et al., 2023).

1.7 Theoretical Framework of Risk for Children Born Preterm

Risks from preterm birth to health and neurodevelopment can be increased by existing health and SES factors. This may be observed within the Preterm Infant Vulnerability to Neuro-morbidity Model (Purdy et al., 2008). This model, shown in Figure 1-4, highlights the risk to the child formed by health status, relative risks, and resource availability, based on the Synactive Model of Als (1986). These factors may be protectors or stressors within the child's system (Purdy et al., 2008). Within the model, children born LPT are at greater relative risk from their birth gestation than children born at full term, but at a lower risk than children born at moderate and very preterm gestation.

Figure 1-4

The Preterm Infant Vulnerability to Neuro-morbidity Model (Purdy et al., 2008)



1.8 At Risk Sub-Groups

Reflecting the Preterm Infant Vulnerability to Neuro-morbidity Model, there has been a suggestion of higher impact of preterm birth in at risk sub-groups. Eryigit Madzwarmuse et al. (2015) found that being from disadvantaged SES carried increased risk for worse IQ[9] and executive function in children born preterm. Additionally, boys born preterm have been found to be at greater risk than girls born preterm for lower educational achievement (S. Johnson et al., 2009; Wolke et al., 2008).

[9] Intelligence Quotient

1.9 Enhanced Surveillance Following Preterm Birth

In the UK, guidelines provide that babies born before 30 weeks' gestation are routinely provided with enhanced post-natal surveillance to the age of two years for development disorders, and children born before 28 weeks' gestation also have a developmental assessment at age 4 years (National Institute for Health and Care Excellence, 2017). Whilst babies born LPT do not have access to enhanced follow-up care and monitoring, unless they have an identified medical condition (National Institute for Health and Care Excellence, 2017). Furthermore, babies born LPT have generally been grouped with term births in neonatal care (Boyle, 2020). Consequently, they have been described as 'the forgotten' infants due to a lack of the required support at birth and in early life (Demestre, 2017).

Therefore, children born LPT are perhaps more dependent on the surveillance by teachers within school to identify any issues. In an average UK primary class, there is likely to be two children who were born preterm (Bamber et al., 2019).These will generally be of LPT gestation, as it is the largest preterm group (Office for National Statistics, 2024). However, there is a widespread view in the general public that being born LPT makes little difference and therefore families may not be vigilant for any post-natal issues (Boyle, 2020). Additionally, a study by S. Johnson et al. (2015) found that only 16% of teachers had had any training in the potential educational difficulties facing children born preterm, and 62% of teachers felt ill-prepared to support such children. Therefore, there is both a lack of screening for children born LPT and lack of parental and teacher awareness of the potential issues.

As a result, there have been calls for increased surveillance for this LPT group prior to school entry (Hurtado Suazo et al., 2014; Peacock et al., 2012; Sandoval et al., 2022). However, given the high numbers of children in this group, this may not be feasible (Boyle, 2020). Therefore, there are also calls for further research in trying to establish the sub-groups that are most vulnerable as well as risk and protective factors for these children (Cheong & Doyle, 2020). Alternatively, automated behind-the scenes tracking might be an option, linking routine health and education data to identify children at risk of developmental disorders (B. Wright et al., 2019). On the other hand, Missiuna et al. (2017) suggest a "partnering for change" model that involves collaboration between teachers and health workers to observe children in school to identify children at risk (not specifically preterm) of struggling in school, without the use of standardized assessments. Therefore, greater multi-agency working and routine automated follow-up might be of benefit to children born LPT.

1.10 Later Outcomes in Children Born at LPT Gestation

Children born LPT have been found to have poorer neurodevelopmental outcomes than children born at full term (Baron et al., 2011; Chan & Quigley, 2014; Louis et al., 2022; Quigley et al., 2012; Woythaler et al., 2015). However, this is relatively less explored when compared to outcomes following very preterm birth, and findings are somewhat inconsistent (Kerstjens et al., 2011; Martínez-Nadal & Bosch, 2020). This includes outcomes in the areas of educational achievement; executive function; and graphomotor skills which are discussed in more detail in the following sections, together with a synopsis of the current evidence in these areas.

1.10.1 Education Achievement

1.10.1.1 Conceptualisation of Educational Achievement

A primary area where a poorer outcome has been seen in children born preterm is educational achievement (Aarnoudse-Moens et al., 2009, 2011; Alterman et al., 2022; Chan & Quigley, 2014; Jansen et al., 2020; S. Johnson et al., 2009; Libuy et al., 2023; Pritchard et al., 2009; Quigley et al., 2012; Richards, Drews-Botsch, et al., 2016; Roberts et al., 2011; P. E. Shah et al., 2016; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018; Twilhaar, de Kieviet, van Elburg, et al., 2018).

However, operationalising the concept of educational achievement is complex, and the definition of success may vary. A frequent outcome measure is school grades or grade-point average (York et al., 2015). Therefore, the approach taken in this thesis is to examine differences between children born LPT, and those born full term using these school grade assessments. Such educational achievement has been shown to be more predictive of life outcomes, as it is thought to reflect personality aspects that have independent predictive power outside of that seen in IQ and other cognitive tests (Borghans et al., 2016).

The educational achievement of children born very preterm has been well researched and has found that children born at this gestation generally perform at a poorer level than their full term born counterparts (Aarnoudse-Moens et al., 2009, 2011; Guarini et al., 2019; Jansen et al., 2020; S. Johnson et al., 2009; Pritchard et al., 2009; Richards, Drews-Botsch, et al., 2016; Roberts et al., 2011; P. E. Shah et al., 2016; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018; Twilhaar, de Kieviet, van Elburg, et al., 2018). However, as will be evident from the next section, there is less certainty and evidence of this for children born LPT.

1.10.1.2 Achievement Differences at the Outset of School

There have been a few studies finding increased odds of children born LPT not being school ready (Louis et al., 2022; Quigley et al., 2012; Woythaler et al., 2015). However, two studies did not find a statistically significant difference between children born LPT and term-born children once covariates were controlled (Crockett et al., 2022; Morse et al., 2009). School readiness is broadly defined as the skills a child needs to start school (Ofsted, 2014). A potential issue with these studies is that components of school readiness are not a clearly defined, even nationally (Ofsted, 2014). This issue is discussed in more depth in Section 3.1.1. Consequently, the underlying measures vary which may possibly explain the differing findings.

Additionally, the school readiness measures often include learning areas that are not assessed again in school, such as social skills (Crockett et al., 2022; Quigley et al., 2012), and this makes it difficult to observe whether differences continue after school entry into later education. The current curriculum in England at age 5 years (the outset of school) examines mathematics, reading and writing. These subjects are examined again in each statutory assessment after this age, thereby providing the opportunity to compare the effect of LPT birth at differing ages. This thesis fills the literature gap of a lack of a comparable measure at age 5 years on school entry, by providing a consistent metric of measurement at the outset of school and at ages 7 and 11 years in the study in Chapter Three to evaluate educational achievement.

1.10.1.3 Assessment in Mid-Primary School

A previous study by Chan and Quigley (2014) investigated differences in overall education achievement in children born LPT compared to children born full term, at age 7 years, finding increased odds of not achieving developmentally expected levels of overall educational achievement. However, the effect size observed for in children born LPT was small in comparison to maternal education; gender; and school attendance. Nevertheless, these factors would be compounding for some children born LPT, as maternal education is also a predictor of preterm birth (as shown in Table 1-2).

Similarly, Peacock et al. (2012) found children born moderately/LPT had increased odds of not achieving expected levels of development at age 7 years, but this study merged the two gestational groups of moderately preterm and LPT, meaning adverse effects could potentially come from the moderately preterm gestational group, but not the LPT gestational group.

Therefore, the current evidence is that children born LPT are likely to have increased odds of not reaching the age-related expected levels of attainment but given that there has only been one study investigating this, it would be useful to verify this effect in an additional study. Consequently, whether children LPT have reduced overall educational achievement at age 7 years, compared to full term births, is examined in Chapter Three of this thesis.

1.10.1.4 Assessment at the End of Primary School

There is only one existing study examining educational achievement outcomes at the end of primary school in children born LPT and early term (Alterman et al., 2022). This found no increased relative risk for overall educational achievement for children born LPT, but did so for children born at early term gestation. This result is somewhat unexpected given the theorised reverse gestational gradient of risk, where health and developmental outcomes improve the closer birth is to 40 weeks' gestation (Boyle et al., 2012). Consequently, as this is the only existing study found, it would be useful to verify the effect in a later sample of children born LPT.

In England, since the above studies of educational achievement took place in children aged 5, 7 and 11 years (Alterman et al., 2022; Chan & Quigley, 2014; Peacock et al., 2012; Quigley et al., 2012), a new national curriculum has been introduced (British Association for Early Childhood Education, 2012; Department for Education, 2013). Existing policy and practice are therefore currently based on out-of-date information on the effect of LPT birth on educational achievement.

Additionally, monitoring and surveillance arrangements for the development of children born at very and extremely preterm gestations have increased in the last decade (National Institute for Health and Care Excellence, 2017). This may have led to increased support due to this improved surveillance for the very and extremely preterm gestational group but there are no such arrangements for children born LPT. Furthermore, austerity measures since 2010 have changed practices and managerial structures in education, resulting, for example, in less teaching assistants within schools (Lewis & West, 2017; Martindale, 2022; UNISON, 2018). This may have increased the adverse effect of LPT birth, as the child may resultantly have had less in-school support. Therefore, outcomes of educational achievement in children born LPT warrant further examination in a more current sample exposed to the existing educational system.

1.10.2 Trajectory of Educational Scores

Children born LPT may exhibit poorer level of attainment than children born at full term gestation at the outset of school, as suggested by the studies that find less school readiness (Louis et al., 2022; Quigley et al., 2012; Woythaler et al., 2015). However, there is some evidence that they display a differing learning trajectory to children born full term and have begun to catch up with their full term peers towards to end of their primary education (Alterman et al., 2022; Crockett et al., 2022; Odd et al., 2019).

Alterman et al. (2022) suggest that children born LPT appear from the results in their study to catch up with children born at full term, but recommend that a longitudinal study using a consistent longitudinal sample be conducted to verify this. Similarly, van Beek et al. (2021) suggests that educational and cognitive differences may be present in children born preterm at certain ages but not another and differences may also be remedied over development. This is discussed at greater length in Chapter Four, but this section provides an overview of findings in this area.

There have been very few studies examining educational achievement scores longitudinally in preterm children, either as an entire group or by gestational groups. In the only study looking at children other than those born specifically very preterm, Odd et al. (2019) found that children born preterm as an entire group (i.e. gestation of < 37 weeks), did experience some catching up in their educational scores between the age of 7 and 11 years, with a slower rate of catching up experienced after this point. Interestingly, in sensitivity analysis by gestational group, the moderately/LPT group had statistically significant catching up in their educational scores between the ages of 7 and 16 years, with most of this taking place between 7 and 11 years. Whilst the extremely/very preterm children also experienced catching up in their scores, the rate observed was lower than the moderately/LPT children. However, the rate of increase for the moderately/LPT gestational group was not statistically significant at other ages (11 to 14 years and 14 to 16 years) and the overall effect of catching up was therefore mainly driven by the period from 7 to 11 years.

Nevertheless, results from a further study which investigates outcomes for the very preterm gestational group specifically, do not replicate Odd's findings, with no evidence found of catching up in educational scores (Twilhaar, de Kieviet, van Elburg, et al., 2018). It is posited that preterm birth may produce restrictions on brain plasticity, potentially limiting the scope of change in the trajectory of development (Trickett et al., 2020). Therefore, whether any catching up is experienced remains a debatable issue, and one where further work would be of value.

There are, therefore, somewhat contradictory findings in the very preterm group in longitudinal studies. Whilst the LPT gestational group has only been examined in the context of the wider gestational group of moderately/LPT and then only from age 7 years. However, Baron et al. (2012) suggest that it is preferable to examine the LPT gestational group separately from the moderately preterm gestational group due to differing development outcomes often being observed. Additionally, no study has investigated longitudinal outcomes from the outset of school at age 5 years. This thesis seeks to remediate these gaps by providing a study looking at LPT outcomes from age 5 to 11 years.

1.10.3 Executive Function

Executive function is a group of higher-order processing skills that are required in problem solving and goal-orientated behaviour (Baggetta & Alexander, 2016; Diamond, 2013). Children aged 5 to 10 years are believed to have a two-component model of executive function consisting of “inhibition/shifting” skill and “working memory” skill (Brydges et al., 2014; K. Lee et al., 2013; Messer et al., 2018; Shing et al., 2010). Inhibition is the deliberate suppression of a dominant or automatic response and shifting is the ability to switch attention between tasks. Whereas working memory is the revising and monitoring representations held in the brain (Miyake et al., 2000). Processing speed, the speed at which information can be processed (Kail & Salthouse, 1994), is also important in the execution of executive function skills (Fry & Hale, 1996, 2000; Hulme et al., 1984). These executive function skills have been found to be predictive of academic attainment (Alloway & Alloway, 2010; Cortés Pascual et al., 2019; Gathercole et al., 2004; Gathercole & Pickering, 2000). Further details of the conceptualisation of executive function are included in Section 5.1.1.

1.10.3.1 Children Born Preterm and Executive Function

Children born very preterm have been found to have worse overall executive function (Loe et al., 2014, 2019; López Hernández et al., 2022; Reynold De Seresin et al., 2023), but the findings for children born LPT suggest no overall deficit (Brumbaugh et al., 2013; Hodel et al., 2019). However, executive function is often considered by individual component and in these results findings for children born LPT have varied, with some components not yet examined.

1.10.3.2 Children Born at LPT Gestation and Working Memory

No study has specifically looked at VWM[10] between the ages of 5 to 11 years in children born LPT. However, results before the age of 5 years generally find no effect (Baron et al., 2009, 2011), and nor do studies in the 5 to 11 years age range in the wider moderately/LPT gestational group (Cserjesi et al., 2012; Reijneveld et al., 2021).

Similarly, there are no existing studies of CWM[11] in children aged 5 to 11 years in children born LPT. However, existing studies before the age of 5 years suggest worse CWM (Baron et al., 2011; Hodel et al., 2016). Whilst this adverse effect appears not to persist into by adulthood (Suikkanen et al., 2021).

In VSWM[12] no detrimental effect has been found for children born LPT either before the age of 5 years (Baron et al., 2009; Brumbaugh et al., 2013), or between 5 to 11 years (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016). However, neither of these studies controlled for processing speed, which is an important factor in working memory (Rose et al., 2011), and the study by Baron Weiss, Litman, et al. (2014) did not control for SES factors. Potentially, different results may be reached if these two factors are controlled.

This thesis seeks to address these knowledge gaps by adding a study of VWM and CWM in children born LPT for the first time. It addresses the methodology issues of previous studies in VSWM (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016) by using a good range of SES covariates and examines the results before and after adjustment for processing speed.

1.10.3.3 Children Born at LPT Gestation and Inhibition

There is no existing study investigating the inhibition skills of children born LPT, compared to full term births. However, two studies have been conducted in the wider moderately/LPT gestational group, one finding poorer verbal inhibition skills in children born moderately/LPT results (Cserjesi et al., 2012), and one finding no difference in children born moderately/LPT in motor inhibition skills (Reijneveld et al., 2021). Neither

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[10] Verbal Working Memory

[11] Complex Working Memory

[12] Visuo-Spatial Working Memory

study controlled for the effect of processing speed, which has been suggested to affect executive function (Rose et al., 2011).

Therefore, the study in Chapter Five, examines inhibition in the narrower gestational group of LPT, reflecting the argument of Baron et al. (2012) that the moderately preterm and LPT gestational groups have differing developmental outcomes. It also examines whether the inclusion of processing speed alters the results.

1.10.3.4 Children Born at LPT Gestation and Processing Speed

Two studies found that children born LPT had worse processing speed between the ages of 5 and 11 years (Brumbaugh et al., 2013; Jin et al., 2020). However, both studies had LPT sample sizes of less than 40 children. Low sample sizes can find effects that are not generalizable to the wider population (Button et al., 2013; Tipton et al., 2017). Therefore, examining whether an adverse effect is still present in a larger sample would be useful in establishing any detrimental effect.

Thus, there are a number of elements of executive function (VWM, CWM and inhibition) where the specific effect on children born LPT is not yet known as this has not yet been examined. The methodology of previous studies can be improved by increasing the LPT sample size (Brumbaugh et al., 2016; Jin et al., 2020). Additionally, improvements can be made by examining whether the inclusion of processing speed affects the results, compared to existing studies which did not control for this in studying inhibition (Cserjesi et al., 2012; Reijneveld et al., 2021) and in VSWM (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016). All these elements are addressed in the study in Chapter Five of this thesis.

1.10.4 Graphomotor Skills

An additional area predictive of educational achievement is graphomotor skills (Carlson et al., 2013; Dinehart & Manfra, 2013; Feder & Majnemer, 2007; Giles et al., 2018; Grissmer et al., 2010; Shire, 2016). The next section provides an overview of the conceptualization of graphomotor skills within this thesis and then provides a summary of the existing studies in the graphomotor outcomes of children born LPT, relative to full term. It also identifies the gaps in our current knowledge of the graphomotor skills of children born LPT. A more detailed explanation of the conceptualisation and findings from existing studies is contained within Chapter Six.

1.10.4.1 Conceptualising Graphomotor Skills

Graphomotor skills, the penmanship skills required for writing (Ghanamah et al., 2020; Suggate et al., 2019), are a category of FMS[13]. FMS are skills that require small accurate muscle movements, often in the hand, and hand-eye coordination (Luo et al., 2007). FMS can be examined in either process-oriented assessment; investigating the quality of the movement performed, or product-oriented assessment; examining the completed task. Kinematic assessment, using computer-aided devices to assess movement quality, is a form of process-oriented assessment (Barnett et al., 2020).

1.10.4.2 Children born at LPT Gestation and Graphomotor Skills

Children born very preterm have been found to have poorer levels of graphomotor skills at school age (Bolk et al., 2018; Caravale et al., 2012; Constable et al., 2008; Cooke, 2003; Dathe et al., 2020). However, the graphomotor outcomes of children born at LPT compared to full term, have been less examined, with only two existing studies. These found contradictory results of poorer graphomotor outcomes in children born LPT (Ibrahimi et al., 2023), and no difference in graphomotor outcomes in children born LPT, when compared to full term births (Brumbaugh et al., 2016). Both of these studies took place in product-oriented assessment. They also used a wide-ranging age band of children, of 5 to 12 years for Ibrahimi et al. (2023), and 6 to 13 years for Brumbaugh et al. (2016).

However, it has been posited that motor skills may change over time, and this has been observed in children born very preterm, where elements of poorer FMS have been seen at an early age but not later (Domellöf et al., 2018; M.-X. Liu et al., 2023; Sagnol et al., 2007). This may be linked to changes in postural stability, which partially underlies graphomotor control (Flatters, Mushtaq, et al., 2014). Additionally, aiming and reaching skills, which also underlie graphomotor skills, develop between the ages of 4 to 12 years (Kuhtz-Buschbeck et al., 1998). Results in kinematic assessment of the graphomotor skills of children born very preterm also suggest a possible transition in skills at around the age of 5 years that was not seen in children born at full term (Sagnol et al., 2007). There are, however, no studies specifically investigating the graphomotor outcomes using kinematic assessment in children born LPT.

[13] Fine Motor Skills

The existing literature therefore presents a gap in knowledge of the graphomotor skills of children born LPT in kinematically assessed outcomes. Given the findings from product-oriented assessment using wide age ranges, and the implication from very preterm studies (Domellöf et al., 2018; M.-X. Liu et al., 2023; Sagnol et al., 2007) of potentially differing effects by age, it would be useful for a further study to examine these graphomotor outcomes in children born LPT. This should use more discrete age groupings and would benefit from using an alternative method of assessment, such as kinematic testing. This is therefore investigated within the Chapter Six study of this thesis.

1.11 Conclusion

Within this chapter, I have defined the key concepts and theoretical frameworks relevant to my thesis and justified the thesis' focus on LPT birth. The risk factors for preterm birth, and its prevalence over time and by ethnicity have similarly been discussed. The chapter also provided a rudimentary overview of brain development and the effect this may have on the LPT-born child. The review of existing studies of LPT birth and educational achievement; the trajectory of educational scores; executive function; and graphomotor outcomes has identified several key areas where there were clear gaps in understanding, which it would be of practical benefit to educators and policy makers to fill.

In educational achievement, it was identified that at the outset of school the use of school readiness measures (Crockett et al., 2022; Morse et al., 2009; Quigley et al., 2012; P. E. Shah et al., 2016) to evaluate whether children were reaching age-related expected standards of educational achievement made study comparison difficult, both in terms of comparing studies from differing countries, and by age. There was only one study examining overall educational achievement in the mid-point of primary school (Chan & Quigley, 2014) and one study examining these outcomes at the end of primary school (Alterman et al., 2022). The findings in this study by Alterman et al. (2022) found a negative effect for being born early term but not LPT. This finding is unexpected, given the theorised reverse gradient of gestational outcomes (Boyle, 2020) and therefore a further study examining this would be particularly useful. The study in Chapter Three therefore examines a consistent definition of overall educational achievement (results in reading, writing and mathematics) at ages 5, 7 and 11 years, thereby remediating the gaps found within the existing literature.

Additionally, the review of the literature showed that there had not been a study considering the educational score trajectory of children born LPT specifically, but there had been one which included a sensitivity analysis of the moderately/LPT gestational group (Odd et al., 2019). This trajectory analysis by Odd et al. (2019) commenced at age 7 years, rather than the outset of school at age 5 years, but did suggest some catching up in educational scores. This leaves us without knowledge of the effect in the LPT gestational group from age 5 years to the conclusion of primary school at age 11 years. The study in Chapter Four remedies this by providing a study that investigates educational scores in statutory school tests from age 5 years to age 11 years, considering the trajectory for children born LPT specifically, compared to children born at full term.

In executive function outcomes, it was demonstrated that there are several elements of executive function that have not been specifically examined in children born LPT at primary school age (age 5 to 11 years), including VWM and CWM. There is also the potential to improve on the methodology of previous studies with the inclusion of processing speed as a covariate for inhibition and VSWM. The study in Chapter Five therefore examines VWM and CWM for the first time in children born LPT in this age group. It also includes analyses with, and without, the inclusion of processing speed for the executive function outcomes (VWM, CWM, VSWM and inhibition).

It was notable that there has been no graphomotor study conducted examining outcomes for children born LPT using kinematic assessment. Furthermore, findings of graphomotor outcomes in the very preterm gestational group have been found to differ by age group (Domellöf et al., 2018; Sagnol et al., 2007). Therefore, the study in Chapter Six investigates kinematically assessed outcomes in children born LPT (as well as VMPT, early term), compared to those born full term, in two age ranges (4 to 5 years and 7 to 10 years).

This thesis seeks to fill these gaps in our knowledge of neurodevelopment for children born LPT. This is a large group of children who do not currently have any enhanced surveillance for neurodevelopmental difficulties (National Institute for Health and Care Excellence, 2017), as explained in Section 1. 9. The next chapter (Chapter Two) explains the methods to be used in the thesis' studies. This is followed by the studies themselves in Chapters Three to Six. These studies pursued the general aim of the thesis to investigate the impact of LPT birth compared to full term birth on educational, executive function, and graphomotor outcomes.

Chapter 2 Methods

2.1 The Context of the Research: The BiB Cohort Study

Studies in this thesis use data obtained from the BiB birth cohort (https://borninbradford.nhs.uk). BiB is a longitudinal, multi-ethnic study, established in 2007 in Bradford. The cohort study's purpose is the examination of genetic, nutritional, environmental, behavioural, and social factors in children born in the city from birth into adulthood. The cohort study was created in response to concerns regarding childhood mortality and morbidity in the Bradford area (J. Wright et al., 2013).

2.1.1 The City of Bradford

Bradford is a city in West Yorkshire, in the North of England. The Bradford district is the 13th most deprived local authority area in England (City of Bradford MDC, 2020a). It also has the 10th highest proportion of children living in absolute low-income families in England (Department for Work and Pensions, 2023). This poverty is mainly within the inner-city areas, with around half of the children who live in poverty residing in eight of the district's 30 wards (City of Bradford MDC, 2020b). Additionally, Bradford has higher rates of adults with no qualifications (12%), than the national rate for England (7%), or the regional rate for Yorkshire and Humberside (8%) (Office for National Statistics, 2023a). In Bradford around 26% of the population are of Pakistani origin (City of Bradford MDC, 2022). However, the city is increasingly multicultural and almost half of babies born in the city are of Pakistani heritage (J. Wright et al., 2013).

2.1.2 Recruitment to the Cohort

Recruitment to the BiB birth cohort took place between March 2007 and November 2010. The city has one maternity unit (the Bradford Royal Infirmary) which delivers around 6,000 babies annually. All mothers attending the maternity unit are offered an oral glucose test at 26 to 28 weeks' gestation to assess for gestational diabetes. Approximately 80% of mothers accept this offer and this appointment was used to recruit participants to the BiB study. Fully informed consent was provided from those agreeing to take part (J. Wright et al., 2013). Mothers, and fathers where possible, provided demographic information and consented to data linkage of their own and their child's health and educational records (J. Wright et al., 2013).

2.1.3 BiB Data Collection Timeline

The BiB cohort seeks to collect data from childhood and into adulthood for participating children (J. Wright et al., 2013). As well as the background information provided by the child's mother, routine educational data is collected on statutory school assessments and in-school educational information (such as special educational needs and free school meals). This data is obtained from Bradford Education Authority and is then included in the BiB dataset.

The BiB team have also completed two in-school data sweeps to date: the Starting School sweep, when the children were aged 4 to 5 years old (Shire et al., 2020), and the Primary School Years sweep when the children were aged 7 to 10 years old (Hill et al., 2021). This thesis uses data from both of these sweeps in Chapters Five and Six. Figure 2-1 illustrates the timeline for collection for the principal BiB databases with dates for the data used within this thesis, including the educational assessment data, and the two data sweeps.

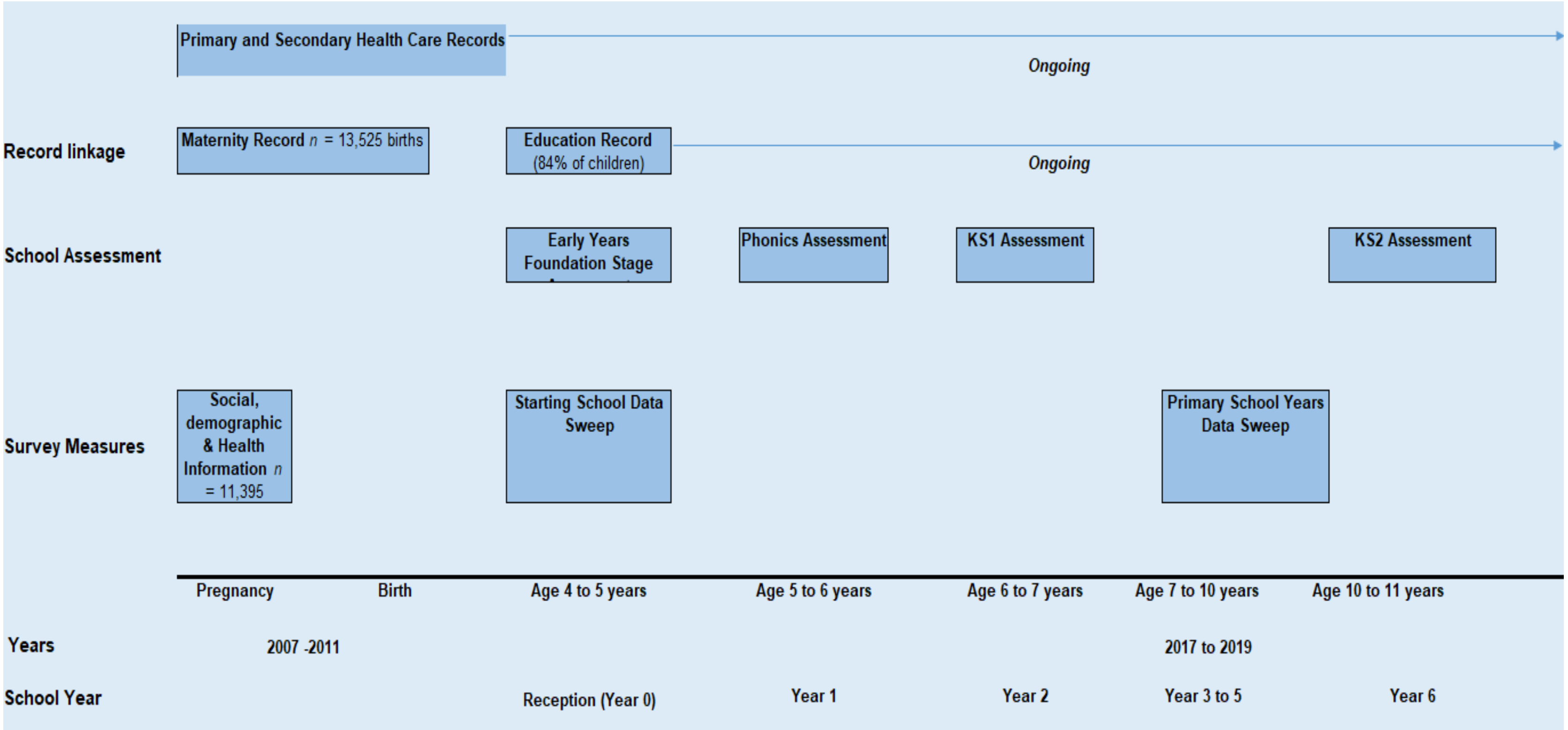
2.1.4 Follow-up Studies: "The Starting School" Data Sweep

The "Starting School" data sweep took place 2012 to 2014 with children in the Reception Year of school. The primary aim of the data sweep was to investigate school readiness. Three domains were selected: physical wellbeing; motor development; and social and emotional development (Shire et al., 2020). Graphomotor skills were selected as a measure of FMS skill and are predictive of academic attainment (Cameron et al., 2012, 2016; Dinehart & Manfra, 2013; Giles et al., 2018; Grissmer et al., 2010).

There were 94 schools asked to participate based on the criteria that they had more than ten children in BIB cohort attending their Reception class. Assessment administrators were trained by staff from BiB and the Universities of Leeds and York. At the schools' request, all the children in the class were eligible to participate, not just children in the BiB cohort (Shire et al., 2020). However, only children from the BiB cohort are considered in this thesis due to requiring their gestational information, which was only present in the BiB cohort dataset.

Figure 2-1

Timeline of Data Linkage and Collection for Data Used in This Thesis



A total of 3,444 children from the BiB cohort took part in the Starting School data sweep. Tested measures included the CKAT[14] (Culmer et al., 2009), which measures graphomotor skill and is described in Chapter Six of this thesis. There were also measures of literacy and communication, as well as the Strengths and Difficulties Questionnaire (both not considered within this thesis). Further details of the Starting School data sweep are available in Shire et al. (2020).

2.1.5 Follow-up Studies: "Primary School Years" Data Sweep

There was an additional data sweep when children were aged 7 to 10 years old, designated the "Primary School Years" data sweep. This took place between 2016 and 2019. Schools were invited to partake if they had a substantial number of children from the BiB cohort within their classes. As in the Starting School data sweep, information sheets were provided to both parents and teachers, consent obtained, and the test administrators were trained by staff from BiB and the Universities of York and Leeds. Also as in the Starting School data sweep, all children in the class were eligible to take part (Hill et al., 2021), but only children from the BiB cohort are considered in this thesis.

The cognitive data from this sweep investigated working memory, inhibition, and processing speed and are considered in Chapter Five of this thesis. Graphomotor skills were once again examined using the CKAT and are considered in Chapter Six of this thesis. These outcome measures are described fully within those two chapters. There were 9,604 children from the BIB cohort participating in the Primary School Years data sweep. Further details of the Primary School data sweep are available in Hill et al. (2021).

2.2 Data Management of the Research Data

An application was made to the BiB Executive Committee for the BiB data required for this thesis. This received approval on the 1st December 2021 (reference number SP445). Subsequently, a data sharing agreement was completed outlining the key provisions of the data sharing, including that the data was kept secure and not shared with any third parties. Additionally, the University of Leeds' Research Data Management Policy was complied with. In compliance with this, the data was kept on

[14]Clinical Kinematic Assessment Tool

the University of Leeds' system; only accessed via a laptop provided by the University of Leeds; and access to the laptop files was password protected.

2.2.1 Ethical Considerations

Ethics approval was obtained from the University of Leeds' School of Psychology Ethics Committee (approval number PSYC-249), as shown in Appendix A. Additional consideration was given to whether further NHS approval was needed using the NHS ethics tool (https://www.hra-decisiontools.org.uk/ethics). This confirmed that additional NHS approval was not required.

2.2.2 Data Protection

All the data was pseudonymized by BiB and transmitted by secure transfer by BiB. Participants in the BiB data are identified via BiB identification numbers and further steps to anonymise the data are included (e.g. exact date of birth is not provided, rather month and year of birth are given). Where the BiB identification number was not included within the sent data (which occurred within the Primary School Years data, where a different identification number was used), BiB provided a linkage database to link this number with the BiB identification number.

2.3 Identification of Covariates to be Used Across the Studies

Observational studies are inherently biased as groups cannot be randomly assigned. One way to reduce bias is to add covariates that also predict the outcome variable (Steyer et al., 2000). The "ignorability assumption" holds where all covariates influencing the treatment or outcome are controlled (Rosenbaum & Rubin, 1983). In the absence of this, selection bias may still be present in the estimated treatment effects (Steiner et al., 2010). Therefore, it important to control for covariates that are likely to predict the outcome. Use of covariates can also decrease the amount of measurement error within a model (Bloom et al., 2007).

Covariates can take the form of confounders, mediators or moderators. A confounder is a covariate that acts upon both the predictor and outcome variable. It affects the outcome variable so that excluding it would bias results and not accurately represent the true relationship between the predictor and outcome (Pourhoseingholi et al., 2012).

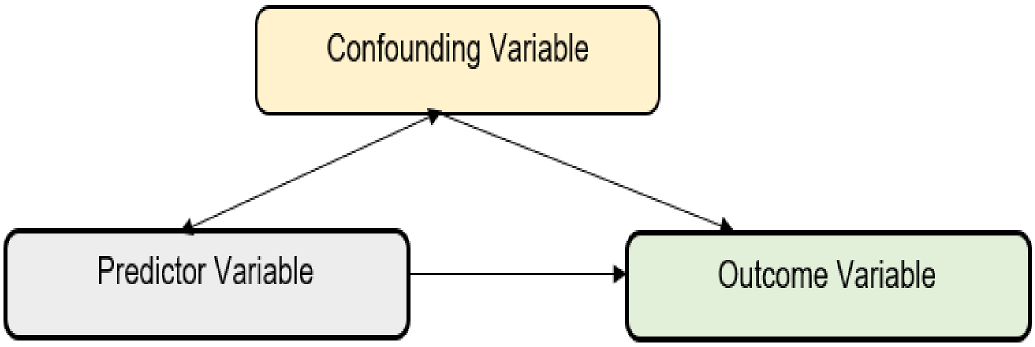
To be a confounding variable, the covariate must display three properties: it must associate with the outcome variable and therefore be a risk for the outcome; it must also be associated with the exposure variable, and therefore the distribution of it between the exposed and unexposed groups is unequal; and lastly, it must not be an effect of the exposure, nor a factor on the causal pathway to the outcome (Jager et al., 2008), as shown in Figure 2-2. Confounders can be controlled for via stratification where sub-groups are formed to stratify the risk from differing groups (Jager et al., 2008).

A moderator variable affects the strength and direction of a relationship between the predictor and outcome variable. A moderator interacts with the predictor variable, and it is this interaction that influences the magnitude or direction of the relationship (Fairchild & McQuillin, 2010).

Finally, a mediator variable is a variable that explains how a predictor and outcome variable are related and is intermediate on the path between them. Therefore, analyses with mediator variables can reveal the direct and indirect effects (Fairchild & McQuillin, 2010).

Figure 2-2

Effect of a Confounding Variable



Note. A confounding variable affects both the outcome variable, the predictor variable and is not on the pathway from the predictor to the outcome variable.

In order to decide the most appropriate covariates, previous studies evaluating preterm birth and education, cognitive and motor studies were drawn on, and a DAG[15] completed. The variables used in previous preterm studies are shown in Table 2-1, and these variables were consequently used for the studies within this thesis. The studies in the thesis also had some specific additional variables, which were relevant solely to that chapter, e.g. handedness in the graphomotor studies in Chapter Five. Where this is the case, this is indicated in the methods section of that particular chapter.

2.3.1 Directed Acyclic Graph (DAG)

Drawing on the theory from previous studies, a DAG was created using DAGitty.net software (Textor et al., 2017). DAGs show the theorised relationship between the predictor(s), the covariates and the outcome variables (Textor et al., 2017). The DAG for this thesis is shown in Figure 2-3. Theorised causal relationships are shown in DAGs by arrows between the variables from believed cause to effect, those without a presumed causal link have no connecting pathway (Williams et al., 2018). DAGs allow identification of the theorised non-causal path and help identify potential mediators and confounding variables in the model (Digitale et al., 2022).

Limitations of DAGs include that they cannot provide insight into the theorised magnitude of the relationships they portray and, due to lack of empirical knowledge by the researcher developing the model, there may be variables that are excluded that should be included. However, they are a useful tool to guide research and identify theorised relationships, and avoid confounding by identifying required covariates (Digitale et al., 2022).

[15]Directed Acyclic Graph

Table 2-1

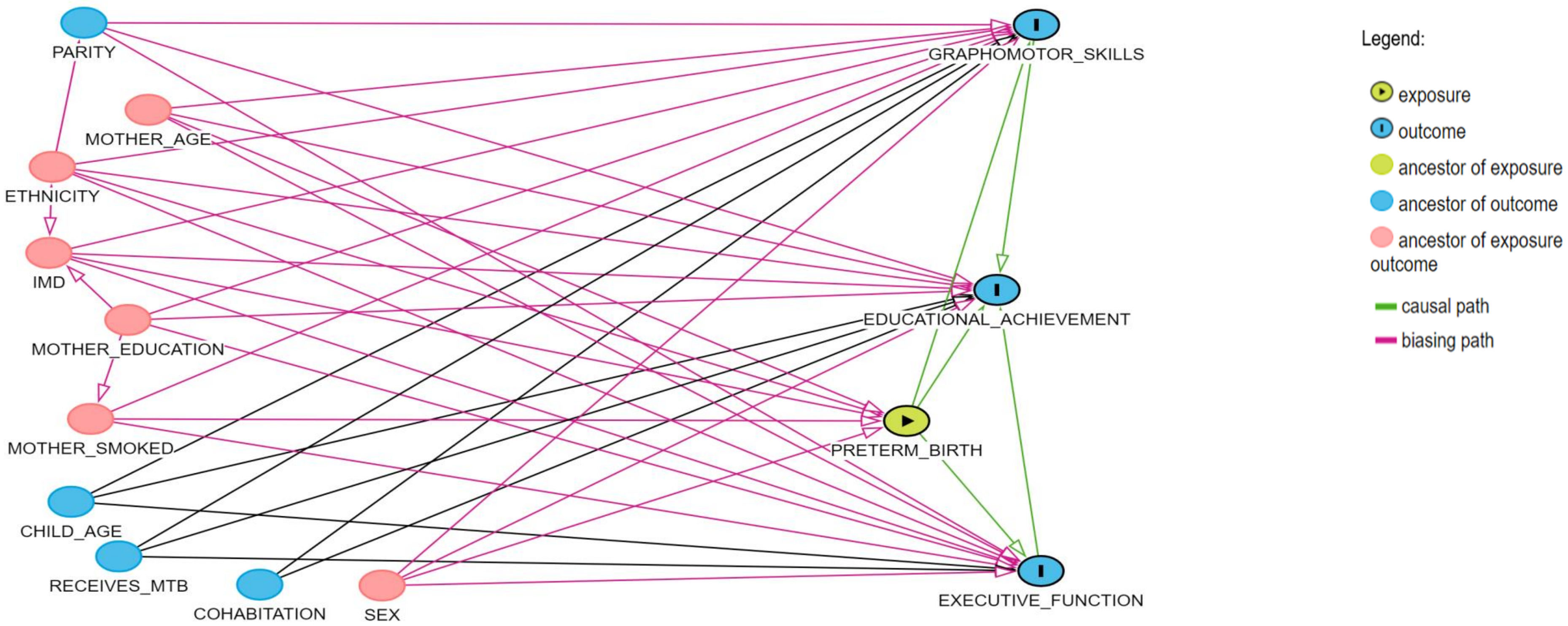
Table of Covariates Used, Drawing on Other Studies of Preterm Birth

Covariate	Previous Studies
Ethnicity	Arnaud et al., 2007; Baron et al., 2009; Baron, Weiss, Litman, et al., 2014; Cameron et al., 2012; Dai et al., 2020; de Jong et al., 2012; Peacock et al., 2012
IMD[16]	Dai et al., 2020; MacKay et al., 2010; Norris et al., 2018; Taylor-Robinson et al., 2011
Maternal Age at the Child's Birth	Arnaud et al., 2007; H. K. Brown et al., 2014; Peacock et al., 2012; Quigley et al., 2012
Maternal Education	Arnaud et al., 2007; Baron et al., 2009; Cameron et al., 2012; Dathe et al., 2020; de Jong et al., 2012; Pettinger et al., 2020; Quigley et al., 2012; P. E. Shah et al., 2016
Means Tested Benefit Receipt	Crockett et al., 2022; Pettinger et al., 2020
Parity	Chan & Quigley, 2014; de Jong et al., 2012; Peacock et al., 2012; Pettinger et al., 2020; Quigley et al., 2012
Sex of Child	Arnaud et al., 2007; H. K. Brown et al., 2014; Cameron et al., 2012; Chan & Quigley, 2014; Dai et al., 2020; Dathe et al., 2020; de Jong et al., 2012; Pettinger et al., 2020; Quigley et al., 2012
Single or Cohabiting Parents	Arnaud et al., 2007; H. K. Brown et al., 2014; Peacock et al., 2012; Quigley et al., 2012
Smoked During Pregnancy	H. K. Brown et al., 2014; Chan & Quigley, 2014; Hua et al., 2022; Norris et al., 2018; Peacock et al., 2012

[16] Index of Multiple Deprivation

Figure 2-3

Directed Acyclic Graph of Theoretical Model between Gestational Group, Covariates, and Outcome Variables



Note. Gestational Group = VMPT, LPT, Early Term and Full Term, Age = age of child in months at testing point. IMD = Index of Multiple Deprivation.

2.4 Conceptualisation of Variables in All Studies in This Thesis

This section details the common exclusion criteria, as well as the conceptualisation of the gestational group variable and the following covariates: sex of child; mother's age at child's birth; maternal education; receipt of means tested benefit; parity; cohabitation; and mother smoking during pregnancy, which are used in all four thesis' studies. Comparator groups were selected on the basis of the hypothesised best performing group based on previous research, where possible. This was done to enable the covariates to generally be in the same direction in each analysis and therefore assist interpretation.

The outcome variables used are particular to each chapter and are therefore described within that chapter's methods section, together with any additional variable criteria (e.g. age at time of testing and handedness), and additional exclusion criteria (e.g. data trimming) used in that chapter.

2.4.1 Common Exclusion Criteria

The following exclusion criteria were used for all studies in this thesis. Firstly, any observations from births over 41 weeks' gestation were deleted as these are categorised as post-term births (El Marroun et al., 2012; Galal et al., 2012; Linder et al., 2017). Multiple births were excluded as these births are theorised to have a different gestational pathway to singleton birth (Tingleff et al., 2023). Finally, children looked after by the local authority (or where this data was missing) were excluded as these children have a substantially different background to children living with their birth families, and are suggested to be a highly heterogeneous group (N. Luke & O'Higgins, 2018).

2.4.2 Gestational Group

The BiB data contained a "gestation in weeks" variable, measured using gestational dates confirmed by ultrasound scan. From this data, any observations for children missing "gestation in weeks" data were deleted.

A new categorical variable was created: gestational group. Gestation was grouped into the following categories which are used in established studies of preterm birth: VMPT (33 weeks' gestation or less) (e.g. Hua et al., 2022; Sejer et al., 2019); LPT (34 to 36 weeks' gestation) (e.g. Dusing and Tripathi 2015; Talge et al. 2012; Vohr 2014; You, Shamsi, et al., 2019); early term (37 to 38 weeks' gestation) (e.g. Alterman et al., 2022;

Baer et al., 2019; Chan et al., 2016; M.-X. Liu et al., 2023; Richards, Kramer, et al., 2016); and full term (39 to 41 weeks' gestation) (e.g. Alterman et al., 2022; Hodel et al., 2016; Quigley et al., 2012). The numbers within these gestational groups vary by study and are detailed in the relevant chapters. Full Term birth (39 to 41 weeks' gestation) is used as the comparator group in all studies.

Results for children born at VMPT gestation are included for comparative purposes and to also examine whether a reverse gradient of gestation risk is displayed, with children born closer to full term having better outcomes, and those born furthest having the worse outcomes (Boyle et al., 2012). Furthermore, many studies that are focussed on LPT birth also include the result for children born VMPT for similar comparison purposes (e.g. Chan & Quigley, 2014; Chyi et al., 2008; Lipkind et al., 2012; Quigley et al., 2012; P.E. Shah et al., 2016; Townley Flores et al., 2021).

2.4.3 Covariates Considered but not Included in Analysis

Consideration was initially given to inclusion of in vitro fertilisation, and drug or alcohol use during pregnancy in the modelling. However, the decision was taken not to include in vitro fertilisation and drug use in pregnancy as they affected very low numbers within the sample (around 0.2% and 1.3%, respectively). In the case of alcohol in pregnancy, around 30.5% of mothers drank during pregnancy and this was recorded as a binary measure of drank or did not drink alcohol. The impact of drinking alcohol on preterm birth appears to be related to quantity consumed, with drinking 10 or more units of alcohol weekly being associated with preterm birth (Kesmodel et al., 2000) but drinking less than this actually being associated with lower risk of preterm birth (Strandberg-Larsen et al., 2017). Therefore the use of a binary measure would not reflect the theoretical risk. Additionally, drinking alcohol during pregnancy was associated with ethnicity in the sample, with over 65% of white mothers consuming alcohol and only 0.1% of mothers of Pakistani heritage.

2.4.4 Child's Sex

This variable was treated as a binary variable of whether the child was biologically male or female. Female is used as the comparator group throughout. Some studies have suggested that males are more likely to be born preterm (Cheng et al., 2011; Cooperstock & Campbell, 1996; Peelen et al., 2016). Sex difference in studies within the general population have also been found to predict the outcomes studies within this thesis such as educational achievement (Ogden et al., 2023); executive function (Ibbotson & Roque-Gutierrez, 2023); and motor skills (Liutsko et al., 2020). Therefore, it was important to control for biological sex as it could have a potentially confounding effect.

2.4.5 Ethnicity

Ethnicity was used as a categorical variable of White British, Pakistani, and “Other” directly from the variable created by BiB. This use of the category “Other” reflects the low numbers in categories outside of White British and Pakistani (i.e. from a heritage other than White British or Pakistani). This division is used in other studies within the BiB cohort (Fairley et al., 2014; Marvin-Dowle et al., 2018; Wilson et al., 2023). As in these other studies, White British is used throughout this thesis as the comparator group.

Ethnicity differences have been associated with the outcomes considered in this thesis, including educational achievement (Strand, 2014); working memory (Mooney et al., 2022); and graphomotor skills (Wood, 2021). Therefore, controlling for ethnicity is important in studies examining preterm birth and educational achievement, cognition, and graphomotor skills.

2.4.6 Mother’s Age

Mother’s age at the time of child’s birth was used as a categorical variable. Mother’s age was divided into the following categories: age 20 years or below; age 21 to 34 years; and age 35 years or over. This was done to form larger groups from the continuous age variable in the BIB data.

Mother being aged 35 or over was used as the comparator throughout the thesis. This was used as the comparator because the mother being in the older category is associated with the child having increased educational performance when compared to younger mothers (Fishman & Min, 2018). Mothers aged under 20 years, or 35 or more years have higher incidence of preterm birth (Fuchs et al., 2018).

2.4.7 Index of Multiple Deprivation (IMD)

IMD ranges on a scale of 1 to 10, where an area categorised as 1 is the most deprived, and an area categorised as 10 is the least deprived (Department for Communities and Local Government, 2010). It is measured in seven domains: Income Deprivation; Employment Deprivation; Health Deprivation and Disability; Education and Skills and Training Deprivation; Crime; Barriers to Housing and Services; and Living Environment Deprivation (Noble et al., 2019).

The IMD data in this thesis was transformed from a continuous variable (1 to 10) in the BiB data into a binary variable of IMD Area 1 and IMD Areas 2 to 10. This transformation was conducted as 50% of the children in the cohort lived in an IMD Area categorised as 1, and around 45% lived in IMD Areas of 2 to 6. The resulting binary variable had two groups of similar size. The category of IMD Areas 2 to 10 was used as the comparator group in all analyses.

Increased deprivation is associated with higher rates of preterm birth (Taylor-Robinson et al., 2011). Furthermore, in Bradford child poverty is highly concentrated in areas within the inner city (City of Bradford MDC, 2020b). Such poverty has also been shown to have an association in the general population with the outcomes considered in this thesis, e.g. educational achievement (Nieuwenhuis & Chiang, 2021); executive function (D. Johnson et al., 2021); and motor skills (McPhillips & Jordan-Black, 2007). It therefore has a potentially confounding effect.

2.4.8 Parity

This variable was transformed from a continuous variable (first born to 10 pregnancies) in the BiB data into categories of first born; one to three previous births; and four or more previous births. This was done due to low numbers of families with more than five children (less than 1%). First born was used as the comparator throughout.

Null-parity and parity of more than four children are associated with increased preterm birth (Koullali et al., 2020). Increased parity is also associated with worsened educational achievement (Silventoinen et al., 2023). It is, therefore, a potential confounding factor.

2.4.9 Mother Smoked in Pregnancy

This was a binary variable taken from the BiB data describing whether the mother smoked during pregnancy. Mothers who did not smoke in pregnancy was used as the comparator throughout this thesis. Smoking in pregnancy has been found to be linked to the mother having lower levels of education (Kandel et al., 2009). The baby’s mother smoking in pregnancy is associated with increased risk of preterm birth (Stock & Bauld, 2020). It has also been found to have adverse effects on the child’s neurodevelopment (Wehby et al., 2011). It therefore has a potential moderating and confounding effect on the studies within this thesis.

2.4.10 Cohabitation

This was a binary variable transformed from the cohabitation variable in the BiB data. The categories of living with the baby's father and living with another partner in the original BiB data were collapsed to form a living with partner category, due to small numbers in the living with another partner category (less than 1%). The resultant categories were living with partner or single. Living with partner was the comparator for the thesis. Single mothers have been found to have a higher incidence of preterm birth (Farbu et al., 2014).

2.4.11 Means Tested Benefit

This was a binary variable in the BiB data of receiving means tested benefit or not receiving means tested benefit. In this thesis not receiving means tested benefit is used as the comparator throughout the studies. Receiving means tested benefit, which also indicates that the child is eligible for parental income related free school meal entitlement, has been shown to be negatively associated with educational achievement (Hobbs & Vignoles, 2010). It is, therefore, a potential moderating variable and is resultantly included in the covariates.

2.4.12 Maternal Education

This was used as a categorical variable drawn from the BiB data, with the BiB categories of "other", "don't know" and "foreign unknown" amalgamated to form a larger group. The final categories were higher education (the comparator group throughout the thesis); A-level equivalent; 5 GCSEs equivalent; less than 5 GCSEs equivalent; and other/unknown.

Lower maternal education is associated with increased risk of preterm birth (Ruiz et al., 2015). There is also evidence that maternal education predicts the child's education (Hu & Qian, 2023) and cognitive ability (Cermakova et al., 2023) and therefore it was important to control for this factor in this thesis' studies.

2.5 Research Design

This thesis considers educational achievement between the ages of 5 and 11 years using a cross-sectional logistic regression study in Chapter Three to assess whether children born LPT have increased odds of not reaching expected levels of development as measured by these assessments. In Chapter Four, the thesis investigates z-scored educational scores in a longitudinal study to assess whether children born LPT experience increased attainment over this time, thereby catching up, or any attainment gap grows or is static. This study uses multi-level modelling for this analysis. The thesis then examines working memory, inhibition and processing speed in a cross-sectional linear regression study in Chapter Five. This investigates if children born LPT have worse scores for these constructs than full term born children. Finally, the thesis examines graphomotor tracking, aiming and tracing at two time-points cross-sectionally using linear regression in Chapter Six. G*Power (Faul et al., 2007) was used in the thesis' four studies to assess the power of the sample size to find a statistically significant effect.

2.5.1 Validity and Reliability

Test validity requires that the attributes being studied causes the variation in the outcome (Borsboom et al., 2004). The thesis uses established measures of educational achievement using statutory school tests; executive function by using items based on established cognitive tests such as forward and backward digit recall (Fraello et al., 2011; Omizzolo et al., 2014; Trickett et al., 2022; Wehrle et al., 2021), the Flanker task (Daamen et al., 2015; Décaillet et al., 2023; James et al., 2020), as well as graphomotor skills in the using the CKAT (Culmer et al., 2009; Giles et al., 2018; Shire, 2016).

There were also attempts to ensure consistency in the data gathering processes, for example the test procedures were the same in the Starting School data sweep and the Primary School Years data sweep (Hill et al., 2021; Shire et al., 2020).

The concept of general validity is the estimation how well the sample's findings transfer to the wider population (Andrade, 2018). In assessing the generalisability to wider populations it is relevant that all the thesis' studies used the BiB cohort data which is more multi-ethnic and has greater levels of deprivation than generally seen in the UK (City of Bradford MDC, 2020b). However, there are a number of large cities in the UK, and elsewhere, where similar demographics are present. Furthermore, few previous studies of children born prematurely have been set in such areas and this thesis contributes to our knowledge of the specific effects of preterm birth for children living in these settings. Therefore, the thesis studies will have greater generalisability to similar areas.

Reliability is defined as the consistency of the results (Andrade, 2018). The application of this was considered within each of the studies. For example, there is a potential threat to reliability in the thesis' study of educational achievement that the curriculum changes and that the pass rates varies. 58% of children achieved expected levels in 2016 but 70% reached this level in 2017 in the KS2[17] assessments (Department for Education, 2017). Therefore, the results from one year may not be comparable with the previous year's results, especially when curricular changes have taken place. To help mitigate this threat tests results were only used from one (the most recent available) curriculum for that age group, rather than combining with tests on earlier curricular.

2.6 Chapter Summary

This chapter introduced the BiB cohort study and described the area from which the cohort is drawn. The chapter outlines the variables used throughout this thesis and how they were derived from the data provided by BiB. It finally outlines the studies analyses methods and discusses validity and reliability.

[17] Key Stage Two

Chapter 3

Educational Achievement to Age 11 Years in Children Born at Late Preterm and Early Term Gestations

Chapter Summary

The work presented in this chapter has been published in Archives of Diseases in Childhood (https://adc.bmj.com/content/108/12/1019). The study investigates the impact of LPT and early term gestation, when compared to full term gestation, on national statutory educational assessments in children aged 5 to 11 years, using cross-sectional, logistic regression analysis.

It considers reading, writing and mathematics combined to form an outcome of "overall educational achievement", as well as the subjects of reading, writing and mathematics as individual outcomes. This study is the first to examine these outcomes at the ages of 5 years through to 11 years of age.

It finds that children born LPT experience increased odds of not reaching expected levels of educational achievement in overall educational achievement, compared to children born full term, up to age 7 years in the models adjusted for covariates and to age 11 in the unadjusted model. Whilst in individual subjects increased odds are seen in mathematics and writing throughout primary school, and in reading to age 6 years but not beyond. No similar effect was found in the study for children born at early term gestation.

3.1 Introduction

Amongst children born preterm (< 37 weeks' gestation), those that are very premature (< 32 weeks' gestation) are particularly vulnerable to experiencing neurodevelopmental difficulties (Aarnoudse-Moens et al., 2009; Pascal et al., 2018; Poulsen et al., 2013; Wolke et al., 2019), and have an elevated risk of poor educational attainment compared to their full term born peers (Aarnoudse-Moens et al., 2009, 2011; Guarini et al., 2019; Jansen et al., 2020; S. Johnson et al., 2009; Pritchard et al., 2009; Richards, Drews-Botsch, et al., 2016; Roberts et al., 2011; P. E. Shah et al., 2016; H. G. Taylor et al., 2009; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018). However, the specific effect of being born at LPT gestation on educational outcomes have been much less frequently studied and is consequently not as well understood (Martínez-Nadal & Bosch, 2020; Townley Flores et al., 2021).

Nevertheless, studying the effect of LPT birth on education is important, given that 72% of all preterm births are LPT (Office for National Statistics, 2024). Such educational achievement has long-term effects on both health (Adams, 2002; Mirowsky & Ross, 2017; Ross & Wu, 1995), and later SES (Heckman, 2008; Mirowsky & Ross, 2017; Ritchie & Bates, 2013; Spengler et al., 2015).

There is also growing evidence that even children born at early term gestation have worse health and developmental outcomes, when compared to those born at full term (Alterman et al., 2021, 2022; Crump et al., 2013, 2023; Dhamrait et al., 2021; Hedges et al., 2021; Rabie et al., 2015). This is an even larger group than LPT births, at 24% of all births (Office for National Statistics, 2024).

This chapter presents a cross-sectional study investigating educational achievement using national statutory assessments. It compares children born LPT, VMPT and early term to children born full term at the ages of 5 years to 11 years by school subject (reading, writing and mathematics), and in overall educational achievement using a combined reading, writing and mathematics outcome.

3.1.1 Attainment at the Outset of Primary School in Children born LPT and Early Term

There have been a limited number of studies examining children born LPT at the outset of school. These have generally found increased odds of not achieving school readiness when compared to children born full term. Woythaler et al. (2015), Quigley et al. (2012), and Louis et al. (2022) all found poorer school readiness in children born

LPT when compared to children born at full term gestation. However, a US study found only “borderline significant” increased adjusted odds (Morse et al., 2009, p. E624) of children born LPT not being school ready. Similarly, in a Canadian study, Crockett et al. (2022) found that whilst children born LPT had worse odds in the baseline model without covariates, this was not the case when SES covariates were controlled (here the SES covariates were receipt of income assistance, income quintile, mother’s age at first birth, family size, child in care, receipt of support or protection services). Accordingly, Crockett et al. (2022) suggest including adequate SES covariates in the modelling may explain the divergent findings.

There are also a few studies examining the effect of early term birth. These find conflicting results with Quigley et al. (2012) and P. E. Shah et al. (2016) finding no adverse effect of early term birth, but Dhamrait et al. (2021) finding increased likelihood of children born early term not being ‘school ready’, when compared to children born full term.

Differences in results may also be due to the composition of the “school readiness” outcome which varies by study, e.g. the outcome in Dhamrait et al. (2021) was based on the children being developmentally vulnerable in one or more of five domains; whereas the study by Quigley et al. (2012) was based on total points scored over 13 assessment scales. Alternatively, some studies used academic based outcomes of combined reading and mathematics skills (P. E. Shah et al., 2016; Woythaler et al., 2015). Therefore, differing results may be due to differences in the definition of “school readiness”.

Furthermore, the wider ranging school readiness assessments used by Quigley et al. (2012), Morse et al. (2009), Crockett et al. (2022), and Dhamriat et al. (2021), included personal and social development and general knowledge assessments. This potentially provides a good measure of whether the child is socially and academically prepared for school overall. However, these wider measures do not allow easy comparison to achievement in later years where the focus of assessment is on academic subjects such as reading, writing and mathematics. To date, there has been no study using consistent outcome measures from the outset of primary education at age 5 years to its completion at age 11 years and the current study seeks to fill this gap.

Additionally, a small number of studies have examined the effect of LPT and early term birth, compared to full term births, on specific academic subjects at the outset of school. In mathematics, Chyi et al. (2008) found that children born LPT had increased odds of poorer mathematics in teacher assessment (but not in test scores), when compared to full term births. Similarly, Quigley et al. (2012) observed that both children born LPT and early term, compared to those born at full term, had an increased odds of not reaching developmentally expected levels in mathematics. Whereas Richards, Drews-Botsch, et al. (2016) found higher odds of a worse score in mathematics for children born LPT, but not for those born at early term gestation, compared to children born full term.

In reading, Chyi et al. (2008) found that children born LPT, when compared to those born at full term, had higher odds of poorer reading skills and Richards, Drews-Botsch, et al. (2016) found increased odds of worse reading skills in children born LPT, but not those born early term. Whilst Quigley et al. (2012) found that both children born LPT and early term, had an increased risk of not reaching expected levels in “Communication, Language and Literacy” and Crocket et al. (2022) found worse odds for children born LPT in the “Communication” and “Language “domains. Therefore, there is evidence that reading and mathematics at age 5 years may be adversely affected by LPT birth, but there is less clear evidence for early term births.

There are no existing studies that examined the writing skills at age 5 years of children born LPT compared to full term. In the wider literacy assessments used by Quigley et al. (2012) and Crockett at al. (2022), they were not able to measure attainment in reading and writing as separate subjects, which would allow tracking of any adverse effect throughout education. However, such an assessment of reading and writing separately at the outset of school is afforded in the national UK EYFSP[18] (Department for Education, 2012) used in the current study.

Therefore, the existing research for children born LPT and early term at age 5 years focuses on school readiness, using varying outcome measures (e.g. Louis et al., 2022; Morse et al., 2009; Quigley et al., 2012; Woythaler et al., 2015). It would be beneficial to complement these by examining children born LPT and early term’s outcomes against the core subjects of reading, writing and mathematics as a combined measure of expected educational achievement and individually as subjects, whilst controlling for SES covariates, as suggested by Crockett et al. (2022). This would allow comparison of achievement at later ages.

[18] Early Years Foundation Stage Profile

3.1.2 Attainment in the Mid Primary School Years in Children born LPT and Early Term

There have been few studies evaluating the overall educational impact in the mid-primary school years on children born LPT. Chan and Quigley (2014) found children at age around 7 years old born LPT were less likely than children born at full term to achieve expected developmental levels in reading, writing and mathematics as a combined measure, but found no adverse effect for early term birth. Whilst in a differing measure of overall attainment (mathematics; science and social studies; and Language and Literacy), Hedges et al. (2021) found that children born early term had worse results than those born full term at age 9 years (this study did not also investigate children born LPT). Therefore, only one study investigated overall academic achievement in children born LPT in mid-primary education, finding increased odds of not reaching expected levels (Chan & Quigley, 2014). Whilst there were two studies examining the effect of early term gestation (Chan & Quigley, 2014; Hedges et al., 2021), they used different outcome measures and found contrasting results.

In subject-specific assessment, for reading and writing, Chan and Quigley (2014) found that children born LPT had increased odds of not achieving the expected standard at age 7 years, as did Lipkind et al. (2012) for English (reading and writing combined) in children aged 9 years. However, there are contrary results by Chyi et al. (2008) and Crockett et al. (2022) who found no detrimental effect of LPT birth, compared to full term birth, on reading in children aged 8 to 9 years.

Therefore, previous studies have more strongly suggested an adverse effect from LPT birth on writing (Chan & Quigley, 2014; Lipkind et al., 2012). Whereas the results are less clear in reading, with two studies suggesting no effect (Chyi et al., 2008; Crockett et al., 2022) and two finding an adverse impact (Chan & Quigley, 2014; Lipkind et al., 2012).

Whilst investigating the impact of early term birth, two studies found an adverse effect in reading at age 7 years (Chan & Quigley, 2014; Hedges et al., 2021), but one did not (Searle et al., 2017). Whereas two studies that investigated writing skills did not find increased odds of not reaching expected levels of development for children born early term compared to full term (Chan & Quigley, 2014; Searle et al., 2017).

Mathematics is frequently found as the principal subject in which children born very preterm have difficulties (Aarnoudse-Moens et al., 2011; Jansen et al., 2020; S. Johnson et al., 2009; H. G. Taylor et al., 2009). However, there has been inconsistent findings in children born LPT at around age 7 years in this subject. Only one study (Lipkind et al., 2012) found poorer mathematics in children born LPT than born full term, with two studies finding no adverse effect (Chan & Quigley, 2014; Chyi et al., 2008), and another finding no detrimental effect in the SES adjusted model (Crockett et al., 2022). Whereas in children born early term compared to those born full term, two studies have suggested increased odds of failing to reach expected levels in mathematics (Chan & Quigley, 2014; Searle et al., 2017).

In summary, in the past decade only three studies (Chan & Quigley, 2014; Crockett et al., 2022; Lipkind et al., 2012) have directly investigated the subject specific effects of LPT birth on educational performance in mid primary school. Two of these studies had contradictory findings with regards to the effects of LPT birth on educational achievement. The third study (Crockett et al., 2022) suggests that, after controlling for SES covariates, no statistically significant deficits in attainment remained for children born LPT by the age of around 7 years old. In early term, similarly three studies have taken place (Chan & Quigley, 2014; Hedges et al., 2021; Searle et al., 2017), finding an adverse effect in mathematics but not in reading, and conflicting results in writing.

3.1.3 Attainment at the End of Primary School Years in Children born LPT and Early Term

There is a particularly limited number of existing studies examining the effect of birth at LPT and early term gestation in educational attainment at around age 11 years (the last year of UK Primary School). Alterman et al. (2022) did not find increased risk for children born LPT, compared to full term, of not reaching expected levels of overall development (reading, writing and mathematics combined) at age 11 years. They did however, find that children born early term were at increased risk.

Furthermore, Alterman et al. (2022) did not find increased risk from being born LPT, compared to full term, for either English (combined reading and writing), or mathematics, as individual subjects. However, they did observe higher risk ratios for children born at early term gestation, compared to full term, for both subjects. This study (Alterman et al., 2022) did not report separately on reading and writing, but used a combined measure “English”. This means that we cannot tell whether it was one of the constituent subjects (reading or writing), or both that was not statistically significantly affected from LPT birth. Their sample also was within a predominately White British cohort (84%) so they were only able to control for the categories of White British and “other”. Therefore, their results also may not necessarily generalise to the many multi-ethnic cities in the UK or elsewhere.

Conversely, one earlier study (Chyi et al., 2008) explored the impact on children of being born at LPT gestation in reading and mathematics attainment at age 11 years. They found that children born LPT were more likely to be behind their term-born peers in reading (but not mathematics) in teacher assessment, but not on objective standardised test scores. Given that this study is the only one to observe negative long-term effects of LPT on educational performance, it is hard to unequivocally conclude that children born LPT are at higher risk of adverse educational outcomes without further research. This current study seeks to provide this research.

In this chapter, I provide new insights on how LPT birth impacts on educational achievement, using a recent longitudinal birth cohort: the BiB cohort (J. Wright et al., 2013). The study uses objective measures of educational achievement (standardized school assessments) throughout children’s primary education (at ages 5, 7 and 11 years) for the same school subjects throughout. It also controls for a set of relevant background characteristics that are more comprehensive than the previous studies, as suggested by Crockett et al. (2022). The study also explores the impact of early term birth, a gestational group examined in only a limited number of studies and where the effects are less certain.

By leveraging linked administrative and survey data, the current study evaluates for the first time the effect of LPT and early term birth on objective standardized school assessments at the end of primary school, at age 11 in reading, writing and mathematics, whilst controlling for a set of relevant background characteristics. Adequately controlling for these background variables allows the production of estimates that are less affected by confounding and measurement errors (Pourhoseingholi et al., 2012).

3.1.4 Aim of the Study and Hypotheses

The aim of the study is to investigate the effects of LPT and early term gestation on school performance between the ages of 5 to 11 years, using the statutory school assessments (described in Section 3.2.2.2).

3.1.4.1 Hypothesis One

The first hypothesis is that LPT and early term gestation, when compared to full term gestation, will predict increased odds of not reaching the age-related expected standard for “overall academic achievement” at the ages of 5 years; 7 years and 11 years.

3.1.4.2 Hypothesis Two

The second hypothesis is that children born LPT and early term will predict increased odds of not achieving expected levels in reading, writing and mathematics subject outcomes at age 5, 6, 7 and 11 years.

3.2 Methods

3.2.1 Participants and Study Setting

The sample was drawn from the BiB cohort, described in the Methods Chapter (Section 2.1), and used the exclusion criteria outlined in Chapter Two (Section 2.4.1). Additionally, any observations with missing covariates were excluded. This sample selection process (see Figure 3-1) resulted in 8,681 participants with gestational and control variable data. Once the sample had been trimmed based on this exclusion criteria, educational data was then linked at each assessment point for children who had completed assessments consistent with the current national curricula at time of writing.

This process resulted in final sub-samples consisting of 7860 children with EYFSP data at age 4 to 5 years; 8031 with Phonics data at age 5 to 6 years; 5560 with KS1[19] data at age 6 to 7 years, and 2386 with KS2 data at age 10 to 11 years old. The educational variables are explained in Section 3.2.2.2. The smaller amount of KS2 data available was due to COVID-19 related school closures in 2020/2021. Sample characteristics by gestational group for each assessment are presented in Appendix B (Tables B1 to B4).

3.2.2 Measures

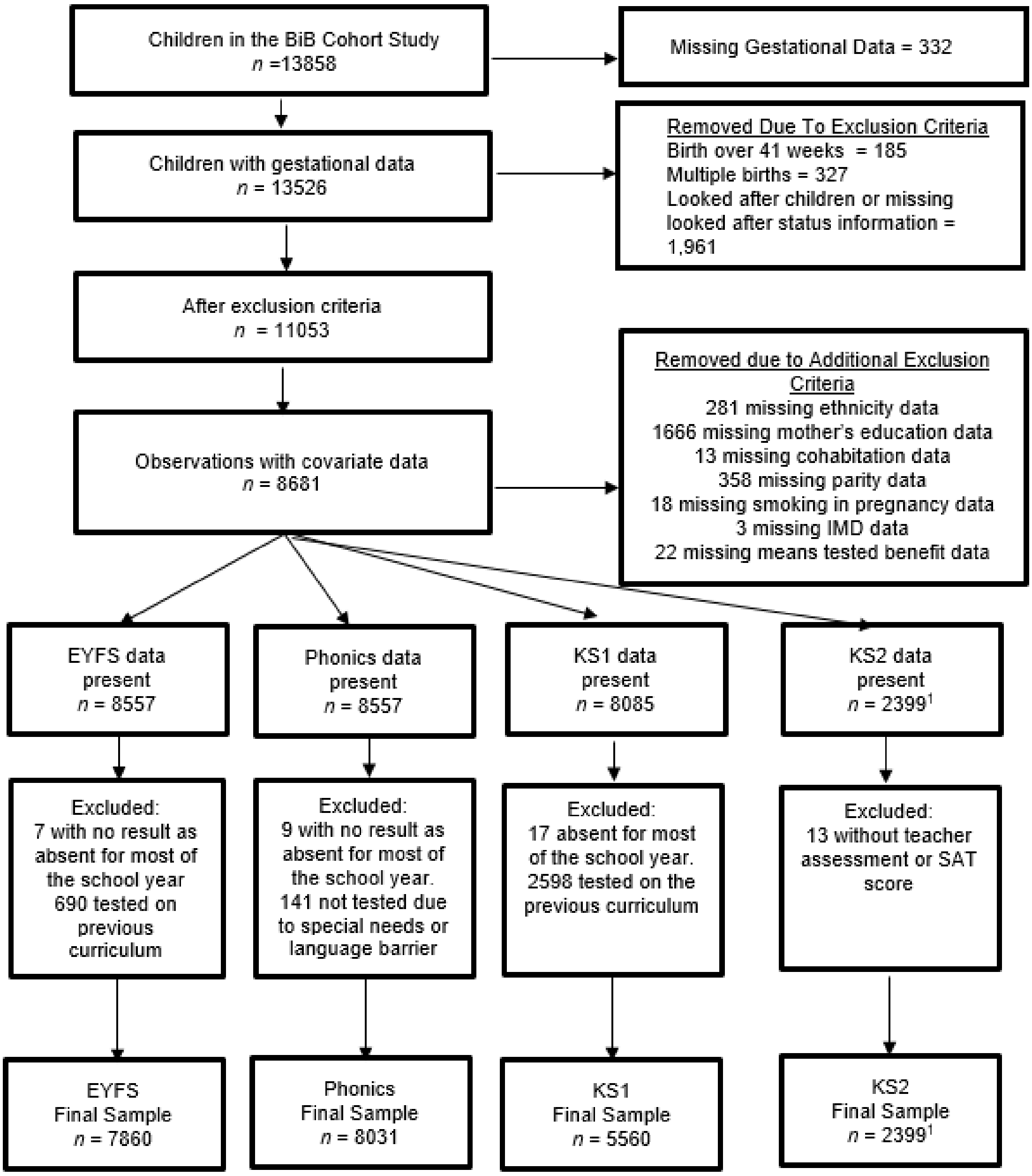
3.2.2.1 Gestational Variable

As used in the other studies in this thesis, gestation is measured by completed weeks and grouped into gestational categories: VMPT (less 34 weeks' gestation); LPT (34 to 36 weeks' gestation); early term (37 to 38 weeks' gestation); and full term (39 to 41 weeks' gestation). As elsewhere in this thesis, full term gestation was used as the comparator group for the study.

[19] Key Stage One

Figure 3-1

Sample Selection for Educational Achievement Study



Note. [1] The numbers tested at KS2 were lower than at other test periods due to Covid-related school closures.

3.2.2.2 Education Outcomes

Primary education in England takes place between age 4 years to 11 years and is currently divided into three stages (EYFS[20]; KS1; KS2). At the end of each stage, statutory assessment occurs against national standards (Department for Education, 2012, 2015b, 2019a). The children in the sample were assessed at these stages, as further explained below.

3.2.2.2.1 Assessment at Age 4 to 5 Years in the EYFSP

At approximately age 5 years, the class teacher assesses pupils against the EYFS standards (Department for Education, 2012). For the children in the sample, this assessment took place between 2013- 2016. This assessment takes place against seven learning areas, which comprise of 17 related learning goals[21], as set out in the EYFS framework (Department for Education, 2012). Mathematics and literacy form two of the seven learning areas, with component learning goals in “number” and “shape, space and measure” for mathematics, and “reading” and “writing” for literacy (Department for Education, 2012). Teacher assessment takes place in final term of the school year based on observations from across the year, reflecting the child’s level of achievement. This assessment indicates whether the child was “meeting expected levels of development”; “exceeding” expected levels, or not yet reaching expected levels (termed “emerging”). This assessment document is referred to as the EYFSP. This EYFSP is subject to local educational authority moderation (Department for Education, 2012).

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[20] Early Years Foundation Stage

[21] These seven areas consist of three prime areas of learning and four specific areas of learning. The prime areas are: Communication and Language (“Listening and Attention”; “Understanding”; and “Speaking” learning goals); Physical Development (“Moving and Handling” and “Health and Self-Care” learning goals); and Personal, Social and Emotional Development (“Self-Confidence and Self-Awareness; “Managing Feelings and Behaviour”; and “Making Relationship” learning goals). The four specific areas are: Literacy (“Reading” and “Writing” learning goals); Mathematics (“Number” and “Shape, Space and Measure” learning goals); Understanding the World (“People and Communities”; “the World”; and “Technology” learning goals) and Expressive Art and Design (“|Exploring and Using Media and Materials” and “Being Imaginative” learning goals).

3.2.2.2.2 KS1 Phonics Assessment at Age 6 Years

A national statutory phonics assessment takes place at age 6 (School Year 1) to establish whether children are working at expected levels of phonics decoding. The test uses a list of 20 real and 20 faux (but phonetically plausible) words. The pass mark varies by year and is standardised nationally against previous years' results. Children can either meet or not meet the expected standard (Department for Education, 2017). For the children in the sample this testing occurred 2013-2018.

3.2.2.2.3 KS1 Testing at Around Age 7 Years

At the end of the KS1 (school Year 2) when children are aged around 7 years, attainment is assessed by the class teacher against national set standards within the KS1 curriculum. This assessment takes place in reading, writing, mathematics and science. This took place 2016-2018 for the children in the sample. The assessment is also informed by national tests in reading and mathematics, which are marked internally by the school. For reading, writing and mathematics children were classified into “working below the pre-key stage standards”, “working at a pre-key stage standard”, “working towards the expected standard”, “working at the expected standard” or “working greater depth” within the expected standard of the national curriculum (Department for Education, 2019b). Whilst assessment made by the class teacher it is subject to external moderation by the local education authority.

3.2.2.2.4 KS2 Testing at Around 11 Years

At the age of 11 years, in school Year 6, children were assessed against the national curriculum KS2 standards. For the children in the sample, this assessment took place 2018-2019. Children were assessed in reading; mathematics; and EGPS[22] in national statutory tests and marks are transformed by standardizing around 100. Children receive a standardised score provided they have a raw score of at least three on the test and children who score below this are described as working below the key stage standard. Standardised scores of 80-99 are classified as “working toward” the expected standard. Scores of 100-109 are regarded as “meeting the expected standard”, with scores of 110-120 described as “exceeding” the expected standard. Writing is judged against national standards by the class teacher and is also assessed as working towards the expected standard, meeting the expected standard and exceeding the

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[22] English Grammar, Punctuation and Spelling

expected standard. This writing assessment is also subject to local education authority moderation (Department for Education, 2019a).

3.2.2.2.5 Assessment Transformation for this Study

Within this study, the results for each assessment were dichotomised to indicate whether the child met or did not meet the expected-for-age standard, reflecting dichotomisation that has been used in similar analyses (Alterman et al., 2022; Chan & Quigley, 2014; Pettinger et al., 2020). In school years where reading, writing and mathematics were assessed (Reception, and Years 2 and 6), an overall attainment measure was derived as the primary outcome. This measure indicated whether a child did not met the expected-for-age standard threshold in reading, writing and mathematics assessments combined (i.e. failed to reach the expected standard in at least one of these subjects).

To maximise the sample size at each age and to investigate the impact on the most recent curricula at time of writing, the study considers all observations available at each time-point. Many of the children were included at a number of time-points, with 80% of the children in the KS2 assessment at age 11 years also observed at age 5 years in the EYFSP, as shown in Table 3-1.

Table 3-1

Comparison of Observations across Time-Points

	EYFS data		Phonics data		KS1 data		KS2 data	
	n	%	*n*	%	*n*	%	*n*	%
Had EYFS data	**7860**	100	7490	95	5505	70	1896	24
Had Phonics data	7490	93	**8031**	100	5422	68	2326	29
Had KS1 data	5505	99	5422	98	**5560**	100	2	0
Had KS2 data	1896	80	2327	98	2	0	**2386**	100

Note. The figure used for each analysis is shown in bold with the other columns showing the number and percentage from this analysis that was used at the other time-points, for example, in the KS2 assessment, 2386 children had data, of these 2 had had KS1 data, 2327 had had phonics data, and 1896 had had EYFS data.

3.2.2.3 Control Variables

The covariates were those outlined in Chapter Two (Section 2.4) with the addition of age in months within the school year (e.g. September = 1, August = 12). This is referred to as "academic month of birth" throughout this chapter. This covariate was included as birth month has been shown to be predictive of education, with children older in the academic school year more likely to achieve a better score (Copper et al., 2023; Oosterbeek et al., 2021; Pettinger et al., 2020).

3.2.3 Missing Data Analysis

Missing data analysis investigated the extent to which control variables with missing data varied both by the proportions within categories in the samples and the overall BiB cohort data (see Table C-1 in Appendix C). It was found that, proportionally, there were no differences greater than 5% between the distribution of data in the full BiB cohort sample and samples analyzed in this study.

3.2.4 Statistical Analysis

Simple and multinomial logistic regression were used to assess whether children born LPT, VMPT and early term had increased odds of not reaching expected levels of development in overall educational achievement and in reading, writing and mathematics at age 5, 7 and 11 years, as well as phonics at age 6 years and EGPS at age 11 years.

This analysis included a baseline model of gestational group as the sole predictor, and the multinomial model with the covariates listed in the Methods Chapter (Section 2.4) with the additional variable of academic month of birth. The OR[23], AOR[24] and the p-values are discussed in the Results Section (Section 3.3), with the OR Regression Tables reported in Appendix D (Tables D-1 to D-16) for the baseline models, and AOR Regression Tables in Tables 3-3 to 3-18 shown in this chapter for the adjusted models.

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[23] Odds Ratio

[24] Adjusted Odds Ratio

3.3 Results

3.3.1 Descriptive Statistics

The number of children and percentages within each gestational group not reaching the expected level of overall educational achievement and in the subject assessments are presented in Table 3-2.

3.3.2 Overall Educational Achievement at Age 5 Years

At the age of 5 years, children born LPT and VMPT, but not early term, had increased odds of not reaching the expected levels of overall educational achievement in both the baseline, shown in Appendix D, Table D-1 (early term: OR 1.09, 95%CI [-0.98, 1.22], p = .130; LPT: OR 1.67, 95%CI [1.33, 2.10], p < .001; VMPT: OR 1.71, 95%CI [1.15, 2.56], p = .009), and adjusted model as shown in Table 3-3 and illustrated in Figure 3-2 (early term: AOR 1.08, 95%CI [0.96,1.22], p = .208; LPT: AOR 1.72, 95%CI [1.34, 2.21], p < .001; VMPT: AOR 1.94, 95%CI [1.25, 3.00], p = .003).

In the covariates, being male, compared to being female (AOR 2.24, 95%CI [2.03, 2.48], p < .001); of Pakistani ethnicity, compared to white British ethnicity (AOR 1.52, 95%CI [1.34, 1.73], p < .001); receiving means tested benefit, compared to not receiving these benefits (AOR 1.23, 95%CI [1.09, 1.38], p = .001); single parenthood (AOR 1.25, 95%CI [1.08, 1.46], p = .003); and mother aged 20 years or less at the child's birth, compared to being 35 years or over (AOR 1.32, 95%CI [1.04, 1.67], p = .021), were associated with increased odds of not achieving expected overall levels of educational achievement, as seen in Figure 3-2 and Table 3-3. Furthermore, academic month of birth was a statistically significant predictor with every month after the start of the school year carrying and additional AOR of 1.19 (95%CI [1.17, 1.20], p < .001). Additionally, all of the categories of the child's mother having less than higher education were statistically significant predictors of not reaching expected levels of overall educational achievement (A Levels: AOR 1.44, 95%CI [1.22, 1.72]; 5 GCSEs: AOR, 1.89, 95%CI [1.63, 2.20]; less than 5 GCSEs: AOR 2.94, 95%CI [2.51, 3.46]; and other education: AOR 1.73, 95%CI [1.39, 2.14] [all p < .001]).

Table 3-2

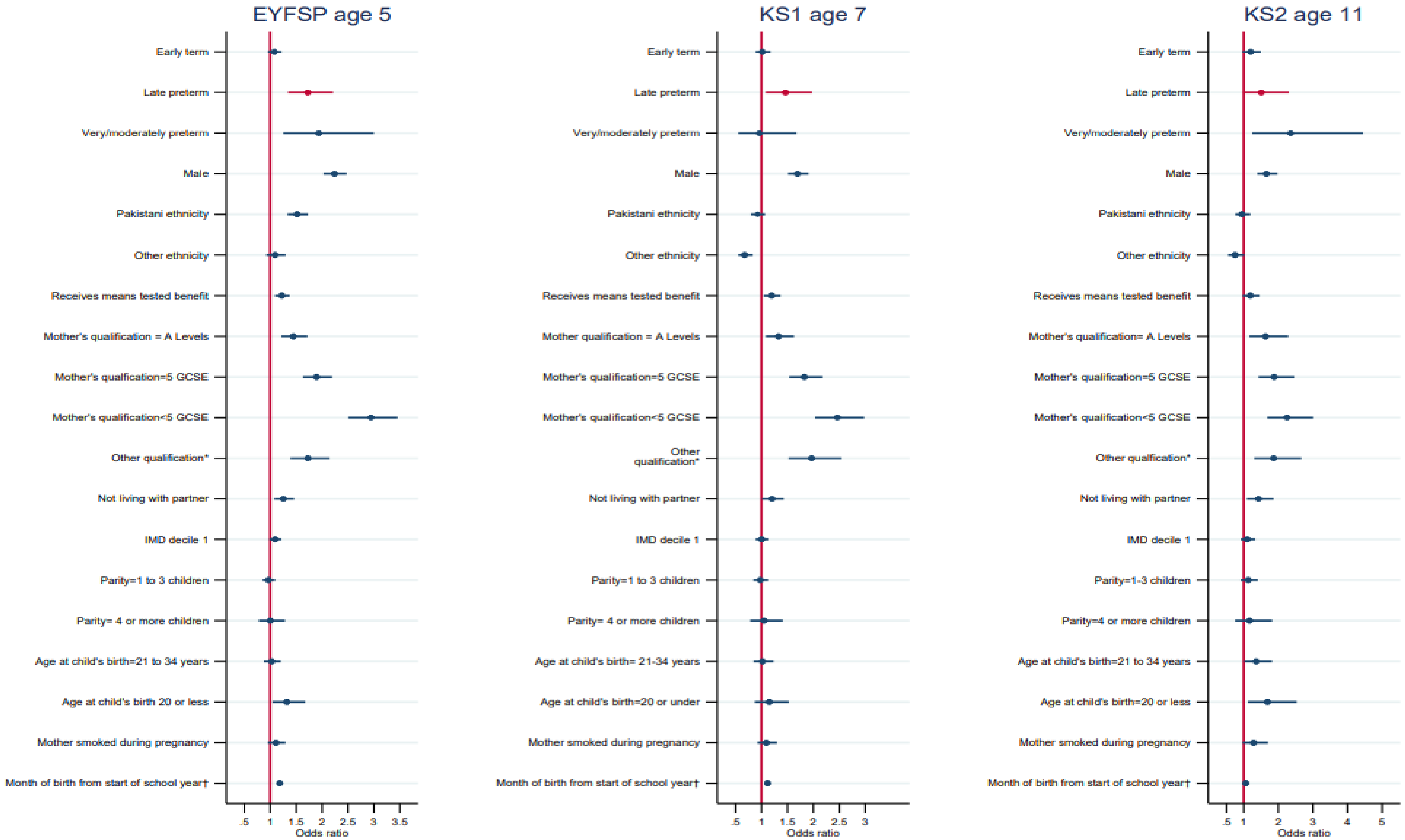
Number and Percentage Not Achieving Expected Levels of Educational Achievement in Each Assessment

Outcome	Education Stage	VMPT		LPT		Early Term		Full Term	
		n	%	*n*	%	*n*	%	*n*	%
Not Achieving Expected Levels in Overall Education Achievement	EYFSP	48	50	149	49	654	38	209	36
	KS1	20	32	86	42	411	33	1347	33
	KS2	23	54	45	45	181	39	611	34
Not Achieving Expected Levels in reading	EYFSP (reading)	38	39	116	38	543	32	1683	29
	Phonics	33	31	91	30	351	20	1157	20
	KS1(reading)	15	24	58	28	297	24	957	24
	KS2 (reading)	15	35	36	36	139	30	472	27
Not Achieving Expected Levels in writing	EYFSP (writing)	44	45	144	47	607	36	1944	34
	KS1 (writing)	18	29	72	35	353	29	1143	28
	KS2 (writing)	14	33	29	29	110	24	338	19
	KS2 (EGPS)	13	30	35	35	98	21	321	18
Not Achieving Expected Levels in mathematics	EYFSP (mathematics)	45	46	127	42	556	33	1736	30
	EYFSP (Number)	43	44	122	40	531	31	1637	28
	EYFSP (S, S and M)	39	40	106	35	475	28	1480	26
	KS1 (mathematics)	14	22	66	32	297	24	941	23
	KS2 (mathematics)	15	35	35	35	103	22	342	19

Note. *n* = number of children. VMPT = Very and Moderately Preterm; LPT = Late Preterm; EYFSP = Early Years Foundation Stage Profile; KS1 =Key Stage One; KS2 = Key Stage Two; EGPS = English Grammar and Punctuation S, S and M = Shape, Space and Measure.

Figure 3-2

Adjusted Odds Ratios For not Reaching Overall Expected Level of Educational Achievement to Age 11 Years



Note. EYFSP = Early Years Foundation Stage Profile; KS1 = Key Stage One; KS2 = Key Stage Two.*Other qualification = foreign with unknown equivalent or unknown by participant. †Month of birth is used an ordinal variable and was transformed relative to the start of the English school year (e.g. September = 1, August = 12) to reflect age within the year.

3.3.3 Overall Educational Achievement at Age 7 Years

In KS1, children born LPT had statistically significantly increased odds of not reaching expected levels of overall educational attainment both in the baseline, as seen in Appendix D, Table D-1 (OR: 1.47, 95%CI [1.10, 1.95], p = .009), and adjusted model shown in Table 3-4 and illustrated in Figure 3-2 (AOR 1.46, 95%CI [1.08, 1.97], p = .013). Whereas the results for the VMPT (OR 0.94, 95%CI [0.55, 1.60], p = .807, AOR 0.96, 95%CI [0.55, 1.67], p = .887) and early term groups (OR 1.00, 95%CI [0.87, 1.15], p = .992, AOR 1.02, 95%CI [0.88, 1.17], p = .807) were not statistically significant in either model.

In the covariates, as shown in Table 3-4 and Figure 3-2, being male (AOR 1.69, 95%CI [1.51, 1.90], p < .001); receipt of means tested benefit (AOR 1.19, 95%CI [1.04, 1.37], p = .010); single parenthood (AOR 1.20, 95%CI [1.01, 1.43], p = .038); academic month of birth (AOR 1.12, 95%CI [1.10, 1.13], p < .001) and maternal education below higher education (A Levels or equivalent: AOR 1.33, 95%CI [1.08, 1.63], p = .006; 5 GCSEs: AOR 1.82, 95%CI [1.53, 2.17], p < .001; less than 5 GCSEs: AOR 2.46, 95%CI [2.03, 2.98], p < .001; other education: AOR 1.97, 95%CI [1.52, 2.54], p < .001) all carried increased odds of not reaching expected levels of development.

3.3.4 Overall Educational Achievement at Age 11 Years

At age 11 years, the results of the baseline model, presented in Appendix D (Table D-1), showed that LPT and VMPT birth, but not early term, were associated with increased odds of not achieving expected levels in overall academic achievement (early term: OR 1.20, 95%CI [0.97, 1.48], p = .089; LPT: OR 1.53, 95%CI [1.02, 2.29], p = .039; VMPT: OR 2.19, 95%CI [1.19, 4.02], p = .011). However, the results were not statistically significant once control variables were included for children born LPT, but remained statistically significant for children born VMPT (early term: AOR 1.20, 95%CI [0.96, 1.50], p = .101; LPT: AOR 1.51, 95%CI [0.99, 2.30], p = .057; VMPT: AOR 2.35, 95%CI [1.25, 4.45], p = .008), as shown in Table 3-5 and Figure 3-2.

In the covariates, as shown in Table 3-5 and Figure 3-2, being male (AOR 1.66, 95%CI [1.39, 1.98], p < .001); single parenthood (AOR 1.42, 95%CI [1.09, 1.86], p = 010); mother aged 21 to 34 years (AOR 1.36, 95%CI [1.02, 1.82], p = .037) or 20 or less years at the child's birth (AOR 1.69, 95%CI [1.12, 2.53], p = .012) and academic month of birth (AOR 1.06, 95%CI [1.04, 1.09], p < .001) carried increased odds of not reaching the expected levels of overall academic achievement.

Table 3-3

Multiple Logistic Regression Table for Overall Educational Achievement at the EYFSP: Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth

Variables	EYFSP Overall Educational Achievement			
	AOR	SE	95% CI LL, UL	p
Intercept	0.05	0.01	0.03, 0.06	**< .001**
Early Term[1]	1.08	0.07	0.96, 1.22	.208
LPT[1]	1.72	0.22	1.34, 2.21	**< .001**
VMPT[1]	1.94	0.43	1.25, 3.00	**.003**
Male[2]	2.24	0.11	2.03, 2.48	**< .001**
Pakistani Ethnicity[3]	1.52	0.10	1.34, 1.73	**< .001**
Other Ethnicity[3]	1.10	0.09	0.92, 1.30	.292
Means Tested Benefit[4]	1.23	0.07	1.09, 1.38	**.001**
Maternal Education: A Levels[5]	1.44	0.13	1.22, 1.72	**< .001**
Maternal Education: 5 GCSEs[5]	1.89	0.14	1.63, 2.20	**< .001**
Maternal Education: < 5 GCSEs[5]	2.94	0.24	2.51, 3.46	**< .001**
Maternal Education: Other Education[5]	1.73	0.19	1.39, 2.14	**< .001**
Single Parent[6]	1.25	0.10	1.08, 1.46	**.003**
IMD: Category 1[7]	1.09	0.06	0.99, 1.22	.092
Parity: 1 - 3 previous births[8]	1.00	0.13	0.78, 1.28	.997
Parity: 4 or more previous births[8]	0.97	0.11	0.77, 1.21	.768
Mother Aged 21 to 34 years[9]	1.03	0.08	0.88, 1.21	.720
Mother Aged ≤ 20 years[9]	1.32	0.16	1.04, 1.67	**.021**
Smoked in Pregnancy[10]	1.11	0.09	0.96, 1.29	.167
Academic Month of Birth	1.19	0.01	1.17, 1.20	**< .001**

Note. n = 7860. Adjusted Model: Pseudo R^2 = 0.11, p < .001. Comparator: Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-4

Multiple Logistic Regression Table for Overall Educational Achievement at KS1: Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked and Child's Academic Month of Birth

Variable	KS1 Overall Educational Achievement			
	AOR	SE	95% CI LL, UL	p
Intercept	0.11	0.02	0.08, 0.14	**< .001**
Early Term[1]	1.02	0.07	0.88, 1.17	.807
LPT[1]	1.46	0.22	1.08, 1.97	**.013**
VMPT[1]	0.96	0.27	0.55, 1.67	.887
Male[2]	1.69	0.10	1.51, 1.90	**< .001**
Pakistani Ethnicity[3]	0.92	0.07	0.79, 1.07	.289
Other Ethnicity[3]	0.68	0.07	0.55, 0.83	**< .001**
Means Tested Benefit[4]	1.19	0.08	1.04, 1.37	**.010**
Maternal Education: A Levels[5]	1.33	0.14	1.08, 1.63	**.006**
Maternal Education: 5 GCSEs[5]	1.82	0.16	1.53, 2.17	**< .001**
Maternal Education:< 5 GCSEs[5]	2.46	0.24	2.03, 2.98	**< .001**
Maternal Education: Other[5]	1.97	0.26	1.52, 2.54	**< .001**
Single Parent[6]	1.20	0.11	1.01, 1.43	**.038**
IMD: Category 1[7]	1.00	0.06	0.88, 1.13	.983
Parity: 1 - 3 previous births[8]	0.98	0.07	0.84, 1.13	.746
Parity: 4 or more previous births[8]	1.05	0.16	0.78, 1.41	.744
Mother Aged 21 to 34 years[9]	1.02	0.10	0.85, 1.23	.830
Mother Aged ≤ 20 Years[9]	1.15	0.17	0.87, 1.52	.326
Smoked in Pregnancy[10]	1.09	0.10	0.92, 1.30	.306
Academic Month of Birth	1.12	0.01	1.10, 1.13	**< .001**

Note. n = 7860. Adjusted Model: Pseudo R^2 = 0.11, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10 ; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: KS1 = Key Stage One; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-5

Multiple Logistic Regression Table for Overall Educational Achievement at KS2: Predicted by Gestational Group, Sex of Child, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked in Pregnancy and Child's Academic Month of Birth

Variable	KS2 Overall Educational Achievement			
	AOR	SE	95% CI LL, UL	p
Intercept	0.09	0.02	0.06, 0.13	**< .001**
Early Term[1]	1.20	0.13	0.96, 1.50	.101
LPT[1]	1.51	0.33	0.99, 2.30	.057
VMPT[1]	2.35	0.77	1.25, 4.45	**.008**
Male[2]	1.66	0.15	1.39, 1.98	**< .001**
Pakistani Ethnicity[3]	0.95	0.11	0.75, 1.19	.649
Other Ethnicity[3]	0.75	0.12	0.55, 1.02	.068
Means Tested Benefit[4]	1.19	0.12	0.97, 1.46	.093
Maternal Education: A Levels[5]	1.63	0.28	1.16, 2.29	**.005**
Maternal Education: 5 GCSEs[5]	1.88	0.26	1.43, 2.47	**< .001**
Maternal Education:< 5 GCSEs[5]	2.25	0.33	1.68, 3.01	**< .001**
Maternal Education: Other[5]	1.86	0.34	1.30, 2.67	**.001**
Single Parent[6]	1.42	0.19	1.09, 1.86	**.010**
IMD: Category 1[7]	1.10	0.11	0.91, 1.33	.319
Parity: 1 - 3 previous births[8]	1.13	0.13	0.91, 1.41	.277
Parity: 4 or more previous births[8]	1.17	0.27	0.75, 1.82	.499
Mother Aged 21 to 34 years[9]	1.36	0.20	1.02, 1.82	**.037**
Mother Aged ≤ 20 years[9]	1.69	0.35	1.12, 2.53	**.012**
Smoked in Pregnancy[10]	1.28	0.18	0.97, 1.70	.080
Academic Month of Birth	1.06	0.01	1.04, 1.09	**< .001**

Note. n = 2386. Adjusted Model: Pseudo R^2 = 0.06, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10]Mother did not smoke pregnancy. Abbreviations: KS2 = Key Stage Two; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

As at KS1 and EYFSP, maternal education being less than higher education was predictive of increased odds of not reaching expected levels of overall educational achievement (A Levels: AOR 1.63, 95%CI [1.16, 2.29], $p = .005$; 5 GCSEs: AOR 1.88, 95%CI [1.43, 2.47], $p < .001$; less than 5 GCSEs: AOR 2.25, 95%CI 1.68, 3.01], $p < .001$; other education: AOR 1.86, 95%CI [1.30, 2.67], $p = .001$).

3.3.5 Reading at Age 5 Years (EYFSP)

As shown in Appendix D (Table D-2), all three gestational groups had increased odds of not reaching expected levels of achievement in reading at age 5 years (early term: OR 1.13, 95%CI [1.01, 1.27], $p = .036$; LPT: OR = 1.48, 95%CI [1.17, 1.88], $p = .001$; VMPT: OR 1.56, 95%CI [1.03, 2.35], $p = .035$). However, once covariates were added, being born early term was no longer statistically significant (AOR 1.12, 95%CI [0.99, 1.27], $p = .083$) unlike VMPT (AOR 1.75, 95%CI [1.12, 2.74], $p = .014$) and LPT birth (AOR 1.50, 95%CI [1.16, 1.94], $p = .002$), as shown in Table 3-6.

In the covariates, being male (AOR 2.23, 95%CI [2.01, 2.48], $p < .001$); Pakistani ethnicity (AOR 1.68, 95%CI [1.46, 1.92], $p < .001$); receiving means tested benefit (AOR 1.31, 95%CI [1.46, 1.92], $p < .001$); single parenthood (AOR 1.23, 95%CI [1.05, 1.44], $p = .009$); mother aged 20 years or less at the child's birth (AOR 1.32, 95%CI [1.03, 1.70], $p = .028$); and academic month of birth (AOR 1.17, 95%CI [1.15, 1.19], $p < .001$) were predictive of increased odds of not reaching expected levels. Mother's education level, compared to the mother having received higher education, also carried increased odds of not achieving expected levels of achievement (A Levels: AOR 1.45, 95%CI [1.20, 1.74]; 5 GCSEs: AOR 1.97, 95%CI [1.68, 2.31]; less than 5 GCSEs: AOR 3.14, 95%CI [2.65, 3.72]; other education: AOR 1.80, 95%CI [1.43, 2.27], (all $p < .001$).

3.3.6 Reading Phonics at Age 6 Years

In the baseline model shown in Appendix D (Table D-2), both the VMPT and LPT gestational groups, but not the early term group, were associated with increased odds of not reaching expected levels in phonics, when compared to full term gestation (LPT: OR 1.73, 95%CI [1.35, 2.23], $p < .001$; VMPT: OR 1.85 95%CI [1.22, 2.81], $p = .002$; early term: OR 1.05, 95%CI [0.92, 1.20], $p = .502$). Once the model was adjusted for covariates, shown in Table 3-7, LPT (AOR 1.76, 95%CI [1.35, 2.30], $p < .001$) and VMPT birth (AOR 1.94, 95%CI [1.25, 3.01], $p = .003$) were associated with increased odds of not achieving expected development standard in phonics, compared to full term gestation, but not early term birth (AOR 1.06, 95%CI [0.92, 1.21], $p = .440$).

In the adjusted model shown in Table 3-7, being male (AOR 1.79, 95%CI [1.60, 2.01], $p < .001$), receiving means tested benefits (AOR 1.29, 95%CI [1.13, 1.47], $p < .001$); the mother being 20 years or less at the time of birth (AOR 1.56, 95%CI [1.20, 2.03], $p < .001$), and academic month of birth (AOR 1.12, 95%CI [1.10, 1.14], $p < .001$) predicted increased odds of not reaching expected levels. Again, all of the maternal educational levels, compared to the mother having higher education, predicted worse odds (A Levels: AOR 1.25, 95%CI [1.00, 1.56], $p = .047$; 5 GCSEs: AOR 2.01, 95%CI [1.67, 2.41], $p < .001$; less than 5 GCSEs: AOR 2.62, 95%CI [2.16, 3.18], $p < .001$; other education: AOR 1.88, 95%CI [1.47, 2.42], $p < .001$).

3.3.7 Reading at Age 7 Years (KS1)

None of the gestational groups were associated with increased odds in the baseline model, shown in Appendix D, Table D-2 (early term: OR 1.02, 95%CI [0.88, 1.19], $p = .764$; LPT: OR 1.29, 95%CI [0.94, 1.76], $p = .114$, VMPT: OR 1.01, 95%CI [0.56, 1.82], $p = .968$). This remained the case in the adjusted model (early term: AOR 1.02, 95%CI [0.87, 1.19], $p = .786$; LPT: AOR 1.24, 95%CI [0.89, 1.72], $p = .197$; VMPT: AOR 1.10, 95%CI [0.60, 2.01], $p = .770$), shown in Table 3-8.

Once again, being male (AOR 1.81, 95%CI [1.59, 2.06], $p < .001$); receipt of means tested benefit (AOR 1.22, 95%CI [1.05, 1.42], $p = .009$); single parenthood (AOR 1.25, 95%CI [1.03, 1.51], $p = .021$); and academic month of birth (AOR 1.12, 95%CI [1.10, 1.14], $p < .001$) predicted increased odds of not reaching expected levels in reading. Similarly, the child’s mother having less than higher education was associated with increased odds of not reaching the expected level (A Levels: AOR 1.36, 95%CI [1.08, 1.71], $p = .010$; 5 GCSEs: AOR 1.78, 95%CI [1.46, 2.17], $p < .001$; less than 5 GCSEs: AOR 2.64, 95%CI [2.13, 3.26], $p < .001$; other education: AOR 2.05, 95%CI [1.55, 2.72], $p < .001$).

3.3.8 Reading at Age 11 Years (KS2)

In the baseline model, shown in Appendix D (Table D-2), children born LPT, but not early term or VMPT, had statistically significant odds of not reaching expected levels at age 11 years in reading, when compared to children born at full term (early term: OR 1.17, 95%CI [0.93, 1.46], $p = .181$; LPT: OR 1.53, 95%CI [1.00, 2.33], $p = .048$; VMPT: OR 1.48, 95%CI [0.78, 2.79], $p = .229$). However, in the adjusted model no gestational group had statistically significant odds (early term: AOR 1.14, 95%CI [0.90, 1.44], $p = .267$; LPT: AOR 1.51, 95%CI [0.97, 2.34], $p = .067$; VMPT: AOR 1.49, 95%CI [0.76, 2.89], $p = .244$), as shown in Table 3-9.

In the covariates, being male (AOR 1.66, 95%CI [1.38, 2.01], $p < .001$); the mother being aged 21 to 34 years (AOR 1.41, 95%CI [1.03, 1.94], $p = .032$), or 20 or less years at the time of the child's birth (AOR 1.67, 95%CI [1.08, 2.59], $p = .021$); academic month of birth (AOR 1.06, 95%CI [1.46, 2.17], $p < .001$); and maternal education less than higher education (A Levels: AOR 1.71, 95%CI [1.18, 2.47], $p = .005$; 5 GCSEs: AOR 2.02, 95%CI [1.49, 2.72], $p < .001$; less than 5 GCSEs: AOR 2.29, 95%CI [1.67, 3.15], $p < .001$; other education: AOR 1.96, 95%CI [1.32, 2.89], $p = .001$) were associated with increased odds of not reaching the expected level in reading.

3.3.9 Writing at Age 5 Years (EYFSP)

Children born LPT (OR 1.75, 95%CI [1.39, 2.21], $p < .001$), and VMPT (OR 1.63, 95%CI [1.09, 2.44], $p = .018$), but not early term (OR 1.09, 95%CI [0.97, 1.22], $p = .154$), had increased odds of not achieving expected levels of achievement in writing in the EYFSP, in the baseline model shown in Appendix D (Table D-3). This remained the case in the model adjusted for covariates, shown in Table 3-10, with children born LPT having an AOR of 1.81, 95%CI [1.41, 2.33], ($p < .001$) and children born VMPT having AOR of 1.83, 95%CI [1.18, 2.84], ($p = .007$). The result for early term birth was not statistically significant (AOR 1.07, 95%CI [0.94, 1.20], $p = .315$).

In the covariates, being male (AOR 2.39, 95%CI [2.16, 2.65], $p < .001$); Pakistani ethnicity (AOR 1.58, 95%CI [1.39, 1.80], $p < .001$); receiving means tested benefits (AOR 1.28, 95%CI [1.14, 1.44], p < .001); single parenthood (AOR 1.27, 95%CI [1.09, 1.47], $p = .002$); living in an area classified as IMD category 1 (AOR 1.14, 95%CI [1.02, 1.26], $p = .019$); academic month of birth (AOR 1.18, 95%CI [1.16, 1.19], $p < .001$); and mother's highest qualification being below higher education (A Levels: AOR 1.37, 95%CI [1.15, 1.64]; 5 GCSEs: AOR 1.83, 95%CI [1.58, 2.13]; less than 5 GCSEs: AOR 2.71, 95%CI [2.30, 3.19]; other education: AOR 1.55, 95%CI [1.24, 1.93] [all $p < .001$]) had increased odds of not reaching the expected level in writing.

Table 3-6

Multiple Logistic Regression Table for Reading at the EYFSP: *Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth*

Variable	EFYS Reading			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.00	0.02, 0.04	**< .001**
Early Term[1]	1.12	0.07	0.99, 1.27	.083
LPT[1]	1.50	0.20	1.16, 1.94	**.002**
VMPT[1]	1.75	0.40	1.12, 2.74	**.014**
Male[2]	2.23	0.12	2.01, 2.48	**< .001**
Pakistani Ethnicity[3]	1.68	0.12	1.46, 1.92	**< .001**
Other Ethnicity[3]	1.16	0.11	0.97, 1.39	.098
Receives Means Tested Benefit[4]	1.31	0.08	1.16, 1.48	**< .001**
Maternal Education: A Levels[5]	1.45	0.14	1.20, 1.74	**< .001**
Maternal Education: 5 GCSEs[5]	1.97	0.16	1.68, 2.31	**< .001**
Maternal Education: < 5 GCSEs[5]	3.14	0.27	2.65, 3.72	**< .001**
Maternal Education: Other[5]	1.80	0.21	1.43, 2.27	**< .001**
Single Parent[6]	1.23	0.10	1.05, 1.44	**.009**
IMD: Category 1[7]	1.05	0.06	0.94, 1.17	.372
Parity: 1 - 3 previous births[8]	1.01	0.13	0.78, 1.30	.967
Parity: 4 or more previous births[8]	0.92	0.11	0.73, 1.16	.501
Mother Aged 21 to 34 years[9]	1.15	0.10	0.97, 1.36	.112
Mother Aged ≤ 20 years[9]	1.32	0.17	1.03, 1.70	**.028**
Smoked in Pregnancy[10]	1.15	0.09	0.98, 1.34	.088
Academic Month of Birth	1.17	0.01	1.15, 1.19	**< .001**

Note. n = 2386. Adjusted Model Pseudo R^2 = .06, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10]Mother did not smoke pregnancy. Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-7

Multiple Logistic Regression Table for Phonics: *Predicted by Gestational Group, Sex of Child, Ethnicity, Receipt of Means tested Benefits, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth*

Variable	Phonics			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.01	0.03, 0.05	**< .001**
Early Term[1]	1.06	0.08	0.92, 1.21	.440
LPT[1]	1.76	0.24	1.35, 2.30	**< .001**
VMPT[1]	1.94	0.43	1.25, 3.01	**.003**
Male[2]	1.79	0.11	1.60, 2.01	**< .001**
Pakistani Ethnicity[3]	0.99	0.07	0.85, 1.15	.895
Other Ethnicity[3]	0.83	0.08	0.68, 1.01	.062
Means Tested Benefit[4]	1.29	0.09	1.13, 1.47	**< .001**
Maternal Education: A Levels[5]	1.25	0.14	1.00, 1.56	**.047**
Maternal Education: 5 GCSEs[5]	2.01	0.19	1.67, 2.41	**< .001**
Maternal Education: < 5 GCSEs[5]	2.62	0.26	2.16, 3.18	**< .001**
Maternal Education: Other[5]	1.88	0.24	1.47, 2.42	**< .001**
Single Parent[6]	1.14	0.10	0.96, 1.34	.129
IMD: Category 1[7]	1.01	0.06	0.90, 1.15	.819
Parity: 1 - 3 previous births[8]	1.03	0.08	0.89, 1.19	.695
Parity: 4 or more previous births[8]	1.17	0.17	0.89, 1.55	.257
Mother Aged 21 to 34 years[9]	1.06	0.10	0.88, 1.28	.522
Mother Aged ≤ 20 years[9]	1.56	0.21	1.20, 2.03	**< .001**
Smoked in Pregnancy[10]	1.09	0.09	0.93, 1.29	.294
Academic Month of Birth	1.12	0.01	1.10, 1.14	**< .001**

Note. n = 7860. Adjusted Model Pseudo R^2 = .07, p < .001 Comparator: [1]Full Term; [2]Female; [3] White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10]Mother did not smoke pregnancy. Abbreviations: AOR = Adjusted odds ratio; SE = Standard Error: CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-8

Multiple Logistic Regression Table for Reading at KS1: Predicted by Gestational Group, Sex of Child, Ethnicity, Receipt of Means tested Benefits, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	Reading at KS1			
	AOR	SE	95% CI LL, UL	p
Intercept	.005	0.01	0.04, 0.07	**< .001**
Early Term[1]	1.02	0.08	0.87, 1.19	.786
LPT[1]	1.24	0.21	0.89, 1.72	.197
VMPT[1]	1.10	0.34	0.60, 2.01	.770
Male[2]	1.81	0.12	1.59, 2.06	**< .001**
Pakistani Ethnicity[3]	1.11	0.09	0.94, 1.31	.224
Other Ethnicity[3]	0.88	0.10	0.70, 1.10	.262
Means Tested Benefit[4]	1.22	0.09	1.05, 1.42	**.009**
Maternal Education: A Levels[5]	1.36	0.16	1.08, 1.71	**.010**
Maternal Education: 5 GCSEs[5]	1.78	0.18	1.46, 2.17	**< .001**
Maternal Education < 5 GCSEs[5]	2.64	0.29	2.13, 3.26	**< .001**
Maternal Education: Other[5]	2.05	0.30	1.55, 2.72	**< .001**
Single Parent[6]	1.25	0.12	1.03, 1.51	**.021**
IMD: Category 1[7,]	0.96	0.07	0.84, 1.10	.563
Parity: 1 - 3 previous births[8]	1.05	0.09	0.89, 1.23	.593
Parity: 4 or more previous births	1.08	0.17	0.78, 1.48	.641
Mother Aged 21 to 34 years[9]	0.97	0.10	0.79, 1.19	.782
Mother Aged ≤ 20 years[9]	1.10	0.17	0.81, 1.49	.553
Smoked in Pregnancy[10]	1.12	0.11	0.93, 1.35	.246
Academic Month of Birth	1.12	0.01	1.10, 1.14	**< .001**

Note. n = 5560. Adjusted Model: Pseudo R^2 = 0.07, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10]Mother did not smoke pregnancy. Abbreviations: KS1 = Key Stage One; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-9

Multiple Logistic Regression Table for Reading at KS2: Predicted by Gestational Group, Sex of Child, Ethnicity, Receipt of Means tested Benefits, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	Reading at KS2			
	AOR	SE	95% CI LL,UL	p
Intercept	0.05	0.01	0.03, 0.08	**< .001**
Early Term[1]	1.14	0.14	0.90, 1.44	.267
LPT[1]	1.51	0.34	0.97, 2.34	.067
VMPT[1]	1.49	0.50	0.76, 2.89	.244
Male[2]	1.66	0.16	1.38, 2.01	**< .001**
Pakistani Ethnicity[3]	1.17	0.15	0.91, 1.50	.213
Other Ethnicity[3]	1.03	0.17	0.74, 1.43	.864
Receives Means Tested Benefit[4]	1.13	0.12	0.91, 1.39	.281
Maternal Education: A Levels[5]	1.71	0.32	1.18, 2.47	**.005**
Maternal Education: 5 GCSEs[5]	2.02	0.31	1.49, 2.72	**< .001**
Maternal Education:< 5 GCSEs[5]	2.29	0.37	1.67, 3.15	**< .001**
Maternal Education: Other[5]	1.96	0.39	1.32, 2.89	**.001**
Single Parent[6]	1.26	0.18	0.95, 1.68	.104
IMD: Category 1[7,]	1.18	0.12	0.97, 1.44	.105
Parity: 1 - 3 previous births[8]	1.22	0.15	0.97, 1.55	.092
Parity: 4 or more previous births[8]	1.24	0.30	0.78, 1.99	.368
Mother Aged 21 to 34 years[9]	1.41	0.23	1.03, 1.94	**.032**
Mother Aged ≤ 20 years[9]	1.67	0.37	1.08, 2.59	**.021**
Smoked in Pregnancy[10]	1.24	0.19	0.92, 1.67	.152
Academic Month of Birth	1.06	0.01	1.03, 1.09	**< .001**

Note. n = 2386. Adjusted Model: Pseudo R^{2} = 0.07, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10] Mother did not smoke pregnancy. Abbreviations: KS2 = Key Stage Two; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

3.3.10 Writing at Age 7 Years (KS1)

In the baseline model, shown in Appendix D (Table D-3), only children born LPT had increased odds of not reaching expected levels in writing at age 7 years, when compared to children born at full term (early term: OR 1.02, 95%CI [0.88, 1.17], p = .808, LPT: OR 1.39, 95%CI [1.03, 1.87], p = .029; VMPT: OR 1.02, 95%CI [0.59, 1.77], p = .945). However, once the covariates were added, shown in Table 3-11, no gestational group had increased odds of not reaching the expected standard, compared to full term (early term: AOR 1.04, 95%CI [0.89, 1.20], p = .649; LPT: AOR 1.36, 95%CI [1.00, 1.86], p = .053; VMPT: AOR 1.07, 95%CI [0.60, 1.90], p = .815).

In the covariates, being male (AOR 2.11, 95%CI [1.87, 2.39], p < .001); single parenthood (AOR 1.24, 95%CI [1.04, 1.49], p = .017); and academic month of birth (AOR 1.11, 95%CI [1.09, 1.13], p < .001) were associated with increased odds of not reaching expected levels of development in writing. Whilst the mother's highest level of education being A Levels was not statistically significant (p = .050), the other educational levels categories had increased odds (5 GCSEs: AOR 1.74, 95%CI [1.45, 2.09]; less than 5 GCSEs: AOR 2.47, 95%CI [2.02, 3.02]; other education: AOR 1.91, 95%CI [1.46, 2.50] [all p < .001]).

3.3.11 Writing at Age 11 Years

In the baseline model, shown in Appendix D (Table D-3), all the gestational groups had increased odds of not reaching expected levels of achievement in writing at age 11 years (early term: OR 1.31, 95%CI [1.02, 1.67], p = .033; LPT: OR 1.71, 95%CI [1.09, 2.68], p = .019; VMPT: OR 2.05, 95%CI [1.07, 3.92], p = .030). These increased odds were also present for all gestational groups in the adjusted model, shown in Table 3-12 (early term: AOR 1.32, 95%CI [1.02, 1.70], p = .033; LPT: AOR 1.64, 95%CI [1.02, 2.62], p = .041; VMPT: AOR 2.10, 95%CI [1.05, 4.21], p = .035).

Additionally, being male (AOR 2.04, 95%CI [1.65, 2.53], p < .001); receiving means tested benefit (AOR 1.39, 95%CI [1.09, 1.77], p = .007); the mother being aged 21 to 34 years (AOR 1.61, 95%CI [1.11, 2.34], p = .012), or 20 years or less at the time of the child's birth (AOR of 1.81, 95%CI [1.10, 2.96], p = .019); academic month of birth (AOR 1.05, 95%CI [1.02, 1.09], p = .001); and maternal education level lower than A Levels (5 GCSEs: AOR 1.99, 95%CI [1.39, 2.84]; less than 5 GCSEs: AOR 2.59, 95%CI [1.79, 3.75]; other education: AOR 2.41, 95%CI [1.56, 3.73] [all p < .001]) were associated with increased odds of not reaching expected levels in writing.

3.3.12 English Punctuation, Grammar Punctuation and Spelling (EGPS) at Age 11 Years

LPT and VMPT birth, but not early term birth, were associated with increased odds of not reaching expected development in EGPS in the baseline model, shown in Appendix D, Table D-3 (early term: OR 1.20, 95%CI [0.93, 1.54], p = .161; LPT: OR 2.40, 95%CI [1.57, 3.68], p < .001; VMPT: OR 1.96, 95%CI [1.01, 3.80], p = .046). The adverse effect remained in the adjusted model, shown in Table 3-13, with LPT birth having adjusted odds of 2.38, 95%CI [1.52, 3.73], (p < .001) and VMPT birth adjusted odds of 2.07, 95%CI [1.03, 4.15], (p = .040), but early term birth was not a statistically significant predictor (AOR 1.23, 95%CI [0.95, 1.60], p = .123).

Furthermore, being male (AOR 1.51, 95%CI [1.22, 1.86], p < .001); mother's age at child's birth 21 to 34 years (AOR 1.53, 95%CI [1.06, 2.22], p = .024) or 20 years or less (AOR 1.80, 95%CI [1.10, 2.95], p = .019); academic month of birth (AOR 1.05, 95%CI [1.01, 1.08], p = .004); and maternal education (A Levels: AOR 1.84, 95%CI [1.17, 2.89], p = .008; 5 GCSEs: AOR 2.33, 95%CI [1.61, 3.38], p < .001; less than 5 GCSEs: AOR 3.09, 95%CI [2.10, 4.55], p < .001; other education: AOR 2.25, 95%CI [1.42, 3.57], p = .001) were associated with increased odds of failing to reach expected levels in EGPS.

3.3.13 Mathematics at Age 5 Years (EYFSP)

The baseline model included in Appendix D, Table D-4, showed an adverse effect for LPT and VMPT birth, but not early term birth, with increased odds of not reaching expected levels of development in mathematics at age 5 years (early term: OR 1.12, 95%CI [1.00, 1.26], p = .051; LPT: OR 1.65, 95%CI [1.31, 2.09], p < .001; VMPT: OR 2.00, 95%CI 1.34, 3.00], p = .001). This was also the case in the adjusted model, shown in Table 3-14, with children born LPT (AOR 1.72, 95%CI [1.34, 2.21], p < .001) and VMPT (AOR 2.30, 95%CI [1.49, 3.56], p < .001), but not early term (AOR 1.11, 95%CI [0.98, 1.26], p = .098), having increased odds.

Table 3-10

Multiple Logistic Regression Table for Writing at the EYFSP: *Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth*

Variable	EFYSP Writing			
	AOR	SE	95% CI LL, UL	p
Intercept	0.04	0.01	0.03, 0.06	**< .001**
Early Term[1]	1.07	0.07	0.94, 1.20	.315
LPT[1]	1.81	0.23	1.41, 2.33	**< .001**
VMPT[1]	1.83	0.41	1.18, 2.84	**.007**
Male[2]	2.39	0.12	2.16, 2.65	**< .001**
Pakistani Ethnicity[3]	1.58	0.11	1.39, 1.80	**< .001**
Other Ethnicity[3]	1.09	0.10	0.91, 1.29	.341
Means Tested Benefit[4]	1.28	0.08	1.14, 1.44	**< .001**
Maternal Education: A Levels[5]	1.37	0.12	1.15, 1.64	**< .001**
Maternal Education: 5 GCSEs[5]	1.83	0.14	1.58, 2.13	**< .001**
Maternal Education: < 5 GCSEs[5]	2.71	0.23	2.30, 3.19	**< .001**
Maternal Education: Other[5]	1.55	0.18	1.24, 1.93	**< .001**
Single Parent[6]	1.27	0.10	1.09, 1.47	**.002**
IMD: Category 1[7]	1.14	0.06	1.02, 1.26	**.019**
Parity: 1 - 3 previous births[8]	0.96	0.12	0.75, 1.23	.748
Parity: 4 or more previous births[8]	0.93	0.11	0.74, 1.17	.542
Mother Aged 21 to 34 years[9]	1.26	0.15	0.99, 1.61	.056
Mother Aged ≤ 20 years[9]	1.01	0.08	0.86, 1.19	.862
Smoked in Pregnancy[10]	1.14	0.09	0.97, 1.32	.102
Academic Month of Birth	1.18	0.01	1.16, 1.19	**< .001**

Note. n = 7860. Adjusted Model Pseudo $R^2 = 0.11$, $p < .001$. Comparator:[1] Full Term; [2] Female; [3] White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years [10] Mother did not smoke pregnancy. Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-11

Multiple Logistic Regression Table for Writing at KS1: Predicted by Gestational Group, Sex of Child, Ethnicity, Receipt of Means tested Benefits, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	Writing at KS1			
	AOR	SE	95% CI LL, UL	p
Intercept	0.07	0.01	0.05, 0.10	**< .001**
Early Term[1]	1.04	0.08	0.89, 1.20	.649
LPT[1]	1.36	0.22	1.00, 1.86	.053
VMPT[1]	1.07	0.31	0.60, 1.90	.815
Male[2]	2.11	0.13	1.87, 2.39	**< .001**
Pakistani Ethnicity[3]	0.93	0.07	0.80, 1.09	.365
Other Ethnicity[3]	0.68	0.07	0.55, 0.85	**< .001**
Means Tested Benefit[4]	1.13	0.08	0.98, 1.31	.081
Maternal Education: A Levels[5]	1.24	0.14	1.00, 1.54	.050
Maternal Education: 5 GCSEs[5]	1.74	0.16	1.45, 2.09	**< .001**
Maternal Education: < 5 GCSEs[5]	2.47	0.25	2.02, 3.02	**< .001**
Maternal Education: Other[5]	1.91	0.26	1.46, 2.50	**< .001**
Single Parent[6]	1.24	0.11	1.04, 1.49	**.017**
IMD: Category 1[7]	1.01	0.07	0.88, 1.15	.914
Parity: 1 - 3 previous births[8]	1.01	0.08	0.87, 1.18	.871
Parity 4 or more previous births[8]	1.11	0.17	0.82, 1.51	.508
Mother Aged 21 to 34 years[9]	1.13	0.11	0.93, 1.38	.234
Mother Aged ≤ 20 years[9]	1.28	0.19	0.95, 1.72	.102
Smoked in Pregnancy[10]	1.08	0.10	0.91, 1.29	.385
Academic Month of Birth	1.11	0.01	1.09, 1.13	**< .001**

Note. n = 5560. Adjusted Model Pseudo R^2 = 0.07, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: KS1 = Key Stage One; AOR = Adjusted odds ratio; SE = Standard Error: CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm, IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-12

Multiple Logistic Regression Table for Writing at KS2: Predicted by Gestational Group, Sex of Child, Ethnicity, Receipt of Means tested Benefits, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	Writing at KS2			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.01	0.02, 0.05	**< .001**
Early Term[1]	1.32	0.17	1.02, 1.70	**.033**
LPT[1]	1.64	0.39	1.02, 2.62	**.041**
VMPT[1]	2.10	0.74	1.05, 4.21	**.035**
Male[2]	2.04	0.22	1.65, 2.53	**< .001**
Pakistani Ethnicity[3]	0.75	0.10	0.57, 0.98	**.037**
Other Ethnicity[3]	0.72	0.14	0.49, 1.04	.082
Means Tested Benefit[4]	1.39	0.17	1.09, 1.77	**.007**
Maternal Education: A Levels[5]	1.53	0.34	0.98, 2.37	.059
Maternal Education: 5 GCSEs[5]	1.99	0.36	1.39, 2.84	**< .001**
Maternal Education < 5 GCSEs[5]	2.59	0.49	1.79, 3.75	**< .001**
Maternal Education: Other[5]	2.41	0.54	1.56, 3.73	**< .001**
Single Parent[6]	1.34	0.21	0.99, 1.81	.058
IMD: Category 1[7]	1.19	0.14	0.95, 1.49	.138
Parity: 1 - 3 previous births[8]	0.99	0.13	0.76, 1.29	.954
Parity: 4 or more previous births[8]	1.04	0.28	0.61, 1.78	.878
Mother Aged 21 to 34 years[9]	1.61	0.31	1.11, 2.34	**.012**
Mother Aged ≤ 20 years[9]	1.81	0.45	1.10, 2.96	**.019**
Smoked in Pregnancy[10]	1.29	0.21	0.94, 1.76	.115
Academic Month of Birth	1.05	0.02	1.02, 1.09	**.001**

Note. n = 5560. Adjusted Model Pseudo R^2 = 0.07, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: KS2 = Key Stage Two; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-13

Multiple Logistic Regression Table for EGPS at KS2: Predicted by Gestational Group, Sex of Child, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	EGPS at KS2			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.01	0.02, 0.06	**< .001**
Early Term[1]	1.23	0.16	0.95, 1.60	.123
LPT[1]	2.38	0.55	1.52, 3.73	**< .001**
VMPT[1]	2.07	0.74	1.03, 4.15	**.040**
Male[2]	1.51	0.16	1.22, 1.86	**< .001**
Pakistani Ethnicity[3]	0.71	0.10	0.54, 0.93	**.015**
Other Ethnicity[3]	0.73	0.14	0.50, 1.07	.107
Means Tested Benefit[4]	1.07	0.13	0.84, 1.36	.610
Maternal Education: A Levels[5]	1.84	0.42	1.17, 2.89	**.008**
Maternal Education: 5 GCSEs[5]	2.33	0.44	1.61, 3.38	**< .001**
Maternal Education < 5 GCSEs[5]	3.09	0.61	2.10, 4.55	**< .001**
Maternal Education: Other[5]	2.25	0.53	1.42, 3.57	**.001**
Single Parent[6]	1.27	0.20	0.94, 1.72	.126
IMD: category 1[7]	1.26	0.15	1.00, 1.58	.051
Parity: 1 - 3 children[8]	1.17	0.16	0.89, 1.53	.255
Parity: 4 or more children[8]	1.22	0.33	0.71, 2.09	.467
Mother Aged 21 to 34 years[9]	1.53	0.29	1.06, 2.22	**.024**
Mother Aged ≤ 20 years[9]	1.80	0.45	1.10, 2.95	**.019**
Smoked in Pregnancy[10]	1.33	0.21	0.97, 1.82	.077
Academic Month of Birth	1.05	0.02	1.01, 1.08	**.004**

Note. n = 5560. Adjusted Model: Pseudo R^2 = 0.07, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: EGPS = English grammar, punctuation spelling; KS2 = Key Stage Two; AOR = Adjusted odds ratio; SE = Standard Error: CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm, IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

In the covariates, being male (AOR 1.84, 95%CI [1.66, 2.04], $p < .001$); Pakistani ethnicity (AOR 1.68, 95%CI [1.47, 1.92], $p < .001$); receipt of means tested benefit (AOR 1.25, 95%CI [1.11, 1.41], $p < .001$); single parenthood (AOR 1.17, 95%CI [1.00, 1.36], $p = .048$); the mother being aged 20 years or below at the child's birth (AOR 1.33, 95%CI [1.04, 1.69], $p = .024$); academic month of birth (AOR 1.18, 95%CI [1.16, 1.20], $p < .001$); and maternal education (A Levels: AOR 1.46, 95%CI [1.22, 1.76], $p < .001$; 5 GCSEs: AOR 1.98, 95%CI [1.69, 2.31], $p < .001$; < 5 GCSEs: AOR 3.03, 95%CI [2.56, 3.58], $p < .001$; other education: AOR 1.76, 95%CI [1.40, 2.21], $p < .001$) were all predictive of increased odds for not reaching the expected standard in mathematics.

3.3.14 Number Skills at Age 5 Years (EYFSP)

The baseline model included in Appendix D (Table D-4), showed all three gestational groups had higher odds of not reaching expected levels in number skills in the EYFSP, compared to full term (early term: OR 1.14, 95%CI [1.01, 1.28], $p = .029$; LPT: OR 1.68, 95%CI [1.32, 2.12], $p < .001$; VMPT: OR 2.00, 95%CI [1.34, 3.00], $p < .001$). However, in the adjusted model, shown in Table 3-15, early term birth was no longer a statistically significant predictor (AOR 1.13, 95%CI [0.99, 1.28], $p = .061$), but LPT birth (AOR 1.76, 95%CI [1.36, 2.26], $p < .001$) and VMPT birth (AOR 2.31, 95%CI [1.49, 3.57], $p < .001$) still had increased odds of not reaching the expected level in number skills.

In the covariates, male sex (AOR 1.77, 95%CI [1.60, 1.97], $p < .001$); Pakistani ethnicity (AOR 1.66, 95%CI [1.45, 1.90], $p < .001$); receipt of means tested benefit (AOR 1.31, 95%CI [1.16, 1.48], $p < .001$); academic month of birth (AOR 1.18, 95%CI [1.16, 1.19], $p < .001$); and maternal education (A Levels: AOR 1.55; 95%CI [1.29, 1.87], 5 GCSEs: AOR 2.14; 95%CI [1.83, 2.51], < 5 GCSEs: AOR 3.20, 95%CI [2.70, 3.79]; other education AOR 1.73, 95%CI [1.37, 2.18], [all $p < .001$]) were predictive of not reaching expected level in number skills.

3.3.15 Shape, Space and Measure at Age 5 Years (EYFSP)

The results for the baseline model in Appendix D (Table D-4) suggested that both VMPT (OR 1.94, 95%CI [1.29, 2.93], $p = .002$) and LPT birth (OR 1.54, 95%CI [1.21, 1.96], $p = .001$), but not early term birth (OR 1.12, 95%CI [0.99, 1.26], $p = .073$) were associated with increased odds of not reaching expected levels in shape, space and measure skills in the EYFSP. This remained the case in the adjusted model, shown in

Table 3-16 (early term: AOR 1.09, 95%CI [0.96, 1.25], *p* = .177; LPT: AOR 1.57, 95%CI [1.21, 2.04], *p* = .001; VMPT: AOR 2.22, 95%CI [1.42, 3.45], *p* < .001).

In the covariates, being male (AOR 1.87, 95%CI [1.68, 2.08], *p* < .001); Pakistani ethnicity (AOR 1.93, 95%CI [1.67, 2.22], *p* < .001); receipt of means tested benefit (AOR 1.22, 95%CI [1.07, 1.38], *p* = .002); single parenthood (AOR 1.19, 95%CI [1.02, 140], *p* = .031); academic month of birth (AOR 1.17, 95%CI [1.15, 1.19], *p* < .001); and maternal education (A Levels: AOR 1.55, 95%CI [1.28, 1.89]; 5 GCSEs: AOR 2.02 95%CI [1.71, 2.38]; < 5 GCSEs: AOR 3.02, 95%CI [2.54, 3.60]; other education AOR = 1.96, 95%CI [1.54, 2.49], [all *p* < .001]) were predictive of not reaching expected levels of development.

3.3.16 Mathematics at Age 7 Years (KS1)

In the baseline model in Appendix D (Table D-5), neither children born early term (OR 1.05, 95%CI [0.90, 1.21], *p* = .556) nor VMPT (OR 0.95, 95%CI [0.52, 1.72], *p* = .855) had increased odds of not reaching expected levels in mathematics at age 7 years. However, LPT birth was associated with increased odds (OR 1.58, 95%CI [1.17, 2.14], *p* = .003). This was replicated in the adjusted model, shown in Table 3-17, with children born LPT having increased odds but not early term nor VMPT (early term: AOR 1.06, 95%CI [0.91, 1.24], *p* = .441; LPT: AOR 1.60, 95%CI [1.16, 2.19], *p* = .004; VMPT: AOR 0.96, 95%CI [0.52, 1.78], *p* = .906).

In the covariates, being male (AOR 1.27, 95%CI [1.12, 1.45], *p* < .001); receipt of means tested benefit (AOR 1.38, 95%CI [1.18, 1.60], *p* < .001); single parenthood (AOR 1.22, 95%CI [1.01, 1.47], *p* = .034); academic month of birth (AOR 1.12, 95%CI [1.10, 1.14], *p* < .001); and maternal education (A Levels: AOR 1.34, 95%CI [1.06, 1.70], *p* = .013; 5 GCSEs: AOR 1.93, 95%CI [1.58, 2.35], *p* < .001; less than 5 GCSEs: AOR 2.59, 95%CI [2.09, 3.21], *p* < .001; other education: AOR 1.99, 95%CI [1.50, 2.64], *p* < .001) were associated with increased odds of not reaching expected levels. Having one to three previous births was associated with decreased odds of not reaching expected levels (AOR 0.81, 95%CI [0.69, 0.95], *p* = .010), compared to the child being the mother’s first-born.

3.3.17 Mathematics at Age 11 Years (KS2)

The baseline model, included in Appendix D (Table D-5), showed that children born LPT and VMPT, but not early term, had increased odds of not reaching expected levels of achievement at age 11 years in mathematics (early term: OR 1.18, 95%CI [0.92, 1.52], *p* = .118; LPT: OR 2.22, 95%CI [1.45, 3.40], *p* < .001; VMPT: OR 2.24, 95%CI [1.19, 4.25], *p* = .013). This pattern remained in the adjusted mode, shown in Table 3-18 (early term: AOR 1.21, 95%CI [0.94, 1.56], *p* = .143; LPT: AOR 2.35, 95%CI [1.50, 3.67], *p* < .001; VMPT: OR 2.46, 95%CI [1.27, 4.77], *p* = .008).

In the covariates, being male was not statistically significant in this instance (*p* = .773). However, single parenthood (AOR 1.45, 95%CI [1.08, 1.95], *p* = .014); mother aged 21 to 34 years old (AOR 1.44, 95%CI [1.01, 2.06], *p* = .042); or 20 years or less at the baby's birth (AOR 1.75, 95%CI [1.09, 2.81], *p* = .021); academic month of birth (AOR 1.05, 95%CI [1.02, 1.08], *p* < .001); and Mother's highest level of education being below A Levels (5 GCSEs: AOR 2.21, 95%CI [1.55, 3.13], *p* < .001; less than 5 GCSEs: AOR 2.48, 95%CI [1.72, 3.59], *p* < .001; other education: AOR 2.21, 95%CI [1.43, 3.43], *p* < .001) predicted increased odds of not reaching expected levels.

3.4 Discussion

The study sought to test the first hypothesis that LPT and early term birth, when compared to children born at full term, are associated with increased odds of not reaching the expected age-related level for overall educational achievement at the ages of 5, 7 and 11 years. The study found that LPT was predictive of increased odds in the unadjusted models at age 5, 7 and 11 years, and in the covariate adjusted model to age 7 years, with the result at age 11 years not significant once covariates were added. The results for early term birth were not statistically significant at any age. The hypothesis is therefore only partially accepted.

The second hypothesis was that children born LPT and early term will have increased odds of not achieving expected level in the individual subjects of reading, writing and mathematics at age 5, 6, 7 and 11 years, compared to children born at full term. In the case of the children born LPT, there were increased adjusted odds ratios for mathematics at every age considered (age 5, 7 and 11 years); increased adjusted odds in writing at age 5 and 11 years; and increased adjusted odds in reading to the age of 6 years. The early term gestational group exhibited increased adjusted odds in writing at age 11 only, but not in any of the other tests considered. This hypothesis is therefore also only partially accepted.

The findings in comparison with other studies and the implications of the findings by both overall educational achievement and for the individual subjects of reading, writing and mathematics are considered in more detail in the next section.

Table 3-14

Multiple Logistic Regression Table for Mathematics at the EYFSP: Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth

Variable	EFYSP Mathematics			
	AOR	SE	95% CI LL, UL	p
Intercept	0.04	0.00	0.03, 0.05	**< .001**
Early Term[1]	1.11	0.07	0.98, 1.26	.098
LPT[1]	1.72	0.22	1.34, 2.21	**< .001**
VMPT[1]	2.30	0.51	1.49, 3.56	**< .001**
Male[2]	1.84	0.10	1.66 - 2.04	**< .001**
Pakistani Ethnicity[3]	1.68	0.11	1.47, 1.92	**< .001**
Other Ethnicity[3]	1.18	0.11	0.99, 1.41	.061
Means Tested Benefit[4]	1.25	0.08	1.11, 1.41	**< .001**
Maternal Education: A Levels[5]	1.46	0.14	1.22, 1.76	**< .001**
Maternal Education: 5 GCSEs[5]	1.98	0.16	1.69, 2.31	**< .001**
Maternal Education: < 5 GCSEs[5]	3.03	0.26	2.56, 3.58	**< .001**
Maternal Education: Other[5]	1.76	0.20	1.40, 2.21	**< .001**
Single Parent[6]	1.17	0.09	1.00, 1.36	**.048**
IMD: Category 1[7,a]	1.08	0.06	0.96, 1.20	.190
Parity: 1 - 3 previous births[8]	0.92	0.06	0.81, 1.05	.237
Parity: 4 or more previous births[8]	0.97	0.13	0.75, 1.26	.843
Mother Aged 21 to 34 years[9]	1.08	0.09	0.91, 1.27	.380
Mother Aged ≤ 20 years[9]	1.33	0.17	1.04, 1.69	**.024**
Smoked in Pregnancy[10]	1.13	0.09	0.97, 1.32	.130
Academic Month of Birth	1.18	0.01	1.16, 1.20	**< .001**

Note. n = 7860. Baseline Model: Pseudo R^2 = 0.00, p < .001 Adjusted Model: Pseudo R^2 = .10, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy.

Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-15

Multiple Logistic Regression Table for Number at the EYFSP: *Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth*

Variable	EFYSP Number			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.01	0.02, 0.04	**< .001**
Early Term[1]	1.13	0.07	0.99, 1.28	.061
LPT[1]	1.76	0.23	1.36, 2.26	**< .001**
VMPT[1]	2.31	0.51	1.49, 3.57	**< .001**
Male[2]	1.77	0.09	1.60, 1.97	**< .001**
Pakistani Ethnicity[3]	1.66	0.12	1.45, 1.90	**< .001**
Other Ethnicity[3]	1.15	0.11	0.96, 1.38	.121
Means Tested Benefit[4]	1.31	0.08	1.16, 1.48	**< .001**
Maternal Education: A Levels[5]	1.55	0.15	1.29, 1.87	**< .001**
Maternal Education: 5 GCSEs[5]	2.14	0.17	1.83, 2.51	**< .001**
Maternal Education < 5 GCSEs[5]	3.20	0.28	2.70, 3.79	**< .001**
Maternal Education: Other[5]	1.73	0.21	1.37, 2.18	**< .001**
Single Parent[6]	1.16	0.09	0.99, 1.35	.065
IMD: Category 1[7]	1.04	0.06	0.94, 1.17	.433
Parity: 1 - 3 previous births[8]	1.06	0.14	0.82, 1.38	.643
Parity: 4 or more previous births[8]	0.96	0.11	0.76, 1.21	.751
Mother Aged 21 to 34 years[9]	1.28	0.16	1.00, 1.64	.051
Mother Aged ≤ 20 years[9]	1.08	0.09	0.91, 1.28	.383
Smoked in Pregnancy[10]	1.11	0.09	0.95, 1.30	.185
Academic Month of Birth	1.18	0.01	1.16, 1.19	**< .001**

Note. n = 7860. Adjusted Model: Pseudo R^2 = 0.11, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-16

Multiple Logistic Regression Table for Space, Shape and Measure at the EYFSP: Predicted by Gestational Group, Sex, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Mother Smoked and Child's Academic Month of Birth

Variable	EFYSP Shape, Space and Measure			
	AOR	SE	95% CI LL, UL	p
Intercept	0.03	0.00	0.03, 0.06	**< .001**
Early Term[1]	1.09	0.07	0.96, 1.25	.177
LPT[1]	1.57	0.21	1.21, 2.04	**.001**
VMPT[1]	2.22	0.50	1.42, 3.45	**< .001**
Male[2]	1.87	0.10	1.68, 2.08	**< .001**
Pakistani Ethnicity[3]	1.93	0.14	1.67, 2.22	**< .001**
Other Ethnicity[3]	1.37	0.13	1.13, 1.64	**.001**
Means Tested Benefit[4]	1.22	0.08	1.07, 1.38	**.002**
Maternal Education: A Levels[5]	1.55	0.15	1.28, 1.89	**< .001**
Maternal Education: 5 GCSEs[5]	2.02	0.17	1.71, 2.38	**< .001**
Maternal Education < 5 GCSEs[5]	3.02	0.27	2.54, 3.60	**< .001**
Maternal Education: Other[5]	1.96	0.24	1.54, 2.49	**< .001**
Single Parent[6]	1.19	0.10	1.02, 1.40	**.031**
IMD: Category 1[7]	1.10	0.06	0.98, 1.23	.109
Parity: 1 - 3 previous births[8]	0.96	0.13	0.74, 1.25	.772
Parity: 4 or more previous births	0.85	0.10	0.67, 1.08	.185
Mother Aged 21 to 34 years[9]	1.26	0.16	0.97, 1.63	.079
Mother Aged ≤ 20 years[9]	1.09	0.10	0.91, 1.29	.353
Smoked in Pregnancy[10]	1.14	0.10	0.97, 1.35	.114
Academic Month of Birth	1.17	0.01	1.15, 1.19	**< .001**

Note. n = 7860. Adjusted Model: Pseudo R^2 = 0.11, $p < .001$. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: EYFSP = Early Years Foundation Stage Profile; AOR = Adjusted odds ratio; SE = Standard Error: CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-17

Multiple Logistic Regression Table for Mathematics at KS1: Predicted by Gestational Group, Sex of Child, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	KS1 Mathematics			
	AOR	SE	95% CI LL, UL	p
Intercept	0.08	0.01	0.06, 0.11	**< .001**
Early Term[1]	1.06	0.08	0.91, 1.24	.441
LPT[1]	1.60	0.26	1.16, 2.19	**.004**
VMPT[1]	0.96	0.30	0.52, 1.78	.906
Male[2]	1.27	0.08	1.12, 1.45	**< .001**
Pakistani Ethnicity[3]	1.01	0.09	0.86, 1.19	.895
Other Ethnicity[3]	0.74	0.09	0.59, 0.93	**.009**
Means Tested Benefit[4]	1.38	0.11	1.18, 1.60	**< .001**
Maternal Education: A Levels[5]	1.34	0.16	1.06, 1.70	**.013**
Maternal Education: 5 GCSEs[5]	1.93	0.20	1.58, 2.35	**< .001**
Maternal Education < 5 GCSEs[5]	2.59	0.28	2.09, 3.21	**< .001**
Maternal Education: Other[5]	1.99	0.29	1.50, 2.64	**< .001**
Single Parent[6]	1.22	0.12	1.01, 1.47	**.034**
IMD: Category 1[7]	1.02	0.07	0.89, 1.17	.804
Parity: 1 to 3 previous births[8]	0.81	0.07	0.69, 0.95	**.010**
Parity: 4 or more previous births[8]	0.84	0.13	0.61, 1.15	.265
Mother Aged 21 to 34 years[9]	0.84	0.09	0.69, 1.03	.097
Mother Aged ≤ 20 years[9]	0.91	0.14	0.67, 1.23	.537
Smoked in Pregnancy[10]	1.01	0.10	0.84, 1.22	.913
Academic Month of Birth	1.12	0.01	1.10, 1.14	**< .001**

Note. *n* = 5560. Adjusted Model: Pseudo $R^2 = 0.06$, $p < .001$. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7] IMD categories 2 to 10; [8]First Born; [9]Mother Aged ≥ 35 years; [10]Mother did not smoke pregnancy. Abbreviations: KS1 = Key Stage One; AOR = Adjusted odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 3-18

Multiple Logistic Regression Table for Mathematics at KS2: Predicted by Gestational Group, Sex of Child, Ethnicity, Means Tested Benefit, Maternal Education, Cohabitation, IMD, Parity, Mother's Age, Smoked in Pregnancy and Child's Academic Month of Birth

Variable	KS2 Mathematics			
	AOR	SE	95% CI LL, UL	p
Intercept	0.05	0.02	0.03, 0.09	**< .001**
Early Term[1]	1.21	0.16	0.94, 1.56	.143
LPT[1]	2.35	0.54	1.50, 3.67	**< .001**
VMPT[1]	2.46	0.83	1.27, 4.77	**.008**
Male[2]	1.03	0.11	0.84, 1.27	.773
Pakistani Ethnicity[3]	0.83	0.11	0.63, 1.08	.163
Other Ethnicity[3]	0.58	0.12	0.39, 0.85	.006
Means Tested Benefit[4]	1.15	0.14	0.91, 1.46	.252
Maternal Education: A Levels[5]	1.55	0.35	1.00, 2.39	.051
Maternal Education: 5 GCSEs[5]	2.21	0.39	1.55, 3.13	**< .001**
Maternal Education < 5 GCSEs[5]	2.48	0.47	1.72, 3.59	**< .001**
Maternal Education: Other[5]	2.21	0.49	1.43, 3.43	**< .001**
Single Parent[6]	1.45	0.22	1.08, 1.95	**.014**
IMD: Category 1[7]	1.03	0.12	0.82, 1.28	.827
Parity: 1 -3 previous births[8]	1.03	0.14	0.79, 1.33	.836
Parity: 4 or more previous births[8]	1.40	0.36	0.84, 2.32	.196
Mother Aged 21 to 34 years[9]	1.44	0.26	1.01, 2.06	**.042**
Mother Aged ≤ 20 years[9]	1.75	0.42	1.09, 2.81	**.021**
Smoked in Pregnancy[10]	1.23	0.19	0.90, 1.67	.198
Academic Month of Birth	1.05	0.02	1.02, 1.08	**.001**

Note. *n* = 2386. Adjusted Model: Pseudo R^2 = 0.06, p < .001. Comparator:[1]Full Term; [2]Female; [3]White British; [4]Does not receive means tested benefit; [5]Higher Education; [6]Living with partner; [7]IMD categories 2 to 10; [8]First born; [9]Mother Aged ≥ 35 years [10]Mother did not smoke pregnancy. Abbreviations: KS2 = Key Stage Two; AOR = Adjusted odds ratio; SE = Standard Error: CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT; Very or Moderately Preterm, IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

3.4.1 Implication of Findings for Overall Educational Achievement

The result of children born LPT at age 5 years having increased odds of not reaching expected levels of educational achievement are consistent with most previous studies investigating school readiness (Louis et al., 2022; Quigley et al., 2012; Woythaler et al., 2015). Though the current findings are contrary to Crockett et al. (2022), who did not find increased odds in their covariate adjusted models, and suggest that this differing result is due to controlling for SES covariates. However, the current study did control for a wide range of SES covariates and still demonstrated that an adverse impact was present for LPT birth, even when these were included.

The current study found no impact in overall educational achievement of early term birth at age 5 years, and this is supported by studies by Quigley et al. (2012) and P. E. Shah et al. (2016). Whilst Dhamrait et al. (2021) found increased odds for children born early term, they used a wide scope of school readiness measure, including some social and emotional aspects, which may account for the difference.

The finding of increased odds at age 7 years for children born LPT, but not early term, of not reaching expected standards in overall attainment accords with Chan and Quigley (2014). Whilst the thesis' study differs from the findings of Hedges et al. (2021), who did find an adverse effect for children born early term at a similar age, the study by Hedges and colleagues did so in a wider overall educational achievement outcome which included science and social studies measures, and this may explain the different results.

The current study found no adverse effect of LPT birth for overall educational achievement at age 11 years in the adjusted model, consistent with Alterman et al. (2022). However, unlike Alterman et al. (2022), the current study also found that the result for early term was non-significant. Given the hypothesised reverse gestational gradient of effect where children born very preterm are the most affected and children born full term the least affected (Boyle et al., 2012), the finding of an adverse effect for early term gestation, but not LPT, in Alterman et al. (2022) is somewhat surprising. The finding of no adverse effect in early term seen in the current study, if there is none within LPT gestation, is more in line with expectations from this gestational gradient.

3.4.2 Implication of Findings for Subject Specific Outcomes

3.4.2.1 Reading

The current study found increased odds of not reaching expected development levels for children born LPT in reading to the age of 6 years, with no adverse effects for early term birth observed in any reading assessment, once modelling was adjusted for covariates.

The finding of a reading deficit in children born LPT at age 5 to 6 years is consistent with other studies (Chyi et al., 2008; Crockett et al., 2022; Quigley et al., 2012; Richards, Drews-Botsch, et al., 2016). However, previous findings after this age have varied with some finding an adverse effect (Chan & Quigley, 2014; Lipkind et al., 2012), and others finding no effect, as in the current study (Chyi et al., 2008; Crockett et al., 2022). As an adverse effect was present in the thesis' study at age 6 years, but not after and this concurs with the majority of studies (Alterman et al., 2022; Chyi et al., 2008; Crockett et al., 2022), it is possible that age around 7 years is a transitional age in reading development for children born LPT.

The current study found no adverse effect from early term birth on reading outcomes at any stage, consistent with Richard Drews-Botsch, et al. (2016). Whilst Quigley et al. (2012) found an adverse effect for children born early term at age 5 years, they did so within a wider "communication, language and literacy" measure and this potentially explains the differing findings. However, Hedges et al. (2021) and Chan and Quigley (2014) both found an adverse effect on children born early term on reading in mid-primary school, unlike the current study. Nevertheless, given the lack of effect seen on children born LPT after age 6 years, it is consistent with the gestational gradient of health and developmental risk in prematurity (Boyle, 2020) that early term births will be at no detriment, if LPT births are unaffected.

3.4.2.2 Writing

For writing outcomes, there was a relatively consistent detrimental effects of LPT birth with a statistically significant effect on three of the four assessments, even after adjusting for control variables outcomes (EYFSP writing; KS2 writing; and EGPS were all statistically significant, but not the KS1 assessment). This is the first study to investigate writing at age 5 years in LPT births and early term, and the results suggest an adverse effect from LPT birth but not from early term. An adverse effect was only present for the children born early term at age 11 years in writing (but not at any of the earlier ages).

Whilst this is the first study to examine writing as an outcome at age 5 years, an adverse effect from LPT birth is suggested from studies using wider literacy measures, such as Quigley et al. (2012) and Crockett et al. (2022). The current study did not find increased odds for children born early term, this differs from Quigley et al. (2012), but this is again potentially explained in that they used a wider measure of communication, language and literacy.

The results for children aged 7 years showed no increased odds of not reaching expected levels for children born LPT (although the results were statistically significant before adjusting for covariates in the baseline model), or early term in writing. This differs from Chan and Quigley (2014), who found higher odds of children born LPT not reaching expected levels at age 7 years but similar to the current study, found no increased odds for children born early term. However, the outcome measured by Chan and Quigley (2014) was tested against an older curriculum to the one analysed in the current study, which is still current at time of writing. The current study's findings are therefore likely to be the most indicative of the existing effect on children born LPT and early term.

At age 11 years, the current study found increased odds of not reaching expected levels in writing for children born LPT. This finding is contrary to Alterman et al. (2022) who did not find such increased odds for children born LPT, but did so for children born early term in a combined measure of "English" (reading and writing combined). The use of this combined measure may account for the differing findings to the study in hand. Additionally, the children in the current study were assessed in a suggested higher-standard curriculum than previously in place (Department for Education, 2016a), whereas Alterman et al. (2022) examined assessment that took place before this new curriculum. The current study therefore represents a more up to date analysis of outcomes for children born early than that by Alterman et al. (2022) and suggests that in the most recent curricular testing there is an adverse effect in writing for early term, LPT and VMPT births at age 11 years, although more studies are required to firmly establish this.

3.4.2.3 Mathematics

There were consistently increased odds of the children born LPT not reaching expected levels in mathematics and these were observed at every assessment point. However, at no stage were higher odds observed in the adjusted models for children born early term in any of the mathematics assessments.

At the ages of 5 and 7 years the current study found an adverse effect of LPT birth, consistent with the bulk of other studies in childhood (Chan & Quigley, 2014; Chyi et al., 2008; Lipkind et al., 2012; Peacock et al., 2012; Quigley et al., 2012; Richards, Drews-Botsch, et al., 2016). The current study did not find an effect for early term at age 5 years or age 7 years, unlike Quigley et al. (2012) and Chan and Quigley (2014). However, the current results do accord with Richards, Drews-Botsch, et al. (2016) in finding no adverse effect for children born early term at age 5 years.

In the current analysis, this adverse effect from LPT birth continued to age 11 years, unlike that found by Chyi et al. (2008) and Alterman et al. (2022). Alterman et al. (2022) conversely found an adverse impact of early term birth. As discussed above, this finding by Alterman and colleagues is somewhat unexpected, given the often observed reverse gradient of gestational risk (Boyle et al., 2012). Additionally, the study by Alterman et al. (2022) was also completed against an earlier curriculum whereas the current study has the advantage of investigating the effects of premature birth in the current curriculum (at time of writing) for this age group and therefore is more likely to illustrate the current impact on children born LPT and early term.

3.4.3 Potential Explanations for the Findings in Educational Achievement

There are several potential explanations why children born LPT may have poorer levels of educational achievement in school. Firstly, there are neural differences at birth with children born LPT being born at a time when the brain is still developing. LTP births have increased incidence of white matter injury compared to term births (Kinney, 2006). White matter has been found to be highly associated with both cognition (measured by reasoning skills) and cognitive based tests of educational achievement (the Woodcock-Johnson IV Test of Achievement) in the general population (Bathelt et al., 2019).

Children born LPT have also been shown to have higher risk of motor and cognitive impairment (Mitha et al., 2024; Pettinger et al., 2023), and special educational needs within school (Alterman et al., 2021). Such motor skills (Giles et al., 2018; Shire, 2016), and cognition (Rohde & Thompson, 2007; Shi & Qu, 2022) have also been shown to predict educational achievement in the general population.

It has also been suggested that the pathology leading to preterm birth may result in lower cognition, health, or attentional issues (Quigley et al., 2012). Children born LPT have increased morbidity and hospital admission, when compared to full term birth

(Dong & Yu, 2011). This may lead to increased school absences due to medical issues which leads to lessened educational achievement. Suggestive of this, Townley Flores et al. (2021) found increased incidence of absenteeism amongst children born moderately and LPT from the very outset of schooling.

The study did not find any evidence of children born LPT or VMPT having increased odds of not working at expected levels in reading after the age of 6 years. This may reflect changes in the type of assessment, as tests after the age of 6 years become more comprehension-based, rather than the decoding skills tested in assessment before this age. It may be that children born preterm initially struggle to master the decoding of words, compared to children born at full term, but do not have difficulty with the comprehension skills tested after this point.

Alternatively, it is also notable that the sample size was lower at age 7 and 11 years, than at the preceding ages and therefore might not have had the statistical power to detect the small effects seen at younger ages. This is somewhat supported by the larger span confidence intervals observed in the study after age 6 years, especially for the children born VMPT. Furthermore, the samples also comprised of differing groups of children, as shown in Table 3.1, e.g. only 24% of the children included in the EFYS assessment at 5 years were included in the KS2 sample (where there was no statistically significant adverse effect).

However, given that the result of an increase in the odds of not working at expected levels for children born LPT in upto age 7 years is also present in most other studies (e.g. Alterman et al., 2022; Chyi et al., 2008; Crockett et al., 2022), it is potentially more likely that this is reflective of the change in assessment demands and that children born LPT are sufficiently able in decoding after this age to understand the text presented.

The results also showed differing effects on writing, where children born VMPT had no statistically significant difference at age 7 years and the result was also not significant for children born LPT, once the covariates were added. However, the result was significant for both groups at age 11 years. The sample at age 7 years were largely not the same children examined at age 11 years, when only two of the children included in the sample also had data at age 7, and this may have been a factor.

3.4.4 Strengths and Limitations of the Current Study

This study makes a substantial contribution to the sparse evidence currently available on the impacts of LPT birth on educational attainment (Martínez-Nadal & Bosch, 2020). It finds reductions in the frequencies with which children born LPT show expected levels of educational achievement, compared to full term-born peers, from the ages of 5 to 11 years. Although, it should be noted that the effect sizes found would be classified as relatively small (Sullivan & Feinn, 2012). This study is the first to observe difficulties in mathematics and writing persisting up to age 11 years in children born LPT using standardised objective assessments of educational performance and controlling for a comprehensive range of factors known to influence later educational attainment.

The research extends previous work that found children born LPT were more likely to experience educational difficulties to age 7 years (Chan & Quigley, 2014; Crockett et al., 2022; Lipkind et al., 2012; Morse et al., 2009; Quigley et al., 2012; Richards, Drews-Botsch, et al., 2016; P. E. Shah et al., 2016; Woythaler et al., 2015), showing these educational disadvantages appear to remain into early adolescence. Importantly, the findings contradict earlier research that suggested difficulties beyond age 7 years were only evident if one examined subjective measures of educational progress (Chyi et al., 2008), or failed to control adequately for confounding SES covariates (Crockett et al., 2022). Both these weaknesses were addressed in the study's design.

In comparing this current study to previous research, this study is the first to sample data from a recent cohort study (all assessments after age 5 years were against the current UK curriculum, at time of writing). Thus, the results are likely to be an especially apposite reflection of LPT birth's impact on children's learning within contemporary education systems.

Considering possible limitations within the study, the data drew from a regional cohort study situated within Northern England (J. Wright et al., 2013). Consequently, the sample contained a higher than typical proportion of children from SES deprived backgrounds and ethnic minorities. However, this can also be viewed as a strength, given that the study investigated the effects of birth characteristics on later development in a population known to have increased susceptibility to health and educational deprivation (Strand, 2014, 2021). Indeed, even after controlling for SES factors children born LPT were found to have independently increased odds of poorer educational attainment. This points to a clear need for targeted support within disadvantaged communities, to limit the extent birth characteristics, such as LPT birth, provide an additional source of disadvantage.

A further limitation of the study is the low number of children in the VMPT group and this affects the study's ability to estimate the effect size in this group with precision. However, the effect of VMPT birth on education is not the main focus of this thesis has been well-documented in previous studies (Aarnoudse-Moens et al., 2011; Guarini et al., 2019; Jansen et al., 2020; S. Johnson et al., 2009; MacKay et al., 2010; Pritchard et al., 2009; Richards, Drews-Botsch, et al., 2016; Roberts et al., 2011; P. E. Shah et al., 2016; Twilhaar, de Kieviet, Aarnoudse-Moens, et al., 2018).

The objectivity of the measures may also be considered somewhat subjective as they were generally teacher assessed, but subject to external local authority moderation (the assessment at age 5 years in the EYFPS; the assessments at age 7 at KS1; and the writing measures at age 11 years were all teacher assessed, with the reading and writing assessed by examination at age 11 years). This potentially limits the findings, in that there may be some variance in teachers grading children of the same standard differently, due to differing interpretation of the standards. However, Rimfeld, et al. (2019) found that teacher assessed measures in national testing showed good validity in students' abilities. Furthermore, such measures have been used in earlier analyses investigating the effect of preterm birth in primary education (e.g. Alterman et al., 2022; Chan & Quigley, 2014; Odd et al., 2013; Peacock et al., 2012; Pettinger et al., 2020; Quigley et al., 2012) and it is arguably not feasible or ethical to investigate outcomes at a very young age, such as 5 years, in subject examination test conditions.

A final limitation of the study is the risk of bias due to missing data. In Appendix C (Table C-1), this concern is attenuated by showing there are only very small differences in the distribution of the background variables between the BiB full sample and the current study's samples, suggesting that such bias is likely to be minimal.

3.4.5 Conclusion

The results suggest that the effect of LPT birth on overall attainment is often comparable in size to that of being male; mother having 13 or fewer years of education (i.e. A Level education); receipt of means tested benefit; and single parenthood, at least to the age of 7 years. Given these are all already well-established important factors influencing childhood attainment (Chan & Quigley, 2014; Norris et al., 2018; Peacock et al., 2012; Pettinger et al., 2020; Quigley et al., 2012) this finding argues for greater appreciation of the impact of LPT birth on educational outcomes in early to mid-primary education.

In contrast, no evidence was found of early term births showing statistically significant increased odds of poorer attainment, compared to full term births, outside of writing at age 11 years. This somewhat contradicts earlier work that suggests, at least up to age 9 years, this group maybe more vulnerable to experiencing educational difficulties (Hedges et al., 2021; Searle et al., 2017). However, some of this previous research has had the advantage of working with larger datasets (Dhamrait et al., 2021; MacKay et al., 2010; Searle et al., 2017). It is also important to note that in the current results the effects of early term birth tended to be smaller in size but in the same direction as those for LPT birth. This is perhaps suggestive of a linear effect of gestational age on education, which diminishes in size the closer to full term a child is born (Pettinger et al., 2020).

In conclusion, this study established that a substantial number of children born LPT were likely to experience educational difficulties into early adolescence in maths and writing, and that this association is independent of maternal SES characteristics. This raises questions about whether more proactive monitoring and support is necessary within this group, during the pre-school years and into formal education. Such action would be contrary to current presumptions, that LPT births require no additional surveillance (National Institute for Health and Care Excellence, 2017). Given the large size of the LPT group, routinely collected linked data may have potential in increasing integrated automated monitoring (B. Wright et al., 2021). Furthermore, teaching professionals report feeling ill-equipped to support children born prematurely (Elvert et al., 2021), hence greater training in this area would also be advisable, especially for early years educators.

Chapter 4

Does the Trajectory of Educational Scores for Children Born LPT and Early Term Differ to that of Children Born at Full Term Gestation?

Chapter Summary

This chapter's study explores if the trajectory of educational scores for children born LPT (early term and VMPT) differs from that of children born at full term gestation. The study analyses data between three time-points (ages 5 to 7 years; 5 to 11 years; and 7 to 11 years). Educational scores from statutory national assessments are standardised as z-scores to allow for comparison across time periods. The study uses multi-level modelling to account for the educational scores being nested in the same individuals.

The study finds that children born LPT had poorer scores than children born at full term gestation at each time-point, with no evidence of any catching-up or widening of the achievement gap. However, there was evidence of a group specific increase by children born at early term gestation in educational scores, relative to children born at full term. This increase in scores took place between age 7 years to 11 years (p = .026).

This longitudinal study therefore suggests that children born LPT do not show any statistically significant catch-up with children born at full term in the primary school years. However, children born at early term show statistically significant catching up in their educational scores, compared to the trajectory seen in children born at full term.

4.1 Introduction

There is an often seen negative effect of premature birth on educational achievement in school, generally revealing a gestational gradient with children born at very preterm gestation being most affected, as observed in the previous chapter and preceding studies (Alterman et al., 2022; Chan & Quigley, 2014; Copper et al., 2023; S. Johnson et al., 2011; Quigley et al., 2012; P. E. Shah et al., 2016). This reflects the theorised reverse gestational gradient of outcomes (Alterman et al., 2021; Boyle et al., 2012). As shown in the previous chapter, this reduced educational achievement has sometimes been observed in LPT gestation, showing that children born LPT have increased odds of not reaching expected levels of development, when compared to full term (Chan & Quigley, 2014; Copper et al., 2023; Quigley et al., 2012). There is also limited evidence of children born at early term gestation not reaching expected levels of development in education at ages 5 to 7 years (Hedges et al., 2021; Searle et al., 2017), as discussed in the previous chapter.

It is posited by some authors that, although children born LPT may have poorer outcomes at the outset of school, children born LPT then catch up with their full term peers and reach similar levels of educational achievement by the age of around 8 to 11 years (Alterman et al., 2022; Crockett et al., 2022). However, the evidence available to support this claim is almost entirely drawn from cross-sectional studies (Alterman et al., 2022; Crockett et al., 2022).

There has not been a study specifically investigating the trajectory of school-based educational scores in children born LPT or early term throughout their primary school education using longitudinal methods. Yet these longitudinal methods are argued to be better in providing evidence of the “course of development” (Vignoles, 2021). This is especially pertinent when considering learning as an outcome, as it is established to be influenced by factors “internal” to the child such as working memory (Alloway & Alloway, 2010; Gathercole & Pickering, 2000; St Clair-Thompson & Gathercole, 2006); self-concept (Herrera et al., 2020; Nagengast & Marsh, 2012); and general cognitive ability (Alloway & Alloway, 2010; Mayes et al., 2009); as well as factors “external” to the child, such as the school SES (Perry & McConney, 2010); the home learning environment (Lehrl et al., 2020; Tamis-LeMonda et al., 2019); parental expectations (Pinquart & Ebeling, 2020); and family SES (S. Thomson, 2018; von Stumm et al., 2022). These internal and external factors are argued to be better accounted for in longitudinal analyses (Ebert et al., 2013; Jimerson et al., 1999; Stewart, 2008; Vignoles, 2021).

This chapter seeks to address this and is, to the best of my knowledge, the first longitudinal analysis comparing the trajectory of educational scores in children born LPT to children born at full term gestation. The aim of the study is to assess change to educational scores over the primary school period for children born LPT, relative to the change seen in the scores of the full term gestational group. There are differing possibilities for this, suggested by previous research, as outlined below.

Differences in scores may narrow between children born LPT and full term across the period. This is suggested by some cross-sectional studies (Alterman et al., 2022; Crockett et al., 2022) and a longitudinal study in children born generally preterm (i.e. less than 37 weeks' gestation) by Odd et al. (2019). This longitudinal study also included a sensitivity analysis in children born moderately/LPT, finding some catching-up in educational scores by this moderately/LPT gestational group, when compared to term-births (37 to 42 weeks' gestation) (Odd et al., 2019).

However, this study is not sufficient in itself to tell whether children born LPT are catching-up educationally with their full term born peers. This is because the moderately/LPT gestational groups were combined in this study and the two gestational groups have been argued to have differing developmental outcomes (Baron et al., 2012); and, because the full term and early term gestational groups were also combined. This likewise conflates gestational groups that have been shown to have differing outcomes, with the early term group sometimes having a statistically significant poorer outcome than full term (e.g. Alterman et al., 2022; Hedges et al., 2021; Searle et al., 2017). Therefore, conflating the two term groups is likely to result in a poorer mean score for the overall "term" group than would be seen if the results for full term gestation only were considered. This reflects the gestational gradient of outcomes with optimum outcomes often seen for children born at around 40 weeks' gestation (Boyle, 2020).

An alternative possibility is that the differences in educational scores between the LPT and full term gestational groups may remain constant. This is in line with many previous findings in children born very preterm (Breeman et al., 2015; Linsell et al., 2018; Twilhaar, de Kieviet, van Elburg, et al., 2018; van Beek et al., 2021).

Finally, there is the possibility that the gap in educational scores of children born LPT and full term may increase, especially before adjustment for SES covariates. This reflects the findings of several studies of SES and education (Crawford et al., 2014; van der Kleij et al., 2023; von Stumm et al., 2022). Disadvantaged SES is itself associated with preterm birth (Stacey et al., 2016; Weightman et al., 2012). Therefore, models with preterm birth as a predictor, without the inclusion of controls for SES, may display differences reflecting this confound that would then not be present in the model appropriately adjusted (Crockett et al., 2022).

The next section examines in more detail the suggestion of a differing trajectory of educational scores in children born LPT to children born full term from cross-sectional studies, as well as from wider psycho-educational testing. The section then looks at the evidence from the only two existing longitudinal studies of educational scores in children born preterm: one examining the wider moderately/LPT gestation (Odd et al., 2019) and one examining very preterm gestation (Twilhaar, de Kieviet, van Elburg, et al., 2018). The section subsequently discusses why a longitudinal study is the preferred manner to evaluate evidence of differing educational score pathways, before finally reviewing the importance of adequate treatment of SES.

4.1.1 Cross-Sectional Evidence of Educational Catch-up in Children born LPT and Early Term

There is evidence of potential educational catching up by children born LPT from cross-sectional studies using the MCS[25] data to examine educational achievement at differing time-points. Firstly, in the MCS data, children born LPT compared to those born at full term (39 to 41 weeks' gestation) had increased odds of not reaching expected levels of achievement at age 5 years (Quigley et al., 2012).

This expected level of achievement was a binary measure of reached or did not reach a good level of development drawn on from 13 subject scales[26] which were

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[25] Millennium Cohort Study

[26] As provided by the definition of good level of overall development (Department for Children, Schools and Families, 2008), for this curriculum children had to achieve a score ≥ 78 across 13 subject scales. These subjects were: 1.

scored 1 to 9, with the child needing to score 78 or more (out of a maximum of 117) to be judged to be working at expected levels of development.

Furthermore, children born LPT, compared to full term (39 to 41 weeks' gestation) in the MCS data, also had increased odds of not reaching expected levels of achievement at age 7 years (Chan & Quigley, 2014). Here, reaching expected levels of development was judged by reaching expected levels in reading, writing and mathematics, rather than the wider range of subjects considered at age 5 years.

Children born LPT did not have increased odds of failing to reach expected levels of overall educational achievement (reading, writing and mathematics combined) at age 11 years, when examined within the MCS dataset by Alterman et al. (2022). They also did not have higher odds of not reaching expected levels of educational achievement at age 16 years, when not passing 5 GCSEs at grades A* - C (including passing English and Mathematics) was the primary outcome (Alterman et al., 2022).

Alterman et al. (2022) therefore conclude that these combined findings potentially indicate that children born LPT catch up in terms of educational outcomes with their full term born peers (39 to 41 weeks' gestation). However, Alterman et al. (2022, p. 13) acknowledge that "solid evidence" of any educational catch-up by children born at LPT gestation is best obtained using longitudinal design with consistent outcome measures. Whereas the MCS data studies used a cross-sectional design, and the outcome measures varied by age, as discussed above.

Similarly, evidence of catch up is provided by Crockett et al. (2022) in a further cross-sectional study of educational scores in children born LPT compared to full

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Personal, Social and Emotional Development: Dispositions and Attitudes; 2. Personal, Social and Emotional Development: Social Development; 3. Personal, Social and Emotional Development: Emotional development; 4. Communication, Language and Literacy: Communication and Thinking; 5. Communication, language and literacy: Linking sounds and letters; 6. Communication, language and literacy: Reading; 7. Communication, language and literacy: Writing; 8.Problem solving, Reasoning and Numeracy: Numbers as labels and for counting; 9. Problem solving, reasoning and numeracy: Numbers as labels and for counting; 10. Problem solving, reasoning and numeracy: Shape, space and measures; 11. Knowledge and Understanding the world; 12. Physical development and 13. Creative Development). The child also had to score ≥ 6 in all four communication, language and literacy scales.

term gestation (39 to 41 weeks' gestation). The authors found that children born LPT were often at increased risk of lower achievement at school entry at age 5 years, even when SES was controlled, but differences in educational scores by age 7 to 8 years were not statistically significant once these controls were included. They therefore argue that there is evidence of the children born LPT catching up in their education. However, again the measures were not consistent with a wider range of subjects considered at age 5 years (emotional, social, physical, communication and language), than at age 7 years (numeracy and literacy). Furthermore, the study was cross-sectional and therefore these were not the same group of children examined at each time-point.

Furthermore, the cross-sectional study in Chapter 3 also suggests evidence of children born LPT catching up: children born LPT are shown to have increased odds in the adjusted models of not achieving expected levels of overall educational achievement at ages 5, and 7 but not at age 11 years. Whereas, children born early term did not have increased odds at any age examined.

However, a differing pattern emerges from the cross-sectional MCS studies within children born early term, compared to children born full term. Here, children born early term when compared to full term births (39 to 41 weeks' gestation) were at increased risk of not reaching overall expected levels of development at age 5 years (Quigley et al., 2012). This was based on a composite of 13 subjects and a score of over 78 (out of a possible 117), as discussed above. However, this was no longer the case at age 7 years, where the study did not find increased adjusted odds for the early term group compared to full term (Chan & Quigley, 2014). Here the comparison compared increased odds of not reaching expected levels in reading, writing and mathematics.

However, increased odds were present for not reaching expected levels of development at age 11 years, when not reaching expected levels in reading, writing and mathematics (combined) was considered as the outcome measure (Alterman et al., 2022). Conversely, there were no increased odds, compared to children born at full term, seen at age 16 years when obtaining 5 grade A* - C GCSEs (including English and Mathematics) was the outcome measure. Therefore, the evidence of children born early term catching up is somewhat conflicting and had differing outcome measures (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012).

Whereas children born very preterm showed a more consistent pattern of educational disadvantage compared to children born full term, from age 5 years through to age 11 and 16 years, in these cross-sectional studies using differing educational outcomes (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012).

Similarly, the cross-sectional study in Chapter 3 suggested that children born VMPT did not catch up in educational attainment by the end of primary school. Children born VMPT were shown to have increased odds of not reaching expected levels of educational achievement at age 5 and age 11 years, but there was not a statistically significant difference at age 7 years and large confidence intervals were present. However, only two children (both of whom were born at full term) were included in the sample at age 11 years. Therefore, it would be useful to gain more conclusive evidence from a longitudinal sample.

In summary, there is some evidence of catching up in children born LPT from cohort studies that have examined educational achievement cross-sectionally, whereas the evidence is inconsistent in children born at early term gestation and there is little evidence of catching up in children born at very preterm gestation (Alterman et al., 2022; Chan & Quigley, 2014; Crockett et al., 2022; Quigley et al., 2012). However, these studies have not used consistent outcomes and examined the same sample of children longitudinally. It is, therefore, vital that this is re-examined using longitudinal analysis where the outcome measures are more harmonised.

4.1.2 The impact of being born LPT and Early Term on Psychoeducational Performance

Given no study has explicitly measured longitudinally the trajectory of educational scores in national statutory school testing in children born LPT and early term, we may also look to the longitudinal results from psycho-educational tests, such as the Woodcock-Johnson II Test of Achievement (Woodcock & Johnson, 1989); the Kaufman Test of Educational Achievement (Kaufmann & Kaufmann, 1998); and Wide Range Achievement Test (Wilkinson & Robertson, 2006). These often examine similar constructs to school educational tests, e.g. the Woodcock-Johnson II Test of Achievement examines calculation and applied mathematical problems (Hicks & Bolen, 1996). These tests are also often predictive of later academic educational scores (McGrew & Pehl, 1988; Panter & Bracken, 2009; Zagar et al., 2018).

Results for children born LPT when compared to children born at full term from these assessments have varied. No clinically meaningful adverse effect (defined as confidence intervals greater than one standard deviation in the study) was observed in children born LPT compared to children born at term (37 to 41 weeks' gestation) in picture vocabulary, word identification, mathematical problems and reading comprehension measured by the Woodcock-Johnson Psycho-Educational Battery (Gurka et al., 2010). However, there are some potential issues with this study. Notably, this study compared children born LPT to term births (37 to 41 weeks' gestation), rather than to full term births (39 to 41 weeks' gestation). It is likely that children born at early term, within this wider category of term-birth, will have had poorer results than full term births, given the proposed reverse gestational gradient of risk (Boyle et al., 2012). Therefore, conflating the two gestational groups will have possibly resulted in a lower mean score than had the full term group been used as the comparator. The study also had a small sample of children born LPT (n = 53). Small sample size has been shown to adversely affect the generalisability of findings (Button et al., 2013). Potentially, therefore, results might be different had the differences between full term and LPT born children been examined and the sample size had been greater.

In a recent study, Lock et al. (2024) used psycho-educational tests prepared specifically for the Early Childhood Longitudinal Study in children aged 5 to 11 years. This study found that children born at 35 to 36 gestational weeks did not have lower scores in reading, mathematics and science than those born at term (37 weeks' or greater gestation). However, there were statistically significant differences in the children born 32 to 34 weeks' gestation when compared to children born at term gestation. Additionally, gestation in weeks continued to be a predictor of reading, mathematics and science scores across the time course.

However, this study by Lock et al. (2024) used an unusual grouping for children born moderately preterm of 32 to 34 weeks' gestation and for children born LPT of 35 to 36 weeks' gestation. This is different from the majority of studies that, as used in this thesis, use 32 to 33 weeks' gestation for moderately preterm and 34 to 36 gestational weeks for the LPT classification (e.g. W.A. Engle et al., 2007; Karnati et al., 2020; Loftin et al., 2010; Raju, 2006, 2017). This use of a slightly different gestational grouping makes findings hard to compare. Lock et al. (2024) also compared to children born at “term” (37 or above weeks’ gestation), rather than full term gestation (39 to 41 weeks’ gestation). This can possibly result in a lower mean score than would be seen if full term gestation was used as the comparator, as discussed in the paragraph above. Furthermore, Lock et al. (2024) did not examine whether there was an interaction between time and gestational group, meaning that we cannot tell if one of the groups experienced a differing effect of time over the six-year study period.

In a further psycho-educational based study, Poulsen et al. (2013) found children born LPT scored lower than full term born children in the Bracken School Readiness Assessment at age 3 years. However, they found that psycho-educational differences were more subtle at age 5 years and age 7 years. By these ages, children born LPT scored worse only in two sub-tests (pattern construction at age 5 years and word recognition at age 7 years). Whilst children born early term had worse scores at age 5 years for some cognitive sub-tests (pattern construction and selection) than children born at full term, they did not score differently to full term born children in any sub-tests beyond age five years. The results therefore indicate some potential narrowing of cognitive gaps but with some areas of difference remaining for children born LPT, and the gap closing completely for children born early term.

In contrast, such testing comparing children born very preterm to those born at full term gestation suggests deficits for the very preterm gestational group are stable with no evidence of catching up (Poulsen et al., 2013). This is also the case for children born very preterm within psycho-educational longitudinal studies which examined the trajectory of scores within the same sample of children throughout (Breeman et al., 2015; Linsell et al., 2018; Stålnacke et al., 2019; van Beek et al., 2021).

4.1.3 Longitudinal Evidence of Increased Educational Catch-Up by Children Born LPT and Early Term

All but two (Odd et al., 2019; Twilhaar, de Kieviet, van Elburg, et al., 2018) of the previous studies investigating national school-based educational scores have done so using cross-sectional analyses. However, neither of these two longitudinal studies focussed specifically on the LPT nor the early term gestational groups.

The only study to consider children born LPT did so as part of a wider group sub-analysis (Odd et al., 2019). The principal focus of this study was to investigate children born preterm (birth at less than 37 weeks' gestation, as an overall category), compared to children born at term (birth at 37 to 42 weeks' gestation) in children between the ages of 7 to 16 years. The study did, however, provide a sub-analysis which compared results for children born moderately/LPT (32 to 36 weeks' gestation) and very preterm (less than 32 weeks' gestation) to those born at term birth (37 to 42 weeks' gestation) (Odd et al., 2019). The study used scores derived from combined statutory school assessment scores in reading, writing and mathematics assessments at four time-points (age 7 to age 11 years; age 11 to 14 years; age 14 to 16 years; as well as the change over the entire period of 7 to 16 years).

This study by Odd et al. (2019) found in the moderately/LPT gestational group there was evidence of catching up in education scores, compared to children born at term gestation. This was shown by a statistically significant interaction of time and moderately/LPT gestational group seen both over the entire time period (ages 7 to 16 years) and between the ages of 7 to 11 years. Therefore, the results from the study by Odd et al. (2019) are similar to those suggested by the cross-sectional studies (Alterman et al., 2022; Chan & Quigley, 2014; Crockett et al., 2022; Quigley et al., 2012) in terms of the impact on children born moderately/LPT, with evidence of catching-up in education after the age of 7 years.

Whilst for children born at very preterm gestation there was no statistically significant interaction for the overall time period (ages of 7 to 16 years), there was a positive significant interaction between time and very preterm gestation for the time period from 7 to 11 years (Odd et al., 2019), also indicating a group specific catching up effect.

However, as Odd et al. (2019) did not distinguish between full term and early term gestation we cannot tell if the moderately/LPT group experienced catching up relative to full term gestation. The gestational gradient of risk (Boyle et al., 2012) would theorise that there would be weaker performance by children born early term relative to the full term group and therefore conflating the two groups would lead to lower scores in this overall "term" gestational group. Furthermore, children born early term have also been shown to have poorer educational performance relative to children born full term (Alterman et al., 2022; Hedges et al., 2021; Quigley et al., 2012; Searle et al., 2017). Therefore, it is arguably preferable to consider these as separate gestational groups.

A further longitudinal study of educational scores conducted by Twilhaar, de Kieviet, van Elburg, et al. (2018) focussed on children born very preterm (less than 32 weeks' gestation) compared to children born at full term (37 or more weeks' gestation), from age 5 to 11 years. They found no evidence of an interaction between time and very preterm gestation. The differences in educational scores between children born very preterm and those born at full term were held to be relatively stable. Whilst this is in line with findings from psycho-educational testing (Linsell et al., 2018; Poulsen et al., 2013), it differs from those of Odd et al. (2019) discussed above.

Therefore, the evidence from cross-sectional studies across cohorts suggests that children born LPT may experience accelerated development between ages 7 to 11 years (Chan & Quigley, 2014; Crockett et al., 2022; Quigley et al., 2012). This is supported by a longitudinal study in educational scores between the ages 7 to 11 years in children born moderately/LPT (Odd et al., 2019), with some further evidence of a diminished effect of LPT birth from psycho-educational testing (Poulsen et al., 2013).

Whilst there has been no study examining the learning trajectory of children born early term longitudinally, the results from the MCS cohort suggest that early term children do sometimes have lower attainment than children born full term but are then able to catch up (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012). Furthermore, although one study found that children born very preterm have a group specific increase in scores between ages 7 to 11 years (Odd et al., 2019), the bulk of the evidence for this gestational group is that the difference in scores between children born very preterm and full term is relatively stable (Linsell et al., 2018; Poulsen et al., 2013; Twilhaar, de Kieviet, van Elburg, et al., 2018).

4.1.4 The Advantage of Longitudinal Studies in Assessing Long-Term Development

The bulk of the studies discussed above (Alterman et al., 2022; Chan & Quigley, 2014; Crockett et al., 2022; Quigley et al., 2012), are cross-sectional and measure the outcome and the exposure in participants at defined single time-points (Setia, 2016; Vignoles, 2021) and the majority of research of the development of children born preterm is conducted using such cross-sectional analysis (Durrant et al., 2020).

Cross-sectional studies are argued to provide a useful preliminary evaluation to inform understanding, ahead of a longitudinal study (Caruana et al., 2015). This understanding from cross-sectional studies is important as a key feature in longitudinal studies is that they are subject to increased participant attrition, and that these individuals may present with different characteristics to those who remain in the study, creating bias within the study (Vignoles, 2021).

However, there are a number of advantages of longitudinal assessment over the cross-sectional methods. Longitudinal assessment has the benefit of recognising development as a dynamic and changing process (Durrant et al., 2020) as longitudinal studies allow examination at individual level throughout a time course. This can enable a better understanding of potential causality and directionality. Cross-sectional studies cannot account fully for the influence of time and therefore are less valid in examining potential causal relationships (Vignoles, 2021). Furthermore, academic and cognitive differences may also only become observable as the child ages or may also potentially resolve with development (van Beek et al., 2021).

Longitudinal studies are argued to be particularly suited to examining developmental trajectories of skills as they include consideration of both inter-personal and intra-personal variance in the child’s development, which may not be evident in cross-sectional studies of development (Karmiloff-Smith, 1998).

Furthermore, longitudinal data can incorporate multi-level modelling techniques. These can enable analysis to assess and measure change in the same participant over time and can allow for these factors to be nested in the same individual (Grammer et al., 2013; Rutter, 1994; Vignoles, 2021). This allows the data to have a hierarchical structure with repeated measures over time with the results at level one for each time-point, nesting in the same individual at level two throughout the assessment period (Steele, 2008; Steenbergen & Jones, 2002). The treatment of this nesting is argued to be the principal advantage of multi-level modelling over traditional regression-based models in treatment of repeated measures (Steenbergen & Jones, 2002). Furthermore, failing to provide for the structure of results being nested with the same individuals can result in biased estimation leading to erroneous results (Dowding & Haufe, 2018).

Therefore, longitudinal assessment is purported to provide better evidence of whether change occurs than cross-sectional analysis, and combining this with multi-level modelling allows for individual factors to be considered nested within that individual across the time-points.

4.1.5 Importance of SES Covariates

The effect of SES is suggested to be important in studies of children born preterm as some cross-sectional studies of educational achievement and LPT birth have found that any adverse effect is no longer seen once SES covariates are added (Ahlsson et al., 2015; Crockett et al., 2022; Morse et al., 2009). Disadvantaged SES is associated with preterm birth (Klumper et al., 2020; Stacey et al., 2016; Weightman et al., 2012). This confounding effect from lower SES on both educational outcome and preterm could therefore be a potential explanation of the lower educational achievement observed in preterm birth (Crockett et al., 2022).

Crockett et al. (2022) also suggest that the influence of SES disadvantage increases with age and therefore children born into lower SES households have worsened education outcomes later in school. Children from disadvantaged SES are at increased risk of falling behind in education (Jimerson et al., 1999; Reardon et al., 2013; von Stumm et al., 2022). Indeed, in the UK, children from more advantaged SES outperform educationally those from disadvantaged SES (Crawford et al., 2014). Accordingly, Ahlsson et al. (2015) posit that differences observed in school performance and preterm birth in gestation greater than 30 weeks may be due to disadvantaged SES being also associated with preterm birth, rather than the preterm birth itself. They suggest that this is particularly a factor in studies investigating education later in development when the effect of SES is greater.

4.1.6 Aim of the Study and Hypotheses

The aim of the study was to examine if there was a different longitudinal trajectory in educational scores for children born LPT and early term compared to children born at full term between three time-points (age 5 years to 7 years, age 5 to 11 years and age 7 to 11 years).

4.1.6.1 Hypothesis One

The first hypothesis was that children born LPT will have a differing trajectory of educational scores to children born at full term in primary education (i.e. between the ages of 5 to 7 years, 7 to 11 years and overall (5 years to 11 years).This is based on the previous findings of Odd et al. (2019) and cross-sectional findings (Alterman et al., 2022; Chan & Quigley, 2014; Crockett et al., 2022; Quigley et al., 2012). It is, however, tentative given that this has not been specifically previously examined.

4.1.6.2 Hypothesis Two

The second hypothesis was that children born early term will have a differing trajectory of educational scores in primary education. This is based on the cross-sectional findings (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012) and suggested by the findings from psycho-educational testing (Poulsen et al., 2013). This hypothesis is also tentative, given this has not been examined longitudinally before and the cross-sectional findings are somewhat inconsistent (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012).

The current study is the first to look at the longitudinal trajectory of children born at LPT and early term gestation in their educational scores throughout their primary education journey from the age of 5 to 11 years. It also provides new evidence in children born in a multi-ethnic, longitudinal cohort in a relatively deprived location. Studies in this area have not investigated similar demographics before as Odd et al. (2019) and Twilhaar, de Kieviet, van Elburg, et al. (2018) were only able to distinguish between white and non-white ethnicity.

4.2 Methods

4.2.1 Participants and Study Setting

Data from the BiB cohort dataset was used, as described in Chapter Two. Participants were excluded from the study consistent with the criteria in other chapters and listed in Section 2.4.1. Additionally, participants were excluded if they did not have an educational score from their statutory school assessments in mathematics, reading and writing at T1[27] (age 4 to 5 years in this study); T2[28] (age 6 to 7 years); and T3[29] (age 10 to 11 years) or if they took the assessment outside of the typical school year. Children were only included in the final sample if they had full data for the outcome variables.

Participants were also required to have complete data on the control variables set out in Table 2-1 in the Methods Chapter and in Section 4.2.6 of this chapter, as these factors are known to affect the analysis on preterm birth. The sample selection is shown in Figure 4-1 with sample characteristics by gestational group presented in Appendix E (Table E-1). The children in the sample were aged M = 135.33 months (SD = 3.48 months) at the final time-point: T3. This mean age was similar in all gestational groups: full term: M = 135.35 (SD = 0.09); early term: M = 135. 24 (SD = 0.19); LPT: M = 135.23 (SD = 0.37); VMPT: M = 135.54 (SD = 0.73).

4.2.2 Measures

4.2.2.1 Gestational Variable

Consistent with the other studies in this thesis, gestation is measured by completed weeks and grouped into gestational categories: VMPT (less 34 weeks' gestation); LPT (34 to 36 weeks' gestation); early term (37 to 38 weeks' gestation) and full term (39 to 41 weeks' gestation). As elsewhere in this thesis, full term gestation was used as the comparator group for the study.

4.2.2.2 Time Variable

The analysis used a repeated measure of education scores drawn on three time-points in primary education when statutory assessment testing is completed in English Primary School. The school years this takes place in are: Reception (age 4 to 5 years); School Year 2 (age 6 to 7 years); and School Year 6 (age 10 to 11 years). These years were considered as time variables within the study where time was considered as a factor variable of T1, T2, and T3.

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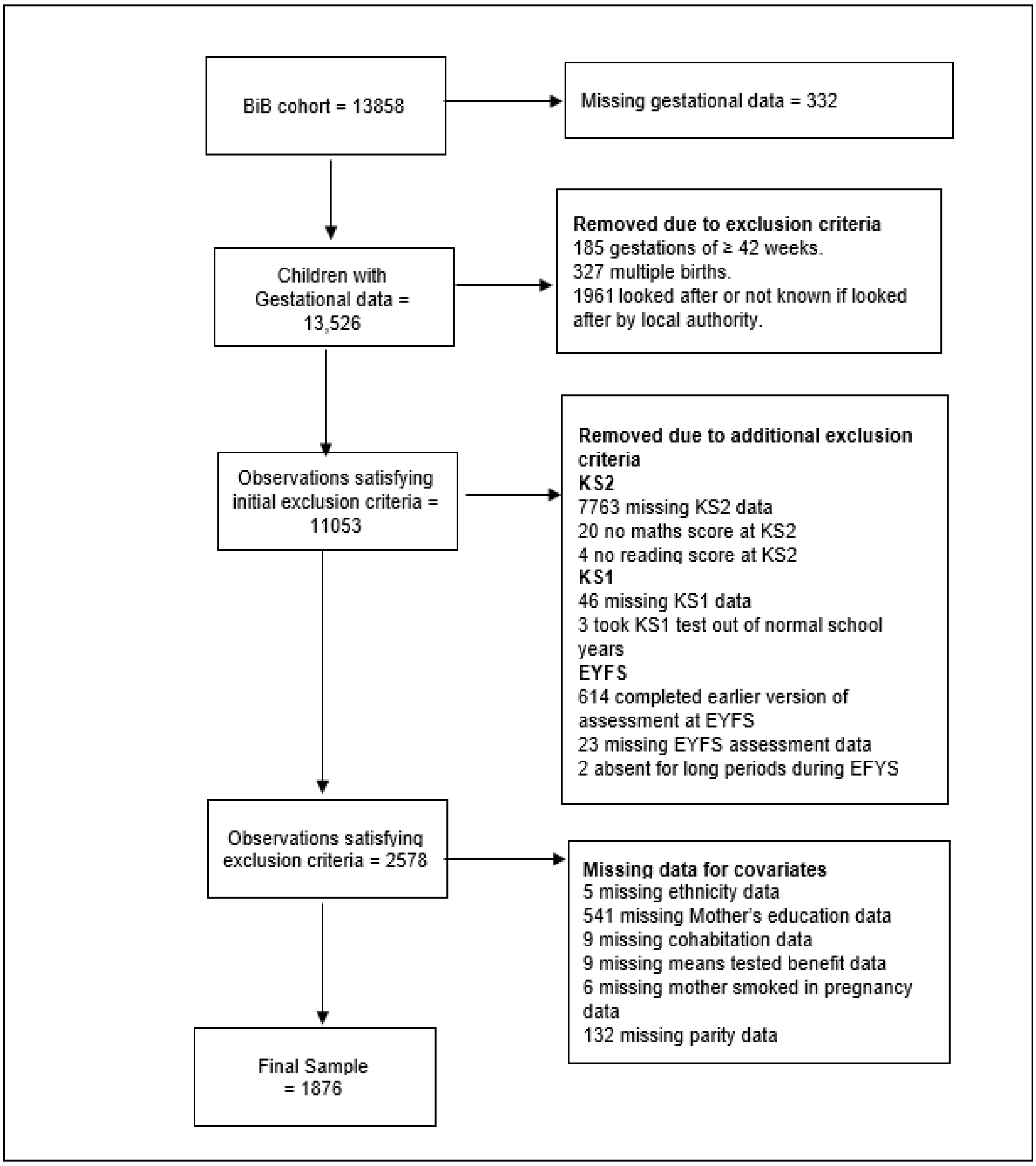
[27] Time 1

[28] Time 2

[29] Time 3

Figure 4-1

Sample Selection for Educational Scores Study



4.2.2.3 Education Scores Outcome Measure

The educational scores were drawn from statutory assessments in reading, writing and mathematics scores which were combined to form an overall total score at each time-point. These total scores were then standardised to z-scores at each time-point. In order to form a comparable score, some data transformation from the raw scores from the original school data was required. The following section provides a full description of how scores at each school assessment were transformed to derive a suitable repeated measure.

4.2.2.3.1 Educational Score at Age 4 to 5 years

The children in the sample were assessed by their teacher against the EYFS 2012 curriculum (Department for Education, 2012). This assessment takes place in the school year the child turned 5 years, which for all children in the study was 2013. This is considered at T1 within this study.

The assessment ranked children as “emerging”, “expected”, and “exceeding” age-related educational expectations, with “emerging” being the lowest and “exceeding” being the highest level of achievement. These outcomes are teacher-assessed across the school year but are also subject to internal school-based moderation, and external moderation by local authority sampling to ensure consistent and accurate judgements (Standards and Testing Agency, 2014a). These judgements are made against set criteria which described behaviours that the child had to have displayed to reach each category. The assessment was conducted against 17 early learning goals. Four of these learning goals are in reading, writing and mathematics, as mathematics is assessed in two learning goals (“number” and “shape, space and measure”).

To transform this ranking into an educational score, these levels were converted into numeric scores reflecting their level of achievement (emerging = 1, expected = 2, exceeding = 3) for each of the four relevant learning goals (reading, writing, mathematics (number), mathematics (shape, space, and measure). These scores were then combined to form a total educational score. This resulted in a minimum possible educational total score of 4 and a maximum possible educational total score of 12.

The mean score from within the sample was *M* = 6.93, (*SD* = 2.23). The maximum sample score was 12, and the minimum sample score was 4. This total score was then converted to a z-score (*M* = 0 [*SD* = 1]), to allow comparison with later assessments.

4.2.2.3.2 Educational Score at Age 6 to 7 years

The second assessment took place at around 7 years. At this point, the children in the sample completed the KS1 curriculum statutory assessment tests. For all the children in the sample this assessment occurred in 2015. These tests are teacher-assessed outcomes that are subject to internal and external moderation (Department for Education, 2015a). The reading assessment and mathematics assessment is also informed by national tests (Standards and Testing Agency, 2014b). Assessment took place against reading, writing, mathematics, and science age-related educational expectations (Department for Education, 2015b). However, only the reading, writing and mathematics scores are considered in the current study in order to produce an outcome harmonised with that at age 4 to 5 years, where the subject of science was not assessed.

The KS1 assessment ranked attainment into differing levels dependent on whether the child was considered to be working below age-related expected levels; at expected levels; or above age-related expected levels. The statutory national curriculum levels in 2015 were ranked as follows; “w” (working towards level 1); level “1” (working below age-related expected levels); levels “2a”, “2b” and “2c” (working at expected levels with 2c being the lowest and 2a the highest); level “3” (working above expected levels); and level “4” (working well above age-related expected levels) (Department for Education, 2015b).

The Department for Education convert these ranking into numeric scores using the numerical conversion scheme (Department for Education, 2019b). Details of this conversion scheme are included in Appendix F (Table F-1). The ranked descriptor assessments (w, level 1, level 2c, level 2b, level 2a, level 3 and level 4) were converted into scores using this scheme.

The resultant scores for reading, writing and mathematics were combined to form a total educational score. The mathematics score was double weighted (i.e. formed 50% of the total educational score, with reading 25% and writing 25%), to reflect scores at age 5 years which had two measures of mathematics included (number and shape, space, and measure). This double weighting also reflects the guidance of the Department for Education in measuring the trajectory of educational scores to provide the most reliable predictor of education scores at 11 years (Department for Education, 2019b). Using this scoring system provides a total maximum potential score of 108 and a total minimum potential score of 12.

The mean sample total educational score within the study at T2 was M = 63.19 (SD = 13.21). The maximum sample total educational score was 84 and the minimum sample score was 12. This total score was then converted to a z-score (M = 0 [SD = 1]), to allow comparison with other assessment points.

4.2.2.3.3 Educational Score at Age 10 to 11 years

The final assessment took place in school Year 6, when the children were aged around 11 years. The children in the sample completed the KS2 curriculum (Department for Education, 2014) and received a standardised numerical educational score from national assessment in reading, writing and mathematics. All the children in the sample were assessed in 2019.

Scores were taken from the actual test scores in reading and mathematics. Additionally, equivalised test scores for writing, which was teacher assessed, were taken using an equivalent score using the Department for Education numerical conversion scheme for children in KS2 assessments (detailed in Appendix F: Table F-2).

There were 22 children in the sample who did not sit the KS2 tests due to working well below the test level (21 children in reading and mathematics and one child in mathematics only). These children are teacher assessed against set criteria and are given an equivalent test score by the Department for Education (2019b); the scoring used for this is also detailed in Appendix F (Table F-3). Therefore, in the current study the Department for Education (2019b) equivalent educational test score was used for mathematics and reading for these children. The children scored in this manner were in similar proportions for each of the gestational groups as shown in Table 4-1.

The marks for reading, writing and mathematics were aggregated to form a total educational score. Mathematics was again double weighted (representing 50% of the total score, to reflect scores at T1 and T2 and the process followed by the Department for Education in England in measuring the trajectory of educational scores (Department for Education, 2019b). Using this method, the maximum possible total educational score was 473, and the minimum possible total educational score was 236 for T3.

In the sample, the mean total educational score within the study was M = 414.66 (SD = 30.53), the maximum total educational score was 473 and the minimum educational score was 248 at T3. This total educational score was then converted to a z-score (M = 0 [SD = 1]), to allow comparison with other time-points.

Table 4-1

Teacher Assessed Scores and Test Assessed Scores by Gestational Group

	VMPT		LPT		Early Term		Full Term	
Derived Score	*n*	%	*n*	%	*n*	%	*n*	%
Mathematics Teacher Assessed Score	0	0	2	2.7	5	1.4	15	1.1
Mathematics Test Score	26	100	74	97.3	359	98.6	1395	98.9
Reading Teacher Assessed Score	0	0	2	2.7	5	1.4	14	1.0
Reading Test Score	26	100	74	97.3	359	98.6	1396	99.0

Note: The Chi square results testing group differences in these scores were not statistically significant for either mathematics or reading: X^2 (3, n = 1876) 1.98, p = .578, for mathematics; X^2 (3, n = 1876) 2.28, p = .516 for reading.

4.2.2.4 Control Variables

Potential maternal and child-related control variables were selected *a priori*, based on those included in existing literature (see Table 2-1 in the Methods Chapter for further details). Additionally, academic month of birth was included as a continuous variable (from September = 1 to August = 12); as birth month has been shown to be predictive of education, with children older in the academic year achieving a better score (Copper et al., 2023; Oosterbeek et al., 2021; Pettinger et al., 2020).

The following covariates were grouped together as SES factors, reflecting the categorisation used in Odd et al. (2019): maternal education; IMD area of residence (Department for Communities and Local Government, 2010); parental receipt of means tested benefit; the age of the mother at the child's birth; and the mother's cohabitation status of either being a single parent or living with their partner. The following covariates were considered as antenatal factors, based on the categorisation used in Odd et al. (2019): the academic month of child's birth; the sex of the child; the mother's ethnicity; whether the mother smoked in the pregnancy and parity (first pregnancy, 1 to 3 previous birth, 4 or more previous births). These control variables were all time invariant conditions.

4.2.3 Statistical Analysis

Descriptive statistics for the sample by gestational group were produced, showing the mean scores with confidence intervals and the standard deviation at T1 (EYFS assessment), T2 (KS1 assessment) and T3 (KS2 assessment).

4.2.3.1 Multi-level Modelling

In order to evaluate changes in the z-score by gestational group across the time period multi-level modelling was used in Stata 17 (StataCorp., 2021) via the 'mixed' function. The main independent variables were time and gestational group.

Time was considered in the first analysis as a factor variable with the trajectories examined: T1 to T3 (age 5 years to 11 years); and T1 to T2 (age 5 to 7 years) which are examined together from the common start point of T1 (the EYFS assessment). The analysis was then repeated with time re-centred at T2 to examine the trajectory from T2 to T3. The modelling for each analysis is shown below.

4.2.3.1.1 Model Specifications

The two models were:

Model 1.1 (Progress from age 5): $y_{ji} = \beta_0 + \sum_{i=1}^{2} \gamma_i \, \mathrm{D}_{ji} + \sum_{k=1}^{3} \beta_k \text{Gestational group}_{jk} + \sum_{i=1}^{2} \sum_{k=1}^{3} \delta_{ik} \mathrm{D}_{ji} \text{ Gestational group}_{jk} + u_j + \varepsilon_{ij}$

Where the subscripts j, i and k denote the child; the time the child is observed; and the gestational group respectively. There are three points in time when a child can be observed, i = 0; 1; and 2, which corresponds to age 5, 7 and 11 years. There are four gestational groups k = 0 for children born at full term; 1 for children born at early term, 2 for children born LPT; and 3 for children born VMPT.
$\text{Gestational group}_{jk}$ is a dummy variable taking value 1 if the child j belongs to the gestational group k, with the baseline "left out" category being the full term gestational group. D_{j1} is a dummy variable taking value 1 if the child j is observed at age 7, and 0 if observed at age 5 or 11 years, and D_{j2} is a dummy variable taking value 1 if the child j is observed at age 11 years and 0 if observed at age 5 or 7 years. β_0 is the intercept measuring the average score at age 5 years for children born at full term, while γ_1 is the differential intercept for full term born children observed at age 7 and γ_2 at age 11 years, meaning that γ_1 (γ_2) captures the average progress from 5 to 7 (11) for a child born at full term. β_k is the differential intercept at age 5 for children with gestational group k. δ_{1k} (δ_{2k}) is the differential average progress from 5 to 7 (11) years for children with gestational group k with respect to full term group. u_j is an individual-specific error term which varies across children but is invariant across time i, while ε_{ij} is an error term that varies across both individuals (children) and time.

Model 1.2 (Progress from age 7 to 11): $y_{jt} = \alpha_0 + \eta\Delta_{j1} + \sum_{k=1}^{3} \alpha_{1k} \text{Gestational group}_{jk} + v_j + \varsigma_{jt}$

Where t takes value 1 for age 11 and 0 for age 7 years, Δ_{j1} take value 1 if t = 1 (age 11) and 0 otherwise. α_0 is the intercept and captures the average z-score at age 7 for children born at full term, η is the differential intercept capturing the average progress from 7 to 11 for a child born at full term, i.e. the difference between the z-score at 11 and at 7 for child j. Whilst α_{1k} captures the differential progress for children belonging to the gestational group k (defined above). v_j is an individual specific error that is time invariant, while ς_{jt} is an error term that varies across children and time.

The models were estimated using individual (child) random effect estimation. Individual fixed effect estimation could not be used as the explanatory variables do not vary across time. However, to take account of endogeneity issues a rich set of covariates were controlled. More precisely, three versions of models 1.1 and 1.2 were estimated: (1) with no additional covariates, (2) with SES covariates, (3) with both SES and antenatal covariates.

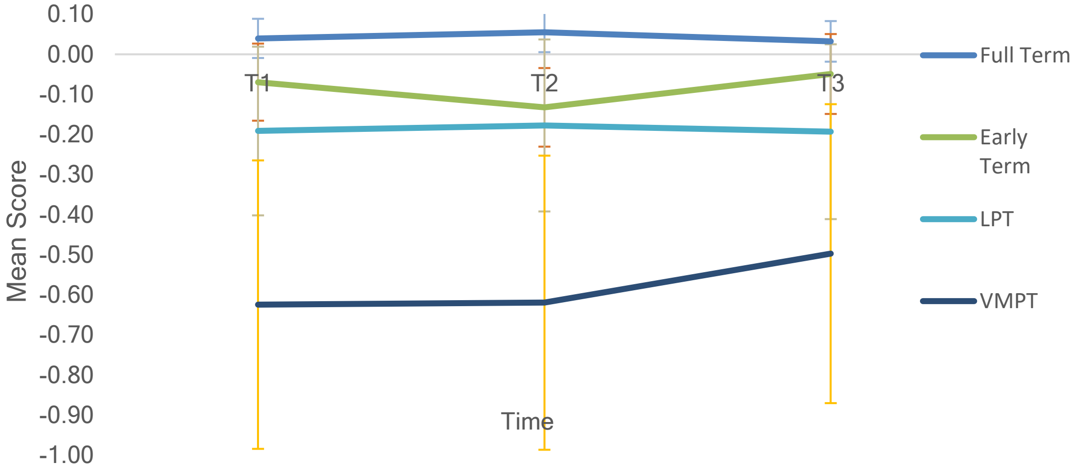
The amount of deviance in the model was used to compare models. This is the sum of the log-likelihood of the observations across all the observations in the model and is an indicator of poorness of fit, with lower values indicating a better fit (D. A. Luke, 2020). The deviance within the model is shown for each of the analyses.

4.3 Results

The mean scores by gestational group at each time-point are shown in Appendix G (Table G-1) and illustrated in Figure 4-2.

Figure 4-2

Line Graph to Show Z-Scored Mean Educational Score by Gestational Group



Note. 95% confidence intervals for each gestational group are shown. T1 = Time 1; T2 = Time 2; T3 = Time 3; LPT = Late Preterm; VMPT = Very and moderately preterm.

4.3.1 Multi-Level Modelling Results

The impact of time on early term, LPT and VMPT gestational groups was considered with time as a factor variable. This was firstly analysed with T1 (the EYFS assessment) as the baseline category and then repeated with T2 (the KS2 assessment) as the baseline category. The analysis modelled the change between T1 and T3 (EYFS to KS2 mean z-scores); the change between T1 and T2 (KS1 to KS2 mean z-scores); and the change between T2 and T3 (KS1 to KS2 mean z-scores) for the early term, LPT and VMPT gestational groups compared to the change seen in the full term gestational group.

The results of this are shown in the multi-level model regression tables in Appendix H (Tables H-1 to H-6). Table 4-2 shows the initial difference in the z-mean educational scores at T1. Whilst Table 4-3 summarised the overall change (T1 to T3); the change between T1 and T2; and the change between T2 and T3 by gestational group.

4.3.1.1 Change in Z-Scored Mean Educational Scores Overall (T1 to T3)

The results were examined for changes in the z-scored mean educational scores overall from T1 (the EYFS assessment) to T3 (the KS2 assessment). No overall effect of time was observed for the full term gestational group (p = .728), seen in Tables H-1 to H-3.

There was also no statistically significant interaction between the LPT, VMPT and early term gestational groups and time. An interaction would show a difference in the change in scores between that gestational group and the full term comparator group over the overall time period, thereby suggesting catching up or an increasing gap, relative to the trajectory seen in the full term gestation group. However, the interaction terms were not statistically significant for any gestational group (early term: p = .559; LPT: p = 951, VMPT: p = .401) as seen in Table 4-3 and Table H-3.

4.3.1.2 Change in Z-scored Mean Educational Score T1 to T2 (EYFS to KS1)

The results were examined for changes in the z-scored mean educational scores from T1 (the EYFS assessment) to T2 (the KS2 assessment). No effect of time for the full term gestational group from T1 to T2 was observed (p = .476), as seen in Tables H-1 to H-3.

There was also no statistically significant interaction between the VMPT, LPT and early term gestational group and T1 to T2 (early term: p = .101; LPT: p = 987, VMPT: p = .947) as shown in Table 4-3 and Table H-3.

4.3.1.3 Change in Z-Scored Mean Educational Scores T2 to T3 (KS1 to KS2)

The results were examined for changes in the z-scored mean educational scores from T2 (the KS1 assessment) to T3 (the KS2 assessment). Again, there was no effect of time for the children born full term (p = .289) seen in Tables H-4 to H-6. There was also no statistically significant interaction between children born LPT (p = .938) and the effect of time, nor children born VMPT (p = .365) and the effect of time, which would indicate that there was a specific group effect of time. However, there was a group specific increase in scores over the period for children born early term (p = .026), as shown in Tables H-4 to H-6 and summarised in Table 4-3.

4.3.1.4 Initial Effect of Gestational Group at T1

The multi-level regression result, seen in Table H-1 and summarised in Table 4-2, showed that children born at LPT (p = .049), and children born at VMPT (p = .001) gestation, had statistically significant poorer z-mean educational scores than children born at full term at the outset (T1). The result for the children born at early term was not statistically significant (p = .062). This continued to be the case when the SES covariates were added, with children born LPT (p = .029) and VMPT (p < .001), but not children born early term (p = .093), exhibiting poorer T1 z-mean educational scores than children born full term, as shown in Table H-2 and summarised in Tables 4-2. This pattern remained when both the SES and antenatal covariates were both included in the model shown in Table H-3 and summary Table 4-2 (LPT: p = .031; VMPT p < .001; early term p = .137).

Table 4-2

Difference in Z-Scored Mean Educational Score at T1, the Outset of School, by Gestational Group

	Unadjusted			Adjusted for SES Factors[a]			Adjusted for SES[a] & antenatal[b] Factors		
Gestational Group	Mean	95% CIs LL, UL	p value	Mean	95% CIs LL, UL	p value	Mean	95% CIs LL, UL	p value
Early Term (β_{11})	-0.11	-0.22, 0.01	.062	-0.10	-0.21, 0.02	.093	-0.08	-0.19, 0.03	.137
LPT (β_{12})	-0.23	-0.46, 0.00	**.049**	-0.25	-0.47, -0.03	**.029**	-0.24	-0.46, - 0.02	**.031**
VMPT (β_{13})	-0.66	-1.05, -0.28	**.001**	-0.67	-1.04, -0.30	**< .001**	-0.68	-1.05, - 0.31	**< .001**

Note. 95% CI = 95% Confidence Interval, LL = Lower Limit, UL = Upper Limit; LPT = Late Preterm; VMPT = Very and Moderately Preterm. [1]T1 to T3 (EYFS z-scored mean educational scores to KS2 z-mean educational scores [age 5 to 11 years]). [2]T1 to T2 (EYFS Z-mean educational scores to KS1 z-mean educational scores [age 5 to 7 years]). 3T2 to T3 (KS1 Z-mean educational-scores to K2 Z-mean educational scores [age 7 to 11 years]). [a]SES covariates: maternal education; IMD area of residence; receipt of means tested benefit; mother's age at child's birth. [b]Antenatal covariates: Academic Month of Birth (September =1, August = 12); Sex of child; Mother's ethnicity.

Table 4-3

Multi-Level Linear Regression Mean Difference Change Overall, T1 to T2 and T2 to T3 Compared to Full Term Gestational Group

	Early Term			LPT			VMPT		
Time Period	Mean Diff.	95% CIs LL, UL	p value	Mean Diff.	95% CIs LL, UL	p value	Mean Diff.	95% CIs LL, UL	p value
Overall Change (T1 to T3)[1]	0.03	0.07, 0.12	.559	0.01	-0.18, 0.19	.951	0.13	-0.18, 0.45	.401
Change T1 to T2[2]	-0.08	-0.17, 0.02	.101	0.00	-0.19, 0.19	.987	-0.01	-0.32, 0.30	.947
Change T2 to T3[3]	0.11	0.01, 0.20	**.026**	0.01	-0.18, 0.19	.938	0.15	-0.17, 0.46	.365

Note. Mean Diff. = Mean change relative to change seen in full term reference group. 95% CI = 95% Confidence Interval, LL = Lower Limit, UL = Upper Limit; LPT = Late Preterm; VMPT = Very and Moderately Preterm. [1]T1 to T3 (EYFS z-scored mean educational scores to KS2 z-mean educational scores [age 5 to 11 years]). [2]T1 to T2 (EYFS Z-mean educational scores to KS1 z-mean educational scores [age 5 to 7 years]). [3]T2 to T3 (KS1 Z-mean educational-scores to K2 Z-mean educational scores [age 7 to 11 years]). Outcomes are the change in z-scored mean educational scores relative to the full term group.

In the model adjusted for SES, shown in Table H-2, in the fixed-effect covariates, all categories of mother's education being lower than higher education (all p <.001) or the mother's highest level of education being defined as "other" (p = .017); receipt of means tested benefit (p < .001); and the mother being aged 21 to 34 years (p =.003); or 20 years or less (p = .004) at the time of the child's birth were associated with a poorer overall educational score at T1 (the EYFS assessment).

In the model adjusted for both SES and antenatal factors shown in Table H-3, in the fixed effect covariates, all categories of mother's highest level of education being lower than higher education (all p <.001) or mother's highest level of education being defined as "other" (p =.014); receipt of means tested benefit (p = .004); and the mother being aged 21 to 34 years (p =.007), or 20 years or less (p = .021) at the time of the child's birth continued to be associated with a poorer z-scored mean educational score at T1 (the EYFS assessment). Additionally, academic month of birth (p = .002); being male (p < .001); being of Pakistani ethnicity (p = .023); and being a single parent (p =.022) were associated with a poorer result at T1: the EYFS assessment.

4.3.1.5 Initial Effect of Gestation at Time 2 (KS1 Assessment at Age 7 years)

The baseline results for T2 showed all three gestational groups had poorer scores than those born at full term in the unadjusted model shown in Table H-4 (VMPT: p = .001; LPT: p = .047; early term: p = .001); the adjusted for SES model shown in Table H-5 (VMPT: p < .001; LPT: p = .028; early term: p = .002); and the adjusted for SES and antenatal covariates model in Table H-6 (VMPT: p < .001, LPT: p = .030; early term: p = .004).

In the model adjusted for SES (shown in Table H-5) in the fixed-effect covariates, all categories of mother's education being lower than higher education (all p <.001), or being defined as "other" (p = .017); receipt of means tested benefit (p < .001); and the mother being aged 21 to 34 years (p =.003) or 20 years or less (p = .004) at the time of the child's birth were associated with a poorer overall educational score at T2.

In the SES and antenatal adjusted model (shown in Table H-6), in the fixed effect covariates, all categories of mother's highest level of education being lower than higher education (all p < .001) or mother's highest level of education being defined as "other" (p = .014); receipt of means tested benefit (p = .004); and the mother being aged 21 to

34 years (p = .007), or 20 years or less (p = .021) at the time of the child's birth continued to be associated with a poorer z-scored mean educational score at T2 (the KS1 assessment). Additionally, academic month of birth (p = .002); being male ($p <$ .001); being of Pakistani ethnicity (p = .023); and being a single parent (p = .022) were associated with a poorer educational score.

4.4 Discussion

The study sought to test the hypotheses that children born LPT and early term would have a differing trajectory of educational scores in primary school (T1 to T2; T1 to T3; and T2 to T3). The study tested this hypothesis using multi-level linear regression in z-scored educational scores. The results found that there was no evidence of a differing trajectory of learning for children born LPT at any of the time periods assessed. However, there was evidence of a group-specific increase in scores for children born early term between T2 and T3 (KS1 [age 7 years] to KS2 [age 11 years]). This indicates that the early term group is catching-up with those born at full term between these ages. The hypothesis of a differing trajectory of education scores for children born LPT is therefore rejected but the hypothesis of a differing trajectory of education scores for children born early term is partially accepted.

4.4.1 Comparison with Previous Studies and Implication of Findings

The present study found no evidence of a differing trajectory of scores for children born LPT to children born at full term gestation at any time. The mean score difference between the children born LPT and those born at full term remained at similar levels throughout the study period, as shown in Figure 4-2, and there was no statistically significant interaction between time and LPT gestation in any of the results. The educational score results for the children born LPT were below those of the full term group in all the models, even when SES covariates were added. This indicates that in this longitudinal sample, LPT birth is itself associated with lower educational scores throughout primary education and lower results are not a by-product of SES factors.

The findings of a constant deficit for the children born LPT are inconsistent with studies drawing on the MCS dataset (Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012), and Crockett et al. (2022), which did not find an adverse effect after age 7 years. However, these studies used cross-sectional methods, whereas longitudinal methods have been shown to be preferable in exploring effects on individuals over time (Vignoles, 2021), as the same group of children are examined throughout.

Using multi-level modelling also enabled the existing study to control for the results being nested within the same children and used a good range of background covariates. Multi-level modelling studies are acknowledged to give more accurate results on the trajectory of learning (Dowding & Haufe, 2018). The current study found that these detrimental effects remained for children born LPT, even when SES factors were well controlled. This is contrary to some cross-sectional studies which have found that adverse effects are removed once adequate SES factors are included (Crockett et al., 2022; Morse et al., 2009).

The findings of stability of results in the LPT gestational group across the time period also differ from those of Odd et al. (2019). However, the study by Odd et al. (2019) used a comparator group of “term” born children, which conflated early term with full term. As children born at early term gestation tend to have slightly lower results, reflecting the reverse gestational gradient of risk (Boyle et al., 2012), this may have the effect of lowering the mean score. It may be that this partially explains why both sets of preterm children considered (very preterm and moderately/LPT) appear to experience accelerated educational progress within the study by Odd et al. (2019). The current study’s finding of a small but persistent effect accords with the continued subtle deficits seen in psycho-educational studies by Poulsen et al. (2013) and Lock et al. (2024).

A further factor that may well have influenced the differing results seen in some cross-sectional studies (Alterman et al., 2022; Crockett et al., 2022) and the longitudinal study by Odd et al. (2019), is that the outcome measures in the current study were all gathered after 2010 and the start of “austerity” in the UK (Martindale, 2022). Hence the children in this chapter’s study have spent their entire education, within these austerity measures. Whereas the other studies in the UK that suggest a catch-up effect for children born LPT (Alterman et al., 2022; Odd et al., 2019) were all within testing, at least partially, before this date.

It could be that the children born preterm had increased support before austerity measures were in place, especially as children born preterm have higher reported special educational needs (Alterman et al., 2021). Children born preterm are more likely, therefore, to be reliant on help from support staff such as teaching assistants than children born at full term. School staff have reported funding cuts in terms of staff, resources and school staffing problems (UNISON, 2018). There have been widespread changes in school provision during this period with suggestions of lower numbers of teachers and support staff and increases in managerial staff, under the argued "marketization" of schools (Martindale, 2022). This trend may have left children born preterm with less support than under the earlier education regime.

The results from the study in this thesis found that children born early term do not have a different trajectory of educational scores to children born full term between T1 and T2 and T1 to T3. However, the early term gestational group z-mean educational scores significantly increased from T2 to T3, where there was a statistically significant interaction of time and gestation group. The early term gestational group started and completed primary schools with results similar to the full term gestational group.

For comparison purposes the results for children born VMPT were also analysed. Similarly to the results for children born LPT, the educational score results for children born VMPT were consistently worse than children born full term at a relatively stable. The results for this group in the multi-level models showed no significant interactions, thus indicating the stability of the results over time. The current study found no evidence of a statistically significant interaction between VMPT birth and time, and this finding is consistent with Twilhaar, de Kieviet, van Elburg, et al. (2018) in children at the same ages of the current study. Similarly, studies using psycho-educational test batteries such as the Kaufman Assessment Battery for Children and Wechsler Abbreviated Scale of Intelligence have shown stable poorer scores in children born very preterm (Linsell et al., 2018; Poulsen et al., 2013).

4.4.2 Potential Explanations for the Findings in the Trajectory of Educational Scores

When considering why children born LPT have persistently worse educational scores, there are a number of different factors that could be driving that relationship; it has been well-established in broader cognitive development literature that educational outcomes are strongly associated with executive function (Bull et al., 2008; Friso-van Den Bos & van De Weijer-Bergsma, 2020; Gathercole et al., 2003, 2004; Gathercole & Pickering, 2000; McCutchen, 1996; Peng et al., 2018; St Clair-Thompson & Gathercole, 2006).

Executive function is an umbrella term for the higher-order cognitive skills relating to problem solving and goal-oriented behaviours. These skills include "inhibition", the deliberate suppression of a response (Miyake et al., 2000); "shifting", diverting attention from one aspect of a problem or activity to another (Miyake et al., 2000) and "working memory", revising and monitoring representations held within the brain (Miyake et al., 2000; Reynold De Seresin et al., 2023).

Whilst children born at very preterm gestation have been found to have worse executive function than children born at full term (Anderson, 2002; Loe et al., 2014; López Hernández et al., 2022; Omizzolo et al., 2014; Reynold De Seresin et al., 2023; Schnider et al., 2020; Wehrle et al., 2021), this has not been widely studied and findings are somewhat inconsistent for children born at LPT gestation (Baron et al., 2009, 2011; Baron, Weiss, Baker, et al., 2014; Brumbaugh et al., 2016; Fitzpatrick et al., 2016; Hodel et al., 2016; Suikkanen et al., 2021). Executive function skills within children born LPT are therefore examined in a study within the next chapter (Chapter Five).

A further factor that could influence the relationship between LPT birth and education is motor skills. Graphomotor skills, the skills involved in writing, are particularly predictive of educational achievement (Giles et al., 2018; Shire, 2016). Children born very preterm have been found to have worse graphomotor skills, but again findings have differed for the LPT gestational group (Brumbaugh et al., 2016; Ibrahimi et al., 2023). This is examined in Chapter Six.

As reviewed in section 1.5.3, in Chapter One, LPT birth occurs when the brain is still developing and this places the child at increased risk for subtle brain injury (Haynes et al., 2013; Kinney, 2006; Volpe, 2022). Children born at LPT gestations also have higher incidence of PVL, which affects neural white matter (Haynes et al., 2013). Neural differences have been found to be still present at the ages of 5 to 11 years (Brumbaugh et al., 2016; Degnan et al., 2015; Rogers et al., 2014), the ages examined in the current chapter. This may therefore be contributory to the adverse effect found, but mediation studies are required to establish this more decisively.

4.4.3 Implications of the Findings

The findings from the study imply that children born VMPT and LPT have persistently worse educational scores and do not catch-up in primary school education. Therefore, it is important for teaching staff to be aware that the evidence is that the gap does not close within the preterm groups and provide appropriate support.

To do so, it is firstly important that schools seek out information on whether a child was born prematurely at school entry point and that this information is passed on to successive teachers. It is also important that health professionals are aware of this persistent gap in educational scores and inform parents so that they can best advocate for their child.

4.4.4 Strengths and Limitations of the Current Study

This is the first study to longitudinally examine school statutory assessment educational scores in children born LPT, VMPT and early term between the outset of school and the end of primary education. It shows that children born at LPT and VMPT gestation have consistently poorer scores, with no evidence of any educational catching up or widening of the educational scores attainment gap. This was done in a recent cohort and is the only study to-date, to the best of my knowledge, to examine a longitudinal cohort educated after the introduction of the austerity measures in 2010. School spending has fallen per pupil in real terms by around 9% since 2010 and this is argued to have put pressure on schools in terms of teachers and support staff (Drayton et al., 2023). The study is therefore more likely than earlier studies to represent the existing impact on children born LPT and VMPT.

An additional strength is that the study considered used a comparator group of full term gestation rather than the wider “term” gestation category as used in the study by Odd et al. (2019). This is important as previous studies (Alterman et al., 2022; Chan & Quigley, 2014; Poulsen et al., 2013) have shown that children born at early term gestation can have poor educational and cognitive results compared to those born at full term. Therefore, conflating early term and full term can result in combining two groups with differing outcomes and may also result in a poorer overall term score, given the theorised gestational gradient of risk suggesting that the closer to 40 weeks’ gestation a birth occurs, the better the health and cognitive outcomes (Boyle et al., 2012).

The current study used a large cohort sample that had a good range of background variables for participants. This allowed for the inclusion of several important social covariates including IMD, means tested benefit, and maternal education. This is vital as previous studies have indicated that SES can be very influential in education scoring (Ahlsson et al., 2015; Crockett et al., 2022). The study also had the advantage of being able to reflect the Department for Education’s national scoring scheme (Department for Education, 2019b) and is the first study to use this. It thus reflects how existing policy and practice measures education scoring to observe change between the ages of 7 to 11 years.

Furthermore, the study looked at educational scores longitudinally using multi-level modelling to allow for the scores emanating from the same children with the same characteristics. Longitudinal modelling is argued to be a better method to assess the effects of time and the in-child factors and out-of-child factors discussed in Section 1.1 (Vignoles, 2021). Furthermore, the study has the strength of examining whether a time by gestation interaction is present before and after the addition of social, and social and antenatal variables and demonstrates that this did not make the difference some authors (Ahlsson et al., 2015; Crockett et al., 2022) suggest to the outcomes for children born LPT, at least within this multi-cultural UK-based sample.

The study used a mixture of teacher-assessed scores (EFYFS, KS1 assessment and KS2 writing score). Examinations in mathematics and reading were included at KS2 and test results are used to inform the teacher judgement at KS1 (Department for Education, 2015a). Although such teacher assessment may be viewed as subjective, it is important to note that in this case the teacher assessment is subject to both internal school moderation and external moderation by the local authority to ensure that the levels given by the teacher are both consistent and fair (Standards and Testing Agency, 2014b). Additionally, these teacher assessments represent an overview of what the child can achieve observed over a year time period, whereas examinations can be argued to reflect only what the child was able to produce that particular day. Additionally, it is perhaps more ecologically valid to use such teacher assessment of what a child can do in their day-to-day learning, especially with very young children who may be adversely affected if put under examination conditions and this may affect their performance.

A further limitation of the study is the low number within the VMPT gestational group. This is common for studies in preterm children as the number of children nationally born at this gestation is low (Office for National Statistics, 2024). This adversely affects the power of the analysis to find a small effect (Button et al., 2013). Hence there is a possibility that a weak interaction between time and VMPT gestational group may not have been detected due to lack of statistical power. Whilst this gestational group is not the main focus of this thesis, there is also variance in findings in the previous two longitudinal studies in this gestational group between Odd et al. (2019) who found an interaction effect of time and very preterm gestation and Twilhaar, de Kieviet, van Elburg, et al. (2018) who did not. Therefore, there would be benefit in a future further study with greater statistical power examining this again.

In common with other longitudinal studies (Cornish et al., 2021; Vignoles, 2021), there was a reasonably large element of missing data. Whilst consideration was given to multiple imputation, there is evidence that this can lead to unstable results when used alongside multi-level modelling (Twisk et al., 2013). Therefore, completed case analysis was considered most appropriate for the research analyses in this chapter.

4.4.5 Suggestions for Next Steps in Research

A study examining factors that might mediate educational scores such as executive function, motor skills and social and emotional factors would be a useful next step in assessing underlying factors that influence education.

Whilst the current study considered children to age 11 years, it would be particularly useful to extend the longitudinal analysis to age 16 years, the end of compulsory education in the UK, and to age 18 years. Furthermore, adult outcomes including university degree classification, job prospects and earnings could also be considered to assess whether the persistent poorer attainment seen in the existing study extends to these ages.

4.4.6 Conclusion

This study is the first to examine if the educational scores of children born LPT and early term have a different trajectory to those born full term gestation within primary education. The results suggest the difference in scores between children born LPT remain reasonably constant throughout primary school. It found no evidence of a catching up effect in the primary school years for children born LPT in the current educational regime, with their scores showing little change. This was not the case for children born early term where a statistically significant time by gestation group was seen between T2 and T3 (age 7 to 11 years), suggesting significant catching up between these time-points. Schools need to ensure that they are aware of the child’s gestational age, that staff are aware that prematurity may be a factor in attainment and that appropriate support is provided where necessary to children born preterm.

Chapter 5

Does Late Preterm Gestation Predict Executive Function Skills in Childhood?

Chapter Summary

This study investigates the impact of being born at LPT, VMPT and early term gestation, compared to full term gestation, on executive function (working memory and inhibition) and processing speed at the ages of 7 to 10 years, using cross-sectional linear regression analysis.

The study finds that there is a small adverse effect of birth at LPT gestation on complex working memory. This complex working memory is associated with educational achievement. However, no effects were found for either VMPT or early term gestation on executive function.

5.1 Introduction

Prematurity is associated with poorer academic attainment at primary school age (5 to 11 years old), as discussed in Chapters 3 and 4 and in other studies (Allotey et al., 2018; Alterman et al., 2022; Odd et al., 2019; Pettinger et al., 2020). The potential reasons for this have policy implications, especially with respect of children born LPT as they are not currently subject to increased health and developmental surveillance, unlike children born extremely or very preterm (National Institute for Health and Care Excellence, 2017).

Various cognitive processes have been suggested to be detrimentally affected by prematurity (Allotey et al., 2018; Brydges et al., 2018; Mulder et al., 2009). One that is of particular interest, as it has an underlying role in academic attainment, is executive function (Baggetta & Alexander, 2016; Bull & Lee, 2014; Cortés Pascual et al., 2019).

As reviewed below in Section 5.1.3, a number of the constituent processes of executive function have either not been examined previously in the LPT population, or the findings are currently somewhat divided. The current chapter seeks to help remedy this by examining executive function components within children born LPT, compared to children full term at the ages of 7 to 10 years.

5.1.1 Executive Function

Executive function is an umbrella term for the higher-order processing functions required for self-regulation, problem solving and goal-orientated behaviours (Baggetta & Alexander, 2016; Diamond, 2013). Whilst there are several executive function models (Karr et al., 2018; Souissi et al., 2022), the most frequently cited (Sambol et al., 2023) is a tripartite model of “inhibition”, “shifting” and “working memory” by Miyake et al. (2000). This model defines “inhibition” as the deliberate suppression of dominant, automatic responses when required; “shifting” as switching attention flexibly between tasks; and “working memory” (sometimes referred to as “updating”) as revising and monitoring representations within the brain.

Whilst adults are generally found to have this tripartite model, the underlying structures forming executive function are suggested to change from childhood to adulthood (van der Ven et al., 2013). A unitary model of executive function as a single construct of higher order functioning is often found in infancy (Brydges et al., 2012; Fuhs & Day, 2011; Wiebe et al., 2008, 2011; Willoughby et al., 2010). Whilst between the ages of 5 to 10 years old, a two-component executive function model is often observed, consisting of a combined inhibition/shifting component, with inhibition the more dominant (Shing et al., 2010; van der Ven et al., 2013); and a working memory component (Brydges et al., 2018; K. Lee et al., 2013; Messer et al., 2018; Shing et al., 2010; St Clair-Thompson & Gathercole, 2006; van der Ven et al., 2013). Finally, the three factor ‘adult’ model of shifting, inhibition and working memory emerges at around age 11 years (Lehto et al., 2003; Rose et al., 2011; Wu et al., 2011).

This chapter examines executive function in children aged 7 to 10 years old and a two-component model of executive function, consisting of working memory and an inhibition factor, represents the most appropriate model for children at this age (Brydges et al., 2018; K. Lee et al., 2013; Messer et al., 2018; Shing et al., 2010). Therefore, the two components of working memory and inhibition in children are reviewed in more detail below. A further factor, processing speed (described in Section 5.1.1.3) is not part of executive function, but is suggested to have a major role in executive function capability (Fry & Hale, 2000; Hulme et al., 1984; Kail, 1991; Rose et al., 2011) and is therefore also relevant in analyses of executive function and is also examined below.

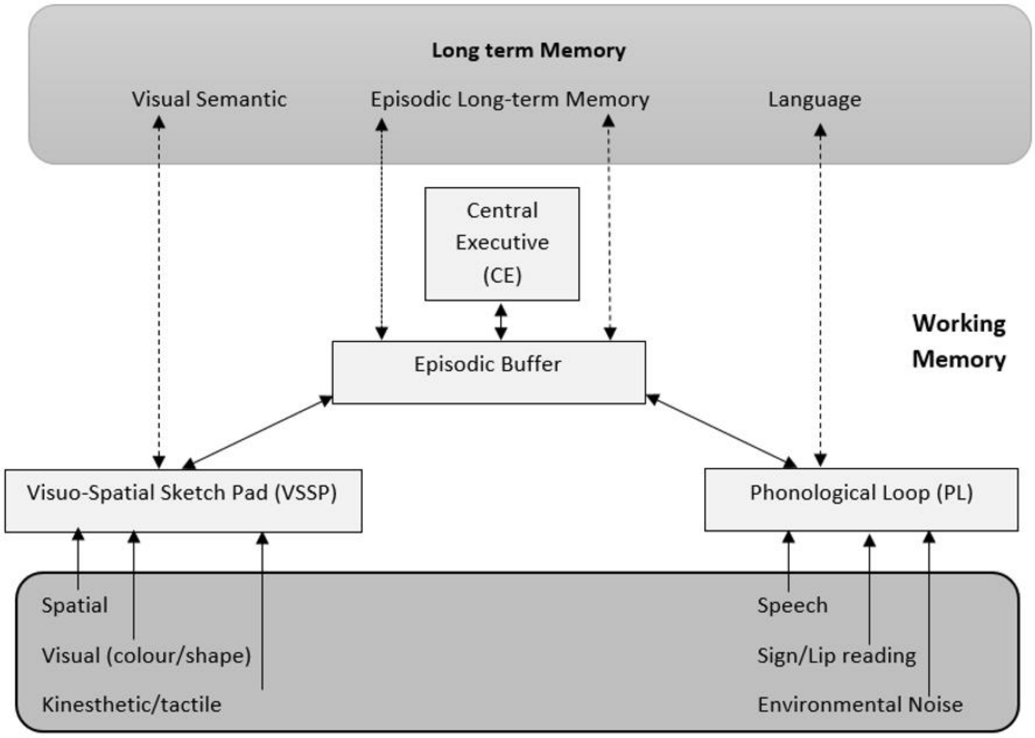
5.1.1.1 Working Memory

The most cited (Morey, 2018) working memory model is the multi-component model of Baddeley and Hitch (1974). This comprises a domain-general control system, the “Central Executive”, responsible for manipulation and processing of information and attentional control and two slave-system storage units, the “Phonological Loop” which holds verbal information in working memory, and “the Visuospatial Sketchpad” which holds visual and spatial information (Baddeley & Hitch, 1974, 1994). A further component, “the Episodic Buffer”, binds information from the different modalities and long-term memory (Baddeley, 2000, 2001). The relationship between the working memory components is illustrated in Figure 5-1.

The working memory literature generally divides working memory into storage and processing components (R. W. Engle et al., 1992; Just & Carpenter, 1992). The storage component is sometimes referred to as “short-term memory”, with working memory solely characterising the involvement of the Central Executive (Alloway & Alloway, 2010; Berg, 2008; Brumbaugh et al., 2013; Bull & Johnston, 1997; Gathercole & Alloway, 2006; Swanson, 1994).

Figure 5-1

The Baddeley and Hitch Working Memory Model: adapted from Baddeley (2019)



However, many models include both elements within a wider conceptualisation of working memory, and therefore describe the storage only components as "simple working memory" and the processing element as CWM (Allen & Waterman, 2015; Baddeley, 2012; Berry et al., 2019; Cowan, 2017; Houdt et al., 2019; Logie, 2011; Waterman et al., 2017).

This latter conceptualisation is applied in this thesis, with CWM referring to the involvement of the Central Executive; VWM referring to the short-term processing of verbal information by the Phonological Loop; and VSWM used for the short-term processing of visuospatial information by the Visuospatial Sketchpad. The episodic buffer is not considered within this chapter as there are currently no standard tasks for testing it within a developmental population (Nobre et al., 2013).

5.1.1.2 Inhibition

Inhibition is defined as the deliberate suppression of a dominant automatic response (Miyake et al., 2000). There are further sub-divisions within the overall concept of inhibition. Firstly, "response inhibition" encompasses self-control and suppression of impulse and “interference control” inhibition describes selective focus on relevant stimuli and suppression of other stimuli (Diamond, 2013).

Inhibition can also be described by the form it takes, with “motor inhibition” requiring the suppression of an unwanted movement (Coxon et al., 2006; Eagle et al., 2008; Schachar et al., 2007) and “verbal inhibition” affecting the delivery of a verbal response (Wildenberg & Christoffels, 2010). It can also be divided into “hot” functioning where there is a motivational aspect (e.g. delayed gratification), or “cool” functioning if the task is non-motivational and is based solely on the processing of information (Huijbregts et al., 2008; Salehinejad et al., 2021).

5.1.1.3 Processing Speed

A secondary system to executive function, “processing speed” is defined as how quickly information can be processed (Kail & Salthouse, 1994). This also increases capacity during childhood to adolescence (Cerella & Hale, 1994; Fry & Hale, 2000; Hale, 1990; Kail, 1991). It has been theorized by some that developmental increases seen in working memory are solely due to processing speed increase (Hulme et al., 1984; Kail, 1992). Therefore, some authors suggest that it is processing speed that drives working memory and in turn, intelligence, which results in academic achievement (Fry & Hale, 1996; Rose et al., 2011). Other commentators suggest processing speed’s impact on working memory may be due to information held in memory decaying as time passes, so the quicker the processing the more accurate the eventual output (Jensen, 1993; Miller & Vernon, 1996). Therefore, it is important to control for processing speed in executive function modelling as it may underlie or mediate executive function.

5.1.2 Executive Function and Academic Achievement

Examining executive function abilities is crucial in understanding the reasons for differences in academic achievement. Research within the general population has demonstrated that executive function is a key predictor in academic achievement (Blair & Razza, 2007; Cortés Pascual et al., 2019; Espy et al., 2004; Jacob & Parkinson, 2015; McClelland & Cameron, 2019; Ribner et al., 2017). However, this relationship between executive function and academic performance is generally investigated within the executive function sub-components of working memory and inhibition (e.g. Privitera et al., 2023; St Clair-Thompson & Gathercole, 2006), as discussed below.

All three components of working memory are suggested as important for learning. VWM has been established to have a role in vocabulary acquisition (Gathercole et al., 1997); language (Gathercole et al., 2004; Majerus & Cowan, 2016); and mathematics (Formoso et al., 2018; Gathercole et al., 2004). VSWM is predictive of mathematics (Bull et al., 2008; Holmes & Adams, 2006; Hubber et al., 2019). Whilst CWM is the most predictive of reasoning (Kyllonen & Christal, 1990); intelligence (Süß et al., 2002); and academic achievement (Alloway & Alloway, 2010; Gathercole et al., 2004; Lépine et al., 2005). CWM is required in a wide range of academic subjects including mathematics (Bull et al., 2008; Holmes & Adams, 2006; Imbo & Vandierendonck, 2007; Lépine et al., 2005; Raghubar et al., 2010); reading (Alloway & Alloway, 2010; De Jong, 1998); writing (Alloway & Alloway, 2010; Lépine et al., 2005); and science learning (Gathercole et al., 2004).

Inhibition allows planning, analysing and selecting the correct response, as well as controlling behaviours and thoughts (Anderson, 2002). It has been found to be a statistically significant predictor for early mathematics (Blair & Razza, 2007); phonemic awareness (Blair & Razza, 2007); letter knowledge (Blair & Razza, 2007); and literacy, mathematics, and science learning in primary school (Gathercole et al., 2004; St Clair-Thompson & Gathercole, 2006).

Processing speed has been found to have a significant role in mathematics (Berg, 2008; Bull & Johnston, 1997; Formoso et al., 2018); reading (Kail & Hall, 1994); and writing (Rindermann et al., 2011). It has also been found to be a predictor of attention in classroom learning, and therefore is a key influence on academic attainment (Jarrold et al., 2014).

5.1.3 Applicability to Preterm Birth

As discussed in Chapter One, prematurity is often divided into the gestational groups of very preterm (less than 32 weeks' gestation), moderately preterm (32 and 33 weeks' gestation) LPT (34 to 36 weeks' gestation) and early term (37 to 38 weeks' gestation), with full term classified as birth at 39 to 41 weeks' gestation (ACOG, 2021; Chan & Quigley, 2014; Quigley et al., 2012). Very preterm birth is associated with an increased risk of cognitive and behaviour difficulties (Aarnoudse-Moens et al., 2009), and it has been proposed that some of these difficulties are due to issues with executive function (Schnider et al., 2020).

5.1.3.1 Executive Function and Processing Speed in Children Born at Very Preterm Gestation

Executive function can be evaluated as a unitary construct, where it is often tested using the BRIEF[30]. This measures parental/teacher perceptions of the child's executive function and provides a global composite score (Gioia et al., 2015). Results suggest that children born very preterm have worsened levels of overall executive function than children born at full term (Loe et al., 2019; López Hernández et al., 2022; Reynold De Seresin et al., 2023), although there are some criticisms of the BRIEF test, which are discussed in section 5.1.3.3.

Outside of evaluations using the BRIEF and other measures of executive function as an overall construct, executive function can be considered by component. In this, an adverse effect has generally been found in children born very preterm birth, compared to those born at full term, on VWM (Anderson et al., 2004; Omizzolo et al., 2014; Wehrle et al., 2021). However, there are some studies that did not find a statistically significant effect (Fraello et al., 2011; J. Sato et al., 2019). This is potentially because of low sample size, as the studies were less than half the size of the studies that did find an effect (Fraello et al. [2011] n = 49; J. Sato et al. [2019] n = 15; compared to Anderson et al. [2004] n = 298; Omizzolo et al. [2014] n = 198; Wehrle et al. [2021] n = 142). Similarly, an adverse effect has consistently been demonstrated in VSWM (Aarnoudse-Moens et al., 2012; Böhm et al., 2004; Mulder et al., 2011; Omizzolo et al., 2014) and CWM (Aarnoudse-Moens et al., 2012; Böhm et al., 2004; Omizzolo et al., 2014).

The results from studies for inhibition in children born very preterm have varied depending on the aspect of inhibition being examined. Interference control inhibition results differ between a detrimental effect being observed (De Kieviet et al., 2014), or not (Aarnoudse-Moens et al., 2012). Whereas response inhibition has more consistently been shown to be worse than that of term-born children (Aarnoudse-Moens et al., 2012; Bayless & Stevenson, 2007; Ford et al., 2011; Loe et al., 2019; Mulder et al., 2011).

Children born very preterm are also more likely to have poorer processing speed (Aarnoudse-Moens et al., 2012; Anderson, 2003; Gnigler et al., 2015; Mulder et al.,

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[30] Behaviour Rating Inventory of Executive Function

2010, 2011; Rose et al., 2011). This slower processing speed in very preterm children has been found to predict poorer executive function, and in turn results in lower cognitive functioning, described as a “cascade of effects” (Rose et al., 2011).

5.1.3.2 Executive Function and Processing Speed in Children Born at Moderately and LPT Gestation

Worsened overall executive function BRIEF scores have not been found in children born LPT (Brumbaugh et al., 2013; Hodel et al., 2019), nor children born at moderately/LPT gestation (Hodel et al., 2016). However, there are some criticisms of the BRIEF as low correlations have been observed between it and other executive function tests (Sheehan et al., 2017; Toplak et al., 2013). Additionally, there are often only low to moderate correlations seen between the BRIEF scores given by teachers and parents for the same child (Schneider et al., 2020). Moreover, due to the differing nature of executive function components, the specific components are also often examined.

5.1.3.2.1 Simple Verbal Working Memory (VWM)

There is little evidence of a detrimental effect of LPT birth on the VWM, but studies are sparse. Findings before the age of 5 years old, generally find no effect (Baron et al., 2009, 2011), even in moderately/LPT children (Hodel et al., 2016) with only one small study (LPT n = 44) reporting an adverse effect (Brumbaugh et al., 2013).

Between the ages of 5 and 11 years old, no study specifically looks at the effect of LPT birth on VWM. However an analysis in children born at moderately/LPT gestation at the ages of 8 to 11 years found no difference to term births (Odd et al., 2012), as did an examination of children aged 7 years old born moderately preterm by Cserjesi et al. (2012). Similarly, Fernández De Gamarra-Oca et al. (2022) investigated VWM and CWM combined in children born moderately and late preterm and found no differences to children born full term at age 6 years.

5.1.3.2.2 Complex Working Memory (CWM)

At preschool age, a large study (LPT n = 278) of children born LPT found lower CWM at age 3 years (Baron et al., 2011), and a study in children born moderately/LPT (moderately/LPT n = 45) found “trend-level” lower span scores in verbal CWM (after adjustment for IQ) at age 4 years (Hodel et al., 2016). However, there are no studies investigating CWM in children born LPT between the ages of 5 and 11 years, and this is a notable gap at present in the literature. By adulthood however, Suikkanen et al. (2021) found adults born LPT had comparable levels of CWM to those born at term.

Given the effects seen in the younger age group and the evolving nature of executive functions which means effects may change with development (Spencer, 2020), there may be an adverse effect on children born LPT during school years. As discussed above, this has not yet been investigated and a study in this area is therefore required.

5.1.3.2.3 Simple Visuospatial Working Memory (VSWM)

No statistically significant differences have been found VSWM before the age of 5 years for children born LPT (Baron et al., 2009; Brumbaugh et al., 2013; Pérez-Pereira et al., 2020), nor moderately/LPT (Hodel et al., 2016), compared to those born at full term. Only two studies have investigated the impact of LPT birth on VSWM between the ages of 5 to 11 years and neither found a detrimental effect (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016). However, both studies were predominately racially White, and effects may differ in a more racially diverse sample. This is suggested as Rea-Sandin et al. (2021) found wide racial disparities between White and other racial groups in meta-analysis investigating racial differences in executive function studies in the USA.

Additionally, Baron. Weiss, Litman, et al. (2014) did not control for SES covariates which have been found to be associated with working memory (Mooney et al., 2022). Therefore, it would be useful to examine the effect of LPT birth on VSWM in a more diverse sample, such as the BiB sample (J. Wright et al., 2013), controlling for a range of SES covariates.

5.1.3.2.4 Inhibition

There are some contradictory findings on the effect of LPT birth on inhibition, with one study (Brumbaugh et al., 2013) finding lower verbal inhibition control but not motor inhibition at age 4 years, and another finding no effect (either verbal or motor related) in children born LPT at age 3 years (Baron et al., 2011). In the moderately/LPT gestational group, Hodel and colleagues (2016) did not find significantly worse inhibition at age 4 for 'cool' inhibition but did so for 'hot' (motivation related). Cool and hot inhibition are both described in Section 5.1.1.2.

One study (Fernández De Gamarra-Oca et al., 2022) investigates inhibition in children born LPT, compared to children born at full term, finding no adverse effect. However, this study used a wide age range of children (7 -14 years) and had a low sample size of children born LPT (*n* = 33). There have also been contradictory results in the combined moderately/LPT gestation with one study finding inhibition to be worse in children born moderately/LPT at age 7 years (Cserjesi et al., 2012), and another showing no effect of birth at moderately/LPT gestation at age 11 years (Reijneveld et al., 2021).

Thus, the limited number of studies investigating inhibition in children born LPT mean the effects of birth at LPT gestation are somewhat uncertain and a further study would be useful, especially in a larger sample of children born LPT.

5.1.3.2.5 Processing Speed

Between the ages of 5 to 11 years, two studies in LPT births found an adverse effect for processing speed but had small samples of LPT children of *n* = 37 for Jin et al. (2020) and LPT *n* = 39 for Brumbaugh et al. (2016). Lower levels of processing speed were also found in children born moderately/LPT at age 6 years (Bogičević et al., 2020); at age 11 years (Reijneveld et al., 2021); and at age 7 to 14 years (Fernández De Gamarra-Oca et al., 2022). A study in a larger sample of children born LPT would help confirm if there is a detrimental effect of being born LPT on processing speed.

5.1.3.3 Potential Neural Impact of LPT Birth on Executive Function

The effects that prematurity may have on brain development due to early ex-utero exposure are reviewed in Section 1.5 in the introduction chapter. However, it is notable in the context of executive function that LPT birth is argued to occur at a critical period in neural development (Matthews et al., 2018) and areas of the brain suggested to be involved in executive function have also been found to differ in children born LPT from those born at full term.

A number of key aspects of brain development take place during the 34 to 36 weeks' gestation at which preterm birth occurs. Primarily, there is a large expansion in amount of cortical grey matter (the outer layer of the cerebrum) at 34 to 40 weeks' gestation (Matthews et al., 2018). Consequently, the brain at 34 weeks' gestation is 65% of its weight at 40 weeks (Kinney, 2006). Furthermore, being exposed to external influences due to premature birth is argued to potential alter brain development (Rice & Barone, 2000).

There are a number of neural differences between children born LPT and those born at full term that are relevant to the executive function development which have been shown to be still present at least into early adolescence. Firstly, Rogers et al. (2014) found decreased grey matter brain volume; reduced right parietal and right temporal grey matter volume; and lesser right parietal lobe surface area in children born LPT compared to full term, at age 6 to 12 years. The parietal lobe has been shown to have a role in verbal CWM and working memory short-term storage and retrieval (Gomes et al., 2023; Jonides et al., 1998; Koenigs et al., 2009). Therefore, potentially children born LPT may have worse CWM than children born full term partly due to decreased parietal lobe volume. Secondly, Brumbaugh et al. (2016) found that children born LPT had increased cerebrospinal fluid volume; decreased cerebrum tissue; less subcortical cerebrum tissue; lower cortical grey matter surface area; and a smaller thalamus than children born full term. The thalamus has also been shown in studies within the general population to have a role in CWM (X. Chen et al., 2023). However, neural differences do not appear to extend to smaller hippocampal volumes which have been found in children born very preterm (Beauchamp et al., 2008), but were not statistically significantly different in children born LPT (Brumbaugh et al., 2016).

Therefore, as reviewed above, there are some discrete differences in the brain between children born LPT and full term that may potentially lead to children born LPT having lower executive function skills. As reviewed in Section 5.1.3.2.2, there has been no examination of CWM within children born LPT between the ages of 5 and 11 years and, as studies suggest that children born LPT have differing subtle neurological structures at this age (Brumbaugh et al., 2016; Rogers et al., 2014), a study examining this is very much needed. The current chapter seeks to fill this gap.

5.1.3.4 Methodological and Systematic Issues with Existing LPT studies

As shown above, there are relatively few studies investigating LPT and executive function in children aged 5 to 11 years; a period when executive function is rapidly developing and changing (Best et al., 2009). There were no studies covering this age group for VWM, only two studies within this age group for VSWM, no studies in CWM, and only one study investigating the effects on inhibition. Therefore, we are often left using suggestive evidence from the wider moderately/LPT group where these two gestational groups have been argued to have very differing medical and psychological outcomes (Baron et al., 2012). Additionally, when an effect is found using combined gestational groups it could be due to the influence of the more preterm group, reflecting the reverse gestational gradient of outcomes (Boyle et al., 2012).

This lack of empirical evidence is compounded by the fact many of the existing studies were only able to recruit relatively small sample of LPT-born children (less than 90 children) and therefore may be less generalizable (e.g. Baron et al., 2009; Brumbaugh et al., 2013, 2016; Jin et al., 2020). Furthermore, the effect of processing speed on inhibition and working memory was not adjusted for in many of the studies (Baron, Weiss, Litman, et al., 2014; Cserjesi et al., 2012; Fitzpatrick et al., 2016; Reijneveld et al., 2021). However, there is evidence that such processing speed plays a key role in working memory and inhibition (McAuley & White, 2011; Rose et al., 2011).

It is vitally important to establish whether children born LPT have deficits in working memory, inhibition and processing speed. This group of children have been shown to at risk of poorer academic attainment in school, as seen in Chapters 3, 4, and other studies (Allotey et al., 2018; Alterman et al., 2022; Chan & Quigley, 2014; Quigley et al., 2012). Understanding whether deficits in this area extend to children born LPT and is therefore potentially contributory to lower level of academic attainment is fundamental to understanding whether interventions and teaching techniques advocated for children born at very preterm gestation (Bamber et al., 2019; S. Johnson et al., 2019) may help raise attainment for children born LPT.

5.1.4 Aim of the Study and Research Questions

This chapter aims to investigate the impact of being born LPT on a range of executive functions, including working memory in its constituent parts of VWM; VSWM; and CWM, together with inhibition and processing speed at age 7 to 10 years. It examines VWM and CWM specifically in the LPT group at this age for the first time. It also controls for a comprehensive range of background health and SES characteristics, including processing speed, in a large multicultural cohort (the BiB cohort).

5.1.4.1 Research Questions

Given the small number of studies in this area, much of this analysis was exploratory. The following research questions and specific predictions were defined.

RQ1: Does LPT birth predict lower scores on VWM in childhood?

The existing evidence reviewed in Section 5.1.3.2.1, is suggestive of no worse effect due to LPT birth by the time children start school (age 5 years) given the lack of effect found in the wider moderately/LPT gestation (Cserjesi et al., 2012; Odd et al., 2012), when children who are born at even earlier gestation (32 to 33 weeks' gestation) are included in the analysis. Therefore, it was predicted that there would be no detrimental effect for children born LPT.

RQ2: Does LPT predict lower scores in CWM in childhood?

As there were no existing studies between the ages of 5 to 11 years in the LPT gestational group, this was an exploratory question. Studies in children younger than 5 years have suggested that children born LPT may have lower CWM (Baron et al., 2011; Hodel et al., 2016), with a study in adults finding no such effect (Suikkanen et al., 2021). Therefore, no specific prediction was made against this research question.

RQ3: Does LPT birth predict lower scores in VSWM in childhood?

The two existing studies in children born LPT between the ages of 5 to 11 years (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016) did not find a statistically significant effect. The prediction was therefore, that this would be replicated in a more ethnically diverse sample, as Fitzpatrick et al. (2016) adjusted solely for White or Non-White, and Baron, Weiss, Baker, et al. (2014) for White and Hispanic. Both of these studies (Baron, Weiss, Baker, et al., 2014; Fitzpatrick et al., 2016) were conducted with LPT gestational groups of predominately White ethnicity (≥ 65% White ethnicity).

RQ4: Does LPT predict lower scores in inhibition in childhood?

As reviewed above (Section 5.1.3.2.4), there was some evidence of a potentially adverse effect from of slightly younger children (Brumbaugh et al., 2013), but was this not apparent from studies in older children born moderately/LPT (Cserjesi et al., 2012; Reijneveld et al., 2021), nor in a small study of children born LPT, compared to born full term (Fernández De Gamarra-Oca et al., 2022). Therefore, this question was exploratory, but the expectation was there would probably be no effect.

RQ5: Does LPT predict lower scores in processing speed in childhood?

The expectation was this would be poorer, given the effect seen in moderately/LPT group at the ages of 5 to 11 years (Bogičević et al., 2020; Fernández De Gamarra-Oca et al., 2022; Reijneveld et al., 2021), and previous results from the two small studies with children born LPT (Brumbaugh et al., 2016; Jin et al., 2020).

5.2 Methods

5.2.1 Participants and Study Setting

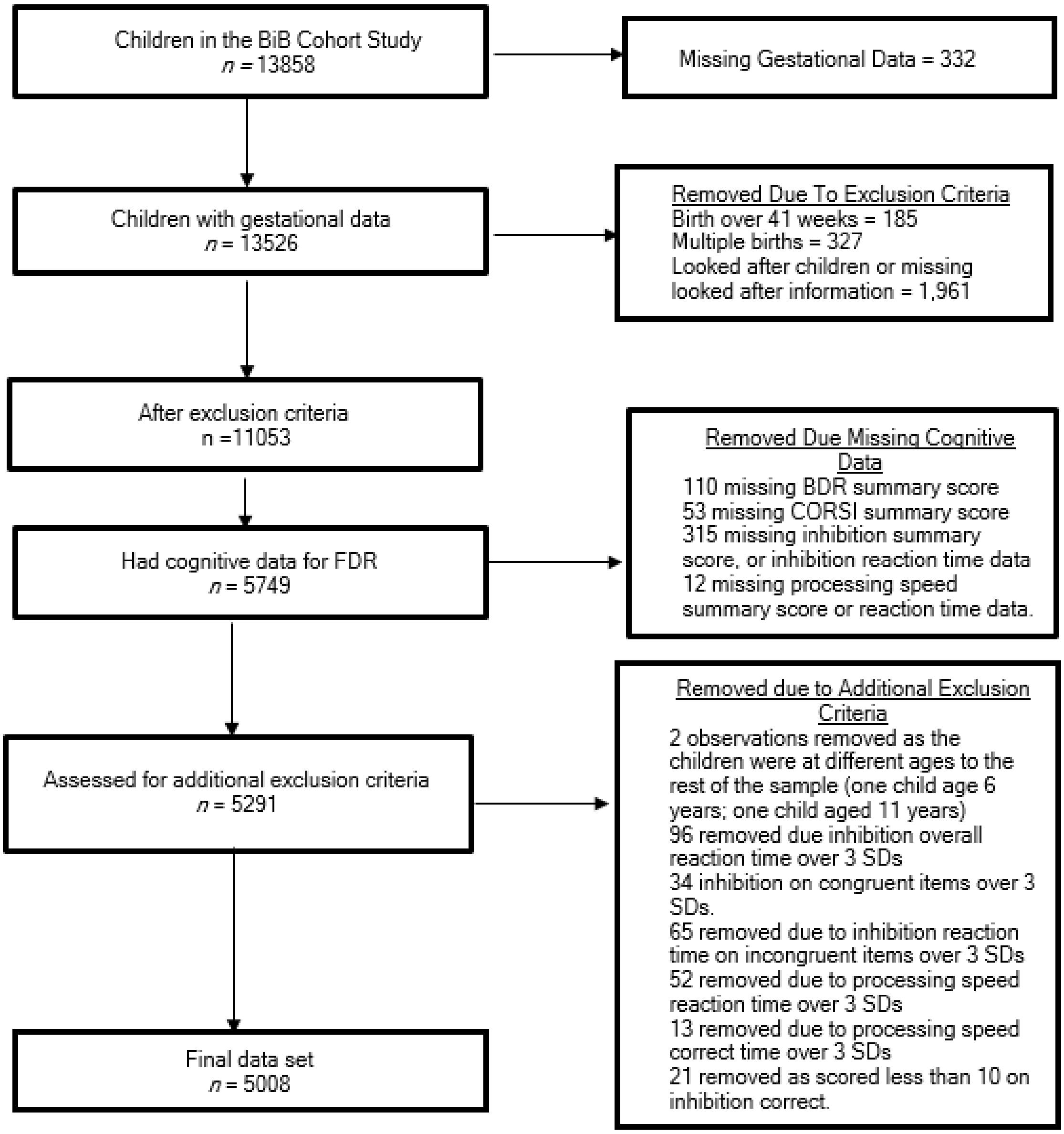
The sample was drawn from the Born-in-Bradford (BiB) birth cohort (borninbradford.nhs.uk), as described in Chapter Two. The children in the sample were aged 84 to 130 months (7 years 0 months to 10 years 10 months), with a mean age of 101.07 months (*SD* = 7.97 months). The mean ages in months by gestational group were very similar to the total sample's mean (full term: *M* = 101.03 [*SD* = 8.03]; early term: *M* = 101.07 [*SD* = 7.83]; LPT: *M* = 101.35 [*SD* = 7.59]; VMPT: *M* = 102.64 [*SD* = 8.28]). The executive function data used is drawn from the Primary School Years data sweep. Details of this sweep are contained in Chapter Two: Section 2.1.5. Sample characteristics by gestational groups for the current study, showing percentage proportions, before and after multiple imputation are presented in Appendix I (Table I-1).

5.2.2 Exclusions and Missing Data

As shown in Figure 5-2, 5,291 of the children from the BiB cohort with gestational data had data for the cognitive variables of the "Primary School Years" testing. The exclusion criteria was the same as used in the previous chapters and outlined in Section 2.4.1, with the following additions: data were trimmed to exclude observations with inhibition scores of greater than three standard deviations from the mean; inhibition correct scores of less than 25% correct; and processing speed reaction time scores of greater than three standard deviations from the mean. This removed children who may have not understood or engaged appropriately with participation in the test battery and was consistent with data-cleaning processes applied in previous analyses of this data, described in Hill et al. (2021).

Figure 5-2

Sample Selection for Executive Function Study



Missing data on any of the covariates were replaced with values computed using a multiple imputation by the chained equations method. This was used to produce 20 imputed datasets, with 10 iterations per dataset (the Stata default). Therefore a total of 200 iterations of the data were completed to form the imputed datasets. This imputation was conducted on missing covariates only, and not for observations with missing outcome variables, as this is the standard practice in preterm studies using cohort datasets (Jansen et al., 2021; MacKay et al., 2010; Mboya et al., 2021; Odd et al., 2012, 2013, 2016, 2019; Peacock et al., 2012; Pettinger et al., 2020; Snelgrove & Murphy, 2015; van Beek et al., 2021). This imputation allows for reporting on the same number of children in the unadjusted and the adjusted (with covariates) models.

5.2.3 Measures

Further details of the process used to obtain the outcome variables examined are set out in Hill et al. (2021). The measures selected reflected the two-component model of working memory and inhibition found in children aged 5 to 10 years old (as explained in Section 5.1.1). The analysis used established measures of VWM, VSWM, CWM, inhibition, and processing speed which have been shown to have both good concurrent validity when assessed against other tests for the same construct (A. Field, 2017) and predictive validity in their predictiveness of scores on related criteria (Rust et al., 2009). The testing of the five executive function outcomes took around 20 to 25 minutes in total to complete (Hill et al., 2022).

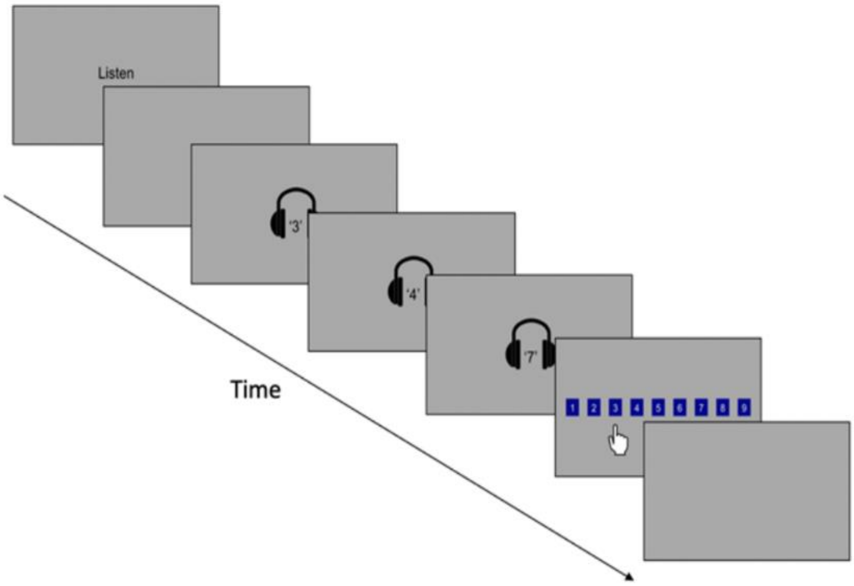
5.2.3.1 VWM Variable: Forwards Digit Recall

The first task was forwards digit recall which evaluates a child’s ability to store verbal information and is used as an established measure of VWM (Alloway & Alloway, 2010; Bull et al., 2008). Testing was completed on a touchscreen using headphones, with the child responding via this touchscreen (as illustrated in Figure 5-3).

Participants heard sequences of digits and had to recall the digits in the same order (forwards) they were presented in by pressing the appropriate digit on the touchscreen. The digit sequence length increased from a length of three digits (e.g., “3, 4, 7”), to a length of six digits (e.g., “6, 7, 1, 8, 2, 5”). There were four sequences at each length, making 16 sequences presented in total. No digit was repeated within any given sequence. The total number of digits presented was 72. The outcome variable was the proportion of digits correctly recalled in the correct order and therefore a higher score indicates a better result.

Figure 5-3

A Schematic Illustration of the Forward Digit Recall Task, Reproduced from Hill et al. (2021, p. 8)



Note. The child hears numbers, in this case 3, 4, 7 on the headphones and then has to select the correct numbers in the order they were heard on the touch screen which displayed the digits 1 - 9.

5.2.3.2 CWM Variable: Backwards Digit Recall

This task measured children's ability to store and manipulate verbal information and was used as an established measure of CWM (Alloway & Alloway, 2010; Bull et al., 2008). The test was identical to forwards digit recall with the exception that children had to recall the digits in the reverse order to that heard. The sequence length increased from a length of two digits to a length of five digits, with four trials at each length, making 16 sequences in total. No digit was repeated in any given sequence. The total number of digits presented was 56. The outcome variable was the proportion of digits correctly recalled in the correct order.

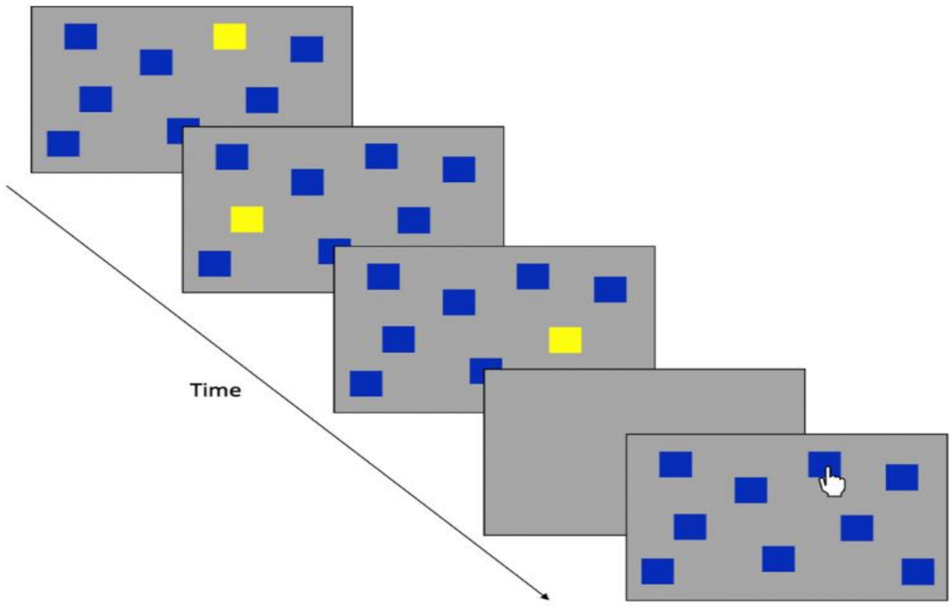
5.2.3.3 VSWM Variable: Corsi Block Tapping

The Corsi Block tapping task evaluated the capacity to store spatial information (Fischer, 2001; Gathercole & Pickering, 2000). As shown in Figure 5-4, participants saw nine randomly arranged blocks on the tablet screen, which lit up yellow, one at a time in a particular spatial sequence, and the participant had to recall the spatial sequence in the same order it was presented.

Sequence length increased from a length of three blocks to a length of six blocks with four sequences at each length, making 16 sequences in total. No block was repeated in any given sequence. The total number of blocks presented was 72. The outcome variable was the proportion of blocks correctly recalled in the correct order; hence a higher score indicates improved performance.

Figure 5-4

A Schematic Illustration of the Corsi Spatial Working Memory Task, Reproduced from Hill et al. (2021, p. 9)



Note. This illustration is of a trial with a span of three. Three of the blue blocks change colour to yellow. The child has to remember the block that changed and the order in which they changed by selecting these blocks in the correct order of blocks on the touchscreen.

5.2.3.4 Working Memory Task Timings

For both the FDR and BDR task presentations, the task presentation to participants commenced with the word “Listen”, presented on the screen for 1000 milli-seconds. This was followed by a blank screen for 1000 milli-seconds. Immediately after this blank screen, the digits were presented aurally, with a 1000 milli-second inter-stimulus interval between each of the presented digits. Each digit utterance was between 350 to 550 milli-seconds long. After the aural presentation of the final digit for the sequence, there was a 1250 milli-second retention period gap. Participants then responded at their own pace in the recall phase. This was followed by a 1000 milli-second inter-trial interval before the next sequence presentation (Berry et al., 2018).

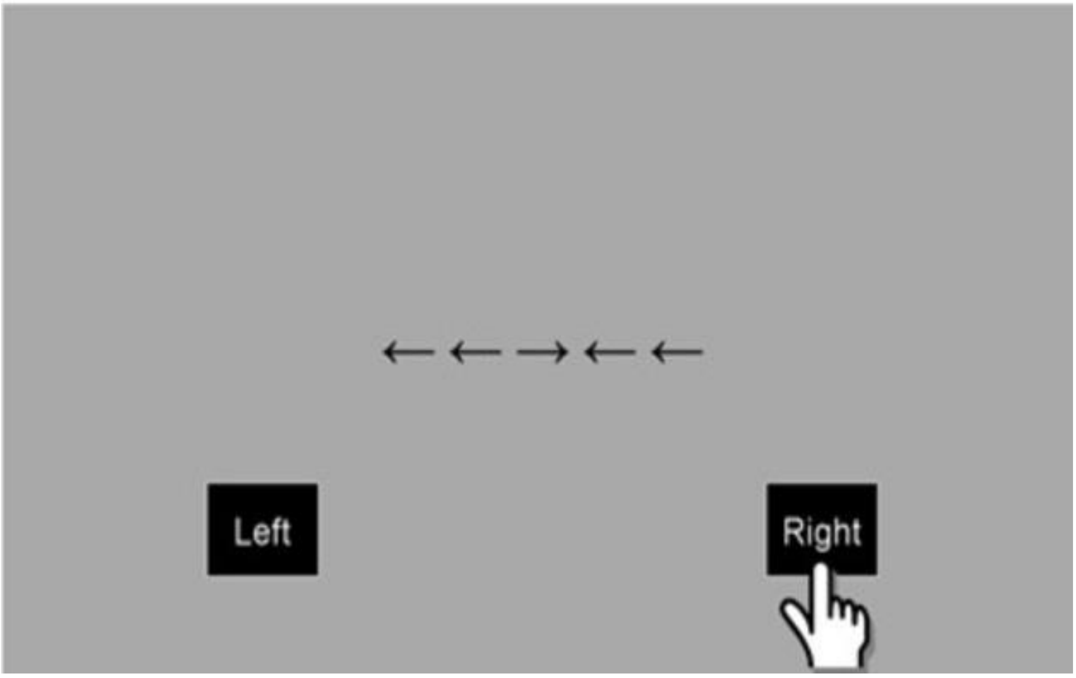
The visuospatial CORSI block task presentation commenced with a fixation cross on the screen, which was presented for 1000 milli-seconds. A sequence of boxes was then displayed, with each box in the sequence lit yellow for 500 milli-seconds, followed by a 1000 milli-second inter-stimulus interval, before the next box in the sequence was lit. After the sequence was complete there was a 1250 milli-second retention period gap, in common with the FDR and BDR task presentations. Participants then recalled the sequence at their own pace, in the recall phase. This was followed by a 1000 milli-second inter-trial interval before the next sequence (Berry et al., 2018).

5.2.3.5 Inhibition Variable

The response inhibition task was based on the Flanker task (Eriksen & Eriksen, 1974): an established test of inhibitory control (Baghdadi et al., 2021). A target arrow was positioned in the centre of the screen surrounded by irrelevant stimuli arrows, which either pointed in the same (“congruent”), or the opposite (“incongruent”), direction to the target arrow. The child had to press the left or right button according to the target arrow’s direction and were instructed to make a response as quickly and as accurately as possible. An illustration of this task is provided at Figure 5-5. After four practice trials, there were 40 test trials, of which 20 were congruent and 20 incongruent. There were equal numbers of left and right pointing stimuli (Hill et al., 2021). The response is more difficult in the incongruent condition (Baghdadi et al., 2021). The score used was the mean of reaction time on the congruent trials subtracted from the mean of the reaction time for the incongruent. A lower score represents better performance.

Figure 5-5

A Schematic Illustration of the Flanker Task: Reproduced from Hill et al. (2021, p. 8).



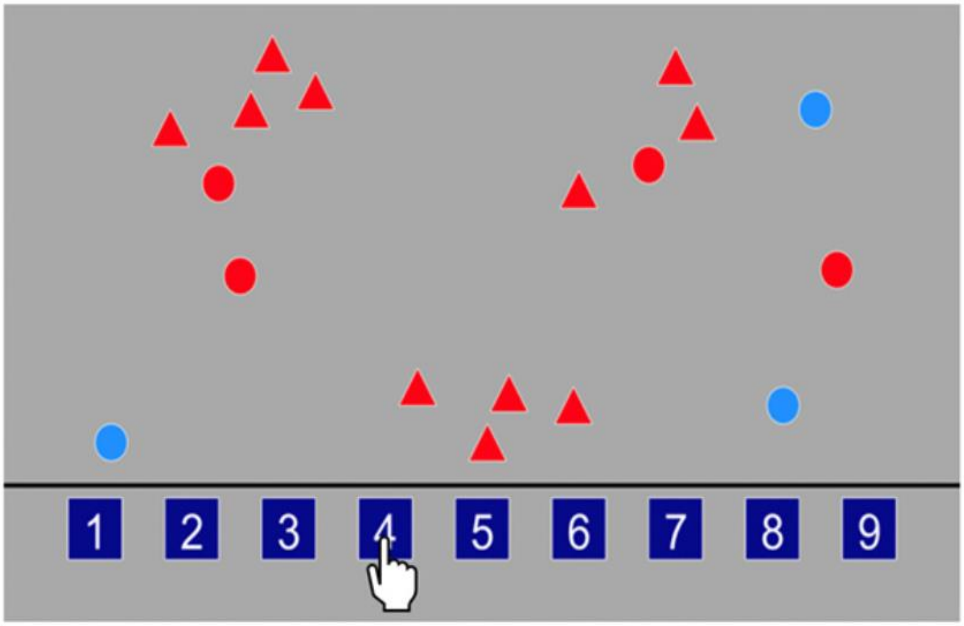
Note. The child is required to look at the middle arrow and press the touch screen button for the direction it is facing, ignoring the irrelevant stimuli surrounding it. In this case, to be correct, the child would press the "Right" button as shown in the diagram.

5.2.3.6 Processing Speed Variable

Children had to identify the number of red circles on the screen, which also featured red triangles and blue circles. They responded by selecting the correct answer from 1 to 9 at the bottom of the screen, as shown in Figure 5-6. There were 18 trials in total and children were instructed to work as quickly and accurately as possible. The mean reaction time for trials correct was used as the outcome variable and a lower score indicates a better performance. This task was used in Hill et al. (2021) and is outlined in the protocol for the collection of the Primary School Years data (Bird et al.,2019).

Figure 5-6

A Schematic Illustration of the Processing Speed Task, reproduced from Hill et al. (2021, p. 8)



Note. The child selected the digit that corresponded to the number of red circles they could see, in this case 4.

5.2.3.7 Gestational Variable

Consistent with other chapters in this thesis, gestation was considered by week, grouped into the following categories: VMPT (less than 34 weeks' gestation); LPT (34 to 36 weeks' gestation); early term (37 to 38 weeks' gestation); and full term (the comparator) (39 to 41 weeks' gestation).

5.2.3.8 Covariates

Control variables were based on previous studies of preterm outcomes and were consistent with those used elsewhere in this thesis and are described in Chapter Two (Methods), Section 2.4, with the following additions: to reflect that children were at different ages when the tests were conducted 'age in months' at the time of testing was included. Secondly, the impact of the addition of processing speed as a control variable was considered, as Rose et al. (2011) suggest it may directly impact on working memory.

5.2.4 Statistical Analysis

The correlation between the outcome variables was first tested. Multiple linear regression analyses then tested if VMPT, LPT, early term gestation (the full term gestational group formed the control group), predicted the outcome variables. Statistical significance was measured by a *p* value of < .05 (two tailed). All analysis was performed using Stata 17.0 (StataCorp., 2021).

As in the other studies with this thesis, the assumptions of normality, linearity and homoscedasticity were examined using scatterplots and examination of the residuals. In the interest of parsimony, where a covariate was not statistically significant it was removed from the model, provided it was non-significant for all outcome variable models. Conversely, in order to allow a consistent comparison, if a covariate was statistically significant in at least one model, it was retained in other models. This inclusion was checked to ensure it did not materially affect the outcome.

Two models were completed for each outcome variable, one with processing speed included, shown in Tables 5-3 to 5-7, and one without (shown in Appendix J, Tables J-1 to J-4). For comparison with these models that used multiple imputed data for covariates that had missing data, a complete case analysis was also completed (see Appendix K, Tables K-1 to K-5) for each outcome variable, as was a model containing age in months and gestational group as predictors for which no data was missing (Appendix L, Table L-1).

Effect size was calculated in terms of standardised mean differences divided by the shared standard deviation (Faraone, 2008). Effect sizes conformed to Cohen's guidelines (small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$) (Cohen, 2013; Sullivan & Feinn, 2012).

5.3 Results

A correlation table presenting the linear relationships between the outcome variables is presented in Table 5-1. This shows that the working memory, inhibition and processing speed variables were moderately correlated with one another (Akoglu, 2018). Table 5-2 shows the mean score and standard error by each gestation group for each outcome variables. The mean scores, once adjusted for covariates, are also illustrated in Figure 5-7 for the working memory variables (VWM, CWM, VSWM), with the mean adjusted scores for inhibition shown in Figure 5-8 and for processing speed in Figure 5-9.

Table 5-1

Pearson's Correlations between the Executive Function Outcomes

Variable	CWM	VWM	VSWM	Inhibition	Processing Speed
CWM	1				
VWM	53**	1			
VSWM	.47**	.41**	1		
Inhibition	.17**	.12**	.15**	1	
Processing Speed	-.31**	-.22**	-.34**	-.16**	1

Note. *n* = 5008. **Correlation is statistically significant at the *p* = .01 level (2-tailed). Abbreviations: CWM = Complex Working Memory; VWM = Verbal Working Memory; VSWM = Visuospatial Working Memory.

5.3.1 Multiple Linear Regression

The multiple regression model results are shown in Tables 5-3 to 5-7 with processing speed included as a covariate with VWM, CWM, VSWM and inhibition, and in Appendix J (Tables J-1 to J-4) for the results without processing speed included as a covariate for these outcomes.

RQ1: Does LPT Birth Predict Lower Scores on VWM in Childhood?

The results for VWM with processing speed regression are presented in Table 5-3. Results showed no effects of gestational group, with no differences in individuals' VWM score dependent upon whether they were born at early term, LPT or even VMPT (early term: $p = .682$; LPT: $p = .589$; VMPT: $p = .457$).

Age at time of testing was statistically significant with each additional month of age associated with a higher score ($p < .001$). All specified levels of education below higher education had a negative impact on the scoring (A Levels: $p = .023$; 5 GCSEs and less than 5 GCSEs both $p < .001$); and mother's age below 35 years (compared to 35 years or over) ($p = .004$) were also statistically significant predictors of a lower score. Additionally, slower processing speed predicted worse VWM scores ($p < .001$). Finally, the child's mother having parity of one to three previous births predicted a higher score compared to being first born ($p = .032$).

Table 5-2

Means, Standard Error and Confidence Intervals for Outcomes by Gestational Group for Executive Function Study

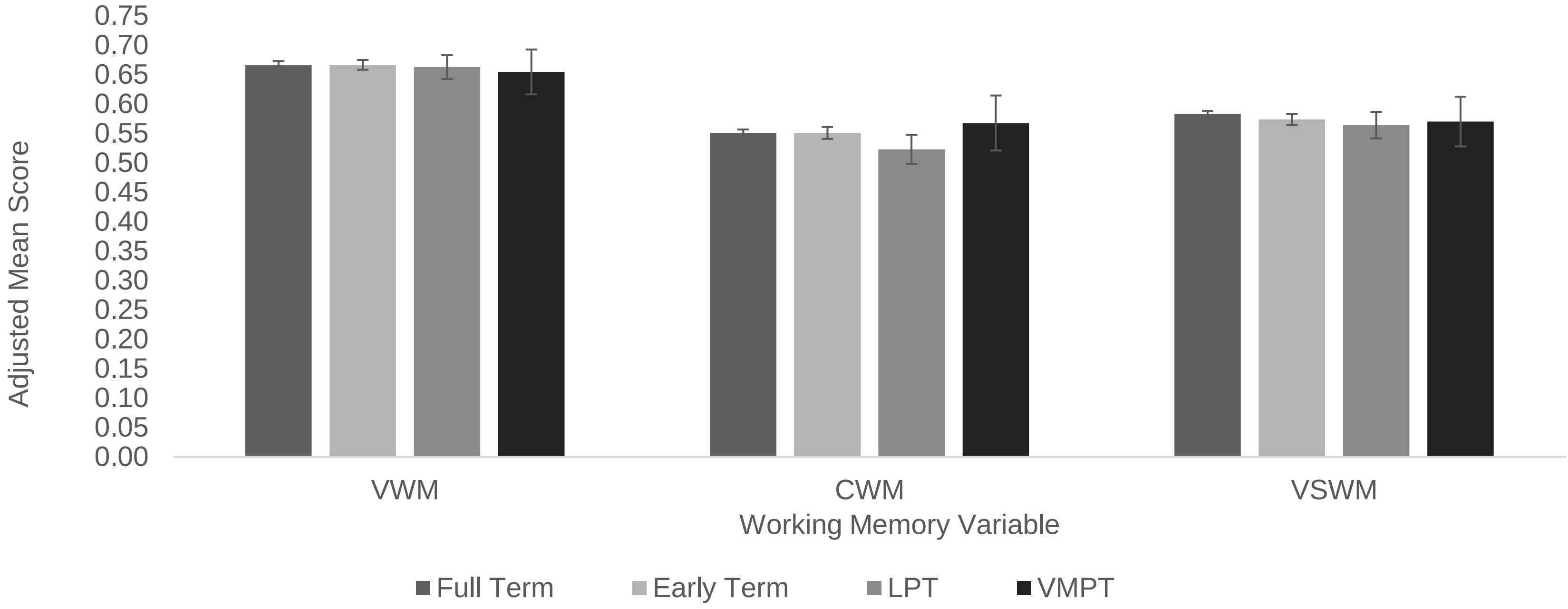
Variable	Full Term (*n* = 3650)			Early Term (*n* = 1119)			LPT (*n* = 186)			VMPT (*n* = 53)		
	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL
VMW[1]	0.67	0.00	0.66, 0.67	0.67	0.00	0.66, 0.68	0.67	0.01	0.64, 0.69	0.65	0.02	0.61, 0.69
CWM[1]	0.55	0.00	0.55, 0.56	0.55	0.00	0.54, 0.56	0.53	0.01	0.50, 0.55	0.56	0.03	0.52, 0.61
VSWM[1]	0.58	0.00	0.58, 0.59	0.58	0.01	0.57, 0.59	0.57	0.01	0.55, 0.59	0.57	0.02	0.52, 0.61
Inhibition[1]	-0.21	0.01	-0.22, -0.20	-0.22	0.01	-0.24, -0.20	-0.20	0.03	-0.25, -0.15	-0.23	0.04	-0.31, -0.14
Processing Speed[2]	4.98	0.02	4.93, 5.02	5.01	0.03	4.94, 5.08	4.97	0.08	4.81, 5.13	5.17	0.17	4.83, 5.50

Note: *n* = 5008. [1]Higher score equates to better performance. [2]Higher score equates to worse performance.

Abbreviations: M = mean, SE = standard error, 95% CI = 95% Confidence Interval, LL = Lower Limit, UL = Upper Limit; CWM = Complex Working Memory; VWM = Verbal Working Memory; VSWM = Visuospatial Working Memory.

Figure 5-7

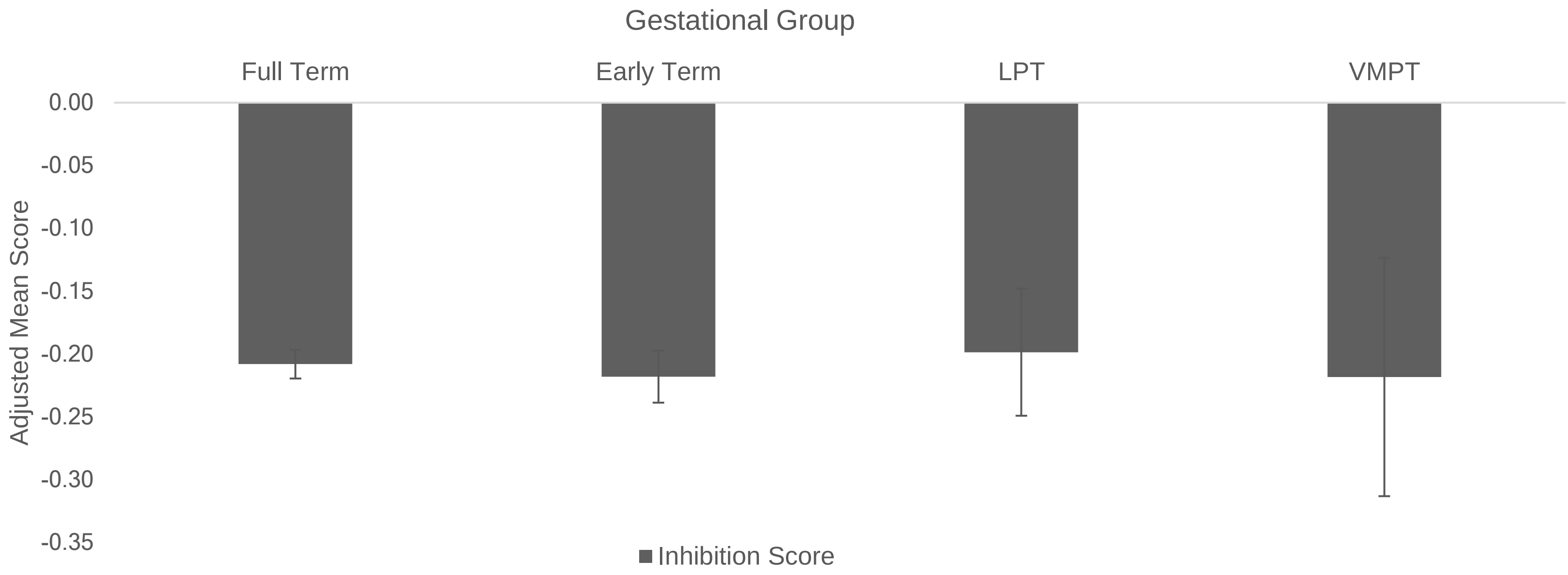
Mean Scores by Gestational Group for the Working Memory Outcomes (Adjusted for the Addition of Covariates) with 95% Confidence Intervals



Note. Mean scores were adjusted for the addition of statistically significant covariates (age in months at time of testing, sex, ethnicity, maternal education, mother's age at child's birth, parity and processing speed). Error bars show 95% confidence intervals. Higher scores indicate better performance. Abbreviations: CWM = Complex Working Memory; VWM = Verbal Working Memory; VSWM = Visuospatial Working Memory.

Figure 5-8

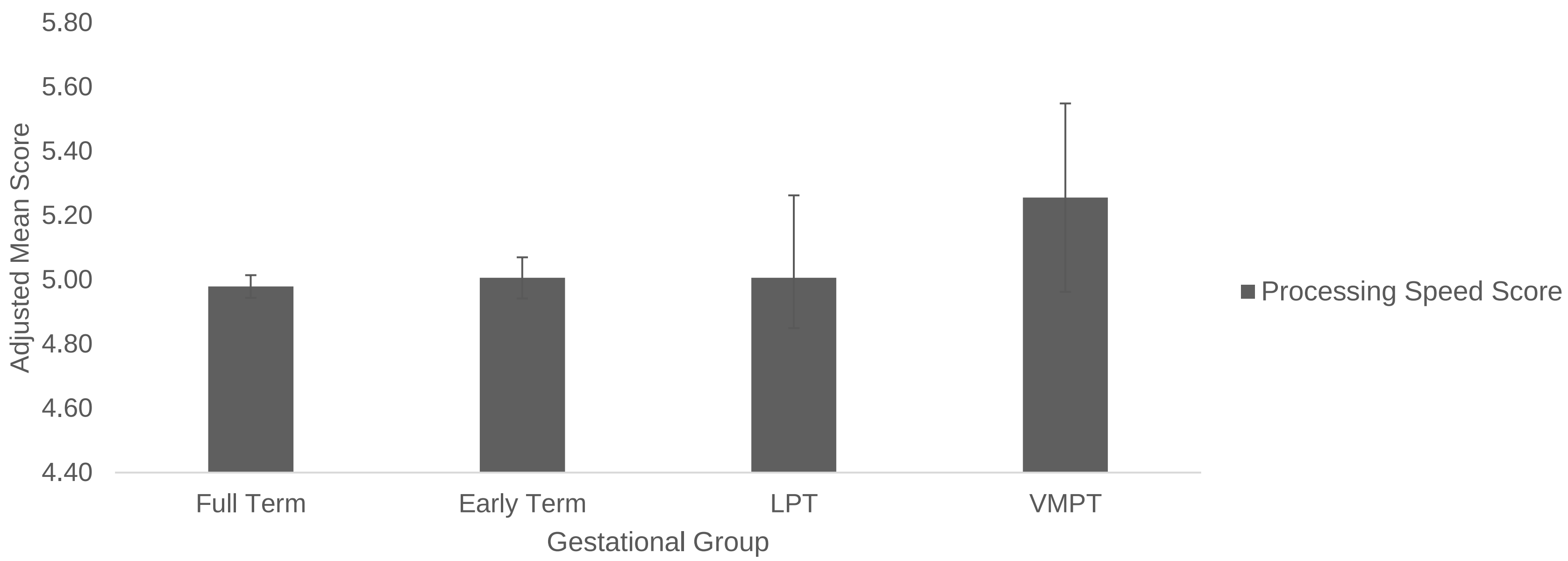
Mean Scores by Gestational Group for the Inhibition Outcome (Adjusted for the Addition of Covariates) with 95% Confidence Intervals



Note. Mean scores were adjusted for the addition of statistically significant covariates (age in months at time of testing, sex, ethnicity, maternal education, mother's age at child's birth, parity and processing speed. Error bars show 95% confidence intervals. Lower scores indicate poorer performance. Abbreviations: LPT = Late Preterm; VMPT = Very and Moderately Preterm.

Figure 5-9

Mean Scores by Gestational Group for the Processing Speed Outcome (Adjusted for the Addition of Covariates) with 95% Confidence Intervals



Note. Mean scores were adjusted for the addition of statistically significant covariates (age in months at time of testing, sex, ethnicity, maternal education, mother's age at child's birth, and parity. Error bars show 95% confidence intervals. Lower scores indicate better performance. Abbreviations: LPT = Late Preterm; VMPT = Very and Moderately Preterm.

RQ2: Does LPT predict lower scores in CWM in childhood?

The results of the regression for CWM with processing speed are shown in Table 5-4. The LPT group's mean score on this outcome was significantly lower (*p* = .029) than full term (the reference category). However, the result was not significant for early term gestation (*p* = .924), nor VMPT gestation (*p* = .516). This was a very 'small' effect (Cohen's *d* = -.16, 95% CI [-.31 to -.01]) (Cohen, 2013) on the LPT gestational group.

This adverse effect for being born LPT was also statistically significant in both the model when gestational group was controlled for age (in months) at testing in complete case analysis (included in Appendix L; Table L-1) (p = .039), and the fully adjusted model in Table 5-4 (*p* = .029). However, the results were not statistically significant for children born VMPT (*p* = .516 in the adjusted model and p = .927 in the baseline model) and the VMPT group scored a similar mean score to children born at full or early term birth in both of these models.

In the covariates, age in months (*p* < .001) and the mother having one to three previous births (*p* = .047) continued to significantly predict a better score. Whilst the mother having less education continued to predict a lower score when compared to mother having higher education (A Levels: *p* = .008; 5 GCSEs: *p* < .001; less than 5 GCSEs: *p* < .001; other education: *p* = .004). Maleness was predictive of a poorer score (*p* < .001) on CWM, unlike in VWM. Whilst slower processing speed was predictive of a worsened CWM score (*p* < .001).

Table 5-3

Linear Regression Table for VWM: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked in Pregnancy and Processing Speed

Variable	VWM				
	B	SE	95% CI LL, UL	β	p
Intercept	0.51	0.03	0.45, 0.57		**< .001**
Early Term[1]	0.00	0.00	-0.01, 0.01	-.01	.682
LPT[1]	-0.01	0.01	-0.03, 0.02	-.01	.589
VMPT[1]	-0.01	0.02	-0.05, 0.02	-.01	.457
Age in Months at testing	0.00	0.00	0.00, 0.00	.15	**< .001**
Male[2]	0.00	0.00	0.00, 0.01	.01	.475
Pakistani Ethnicity[3]	0.04	0.01	0.03, 0.05	.13	**< .001**
Other Ethnicity[3]	0.03	0.01	0.02, 0.05	.08	**< .001**
Maternal Education: A Levels[4]	-0.02	0.01	-0.03, 0.00	-.04	**.023**
Maternal Education: 5 GCSEs[4]	-0.02	0.01	-0.04, -0.01	-.08	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.03	0.01	-0.05, -0.02	-.10	**< .001**
Maternal Education: Other[4]	-0.01	0.01	-0.05, 0.02	-.02	.231
Mother's Age: 21 to 34 years[5]	-0.02	0.01	-0.03, -0.01	-.05	**.004**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.05, -0.01	-.05	**.004**
Parity:1 to 3 previous births[6]	0.01	0.00	0.00, 0.02	.03	**.032**
Parity: ≥ 4 previous births[6]	0.00	0.01	-0.02, -0.02	.01	.753
Mother smoked in pregnancy[7]	-0.02	0.01	-0.03, 0.00	-.04	**.013**
Processing Speed	-0.02	0.00	-0.03, -0.02	-.18	**< .001**

Note: n = 5008. R^2 = 0.10, F (17, 4793.40) = 29.57, p < .001.Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not statistically significant in any model: IMD, means tested benefit. Abbreviations: VWM = Verbal Working Memory B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table 5-4

Linear Regression Table for CWM Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked in Pregnancy and Processing Speed

Variable	CWM				
	B	SE	95% CI	β	p
			LL, UL		
Intercept	0.37	0.04	0.29, 0.45		**< .001**
Early Term[1]	0.00	0.01	-0.01, 0.01	.00	.924
LPT[1]	-0.03	0.01	-0.05, 0.00	-.03	**.029**
VMPT[1]	0.02	0.02	-0.03, 0.06	-.01	.516
Age in Months at testing	0.00	0.00	0.00, 0.00	.18	**< .001**
Male[2]	-0.03	0.00	-0.04, -0.02	-.08	**< .001**
Pakistani Ethnicity [3]	0.02	0.01	0.01, 0.03	.05	**.005**
Other Ethnicity [3]	0.01	0.01	0.00, 0.03,	.03	.101
Maternal Education: A Levels[4]	-0.02	0.01	-0.04, -0.01	-.05	**.008**
Maternal Education: 5 GCSEs[4]	-0.04	0.01	-0.05, -0.02	-.09	**< .001**
Maternal Education: < 5 GCSEs[4]	-0.06	0.01	-0.07, -0.04	-.13	**< .001**
Maternal Education: Other[4]	-0.03	0.01	0.06, -0.01	-.05	**.004**
Mother's Age: 21 to 34 years[5]	-0.02	0.01	-0.03, 0.00	-.04	**.045**
Mother's Age: ≤ 20 years[5]	-0.02	0.01	-0.04, 0.00	-.03	.076
Parity: 1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.03	**.047**
Parity: ≥ 4 previous births[6]	0.01	0.01	0.03, 0.02	.01	.558
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.01	-.02	.359
Processing Speed	0.04	0.00	-0.05, 0.04	-.26	**< .001**

Note. n = 5008. R^2 = 0.14, F (17, 4679.40) = 46.89, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not statistically significant in any model: IMD, means tested benefit. Abbreviations: VWM = Verbal Working Memory B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

RQ3: Does LPT Birth Predict Lower Scores in VSWM in Childhood?

The results for VSWM with processing speed are shown in Table 5-5. As found in VWM, there was no gestational effect for any of the gestational groups (early term: p = .086, LPT: p = .107, VMPT: p = .541).

However, increased age in months (p < .001) at the time of testing again positively predicted performance. Unlike CWM, where it predicted a worsened score, being male predicted a better score in VSWM (p < .001). Whereas maternal education being lower than higher education (A Levels: p = .009; 5 GCSEs: p < .001; less than 5 GCSEs: p < .001); and children being born to a mother under 35 years (Mother aged 21 to 34 years: p = .001; Mother aged 20 or less: p = .006) were predictive of a worse score.

The child's mother already having had children for both categories of 1 to 3 previous births (p = .036) and 4 or more previous births (p = .030), rather than the child being first born, was also predictive of a higher score on VSWM. Additionally, as with VWM and CWM, requiring more processing time predicted a worse score on VSWM (p < .001).

RQ4: Does LPT predict lower scores in inhibition in childhood?

The results from the analysis showed no effects of gestational group on inhibition, as shown in Table 5-6 (early term: p = .411 LPT: p = .720, VMPT: p = .837). For this outcome, age in months was predictive of a higher score (p < .001), as it was for all the outcome variables. Whilst children who had slower processing speed also had worse inhibition scores (p < .001). The child's sex; ethnicity; Mother's education; mother's age; parity; and the mother smoking during pregnancy were not statistically significant predictors for inhibition.

RQ5: Does LPT predict lower scores in processing speed in childhood?

Gestational group showed no effect on processing speed, as shown in Table 5-7 (early term: p = .435; LPT: p = .732; VMPT: p = .057). Only two of the covariates were statistically significant predictors of lower processing speed; increasing age in months was associated with better processing speed (p < .001); and mother having less than 5 GCSEs was associated with worse processing speed compared to the mother having received higher education (p = .015).

Table 5-5

Linear Regression Table for VSWM: *Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked in Pregnancy and Processing Speed*

Variable	VSWM				
	B	SE	95% CI LL, UL	β	p
Intercept	0.43	0.04	0.36, 0.50		**< .001**
Early Term[1]	-0.01	0.01	-0.02, 0.00	-.02	.086
LPT[1]	-0.02	0.01	-0.04, 0.00	-02	.107
VMPT[1]	-0.01	0.02	-0.06, 0.03	-.01	.541
Age in Months at testing	0.00	0.00	0.00, 0.00	.17	**< .001**
Male[2]	0.02	0.00	0.01, 0.03	.07	**< .001**
Pakistani Ethnicity [3]	0.02	0.01	0.01, 0.03	.05	**.002**
Other Ethnicity[3]	0.04	0.01	0.03, 0.06	.09	**< .001**
Maternal Education: A Levels[4]	-0.02	0.01	-0.04, -0.01	-.05	**.009**
Maternal Education: 5 GCSEs[4]	-0.03	0.01	-0.04, -0.02	-.08	**< .001**
Maternal Education: < 5 GCSEs[4]	-0.04	0.01	-0.05, -0.02	.09	**< .001**
Maternal Education: Other[4]	-0.02	0.01	-0.04, 0.00	-.03	.085
Mother's Age: 21 – 34 years[5]	-0.02	0.01	-0.04, -0.01	-.06	**.001**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.05, -0.01	-.05	**.006**
Parity: 1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.03	**.036**
Parity: ≥ 4 births[6]	0.02	0.01	0.00, 0.04	.03	**.030**
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.00	-.02	.152
Processing Speed	-0.04	0.00	-0.05, -0.04	-.28	**< .001**

Note*:* n = 5008. R^2 = 0.16, F (17, 4733.70) = 52.80, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not statistically significant in any model: IMD, means tested benefit. Abbreviations: VSWM = Visuospatial Working Memory B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table 5-6

Linear Regression Table for Inhibition: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked in Pregnancy and Processing Speed

Variable	Inhibition				
	B	SE	95% CI LL, UL	β	p
Intercept	-0.25	0.09	-0.40, -0.09		**.002**
Early Term[1]	-0.01	0.01	-0.03, 0.01	-.01	.411
LPT[1]	0.01	0.03	-0.04, 0.06	.01	.720
VMPT[1]	-0.01	0.05	-0.11, 0.09	.00	.837
Age in Months at testing	0.00	0.00	0.00, 0.00	.06	**< .001**
Male[2]	0.00	0.01	-0.02, 0.02	.00	.948
Pakistani Ethnicity[3]	-0.01	0.01	-0.04, 0.01	-.02	.321
Other Ethnicity[3]	0.00	0.02	-0.03, 0.04	.00	.940
Maternal Education: A Levels[4]	0.02	0.02	-0.01, 0.06	.02	.221
Maternal Education: 5 GCSEs[4]	0.01	0.02	-0.02, 0.04	.01	.655
Maternal Education:< 5 GCSEs[4]	0.01	0.02	-0.02, 0.04	.01	.538
Maternal Education: Other[4]	-0.01	0.02	-0.06, 0.03	-.01	.590
Mother's Age: 21 to 34 years[5]	-0.02	0.02	-0.05, -0.01	-.02	.189
Mother's Age: ≤ 20 years[5]	-0.01	0.03	-0.06, 0.03	-.01	.581
Parity: 1 to 3 previous births[6]	0.01	0.01	-0.01, 0.03	.01	.459
Parity: ≥4 previous children[6]	-0.00	0.02	-0.05, 0.05	.00	.982
Mother smoked in pregnancy[7]	-0.03	0.02	-0.06, -0.01	-.03	.128
Processing Speed	-0.04	0.00	-0.05, -0.03	-.14	**< .001**

Note. n = 5008. R^2 = 0.03, F (17, 4804.70) = 8.79, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not statistically significant in any model: IMD, means tested benefit. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table 5-7

Linear Regression Table for Processing Speed: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, and Mother Smoked in Pregnancy

Variable	Processing Speed				
	B	SE	95% CI LL, UL	β	p
Intercept	9.08	0.21	8.66, 9.50		**< .001**
Early Term[1]	0.03	0.04	-0.04, 0.10	.01	.435
LPT[1]	0.03	0.08	-0.13, 0.19	.01	.732
VMPT[1]	0.29	0.15	-0.01, 0.58	.03	.057
Age in Months at testing	-0.04	0.00	-0.05, -0.04	-.29	**< .001**
Male[2]	-0.06	0.03	0.01, -0.12	-.02	.074
Pakistani Ethnicity[3]	0.17	0.04	0.26, 0.09	.07	**< .001**
Other Ethnicity[3]	-0.03	0.05	0.08, -0.13	-.01	.611
Maternal Education: A Levels[4]	0.05	0.06	0.17, -0.06	.02	.351
Maternal Education: 5 GCSEs[4]	0.08	0.05	-0.01, 0.17	.03	.070
Maternal Education:< 5 GCSEs[4]	0.12	0.05	0.22, 0.02	.05	**.015**
Maternal Education: Other[4]	-0.01	0.07	-0.15, 0.13	.00	.913
Mother's Age: 21 to 34 years[5]	0.02	0.05	-0.07, 0.12	.01	.639
Mother's Age: ≤ 20 years[5]	0.12	0.07	-0.02, 0.27	.03	.095
Parity: 1 to 3 previous births[6]	-0.01	0.04	0.08, 0.06	-.01	.769
Parity: ≥ 4 previous children[6]	0.05	0.07	-0.09, 0.20	.01	.472
Mother smoked in pregnancy[7]	0.00	0.06	-0.11, 0.11	.00	.959

Note: n = 5008. R^2 = 0.10, F (16, 4633.60) = 32.15, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged 35 plus; [6]First Born; [7]Did not smoke. The following variables were removed as they were not statistically significant in any model: IMD, means tested benefit. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

5.4 Discussion

The objective of the study was to examine the executive function components of VWM; CWM; VSWM; and inhibition, alongside processing speed in children born LPT compared to children born at full term. The study found no effect on any of the tasks for children born VMPT or early term, and only a very small effect in CWM for children born LPT.

This research was largely exploratory as there were either no studies on children born LPT in the age group considered, or the existing findings were conflicting. The study therefore makes original findings in the areas of VWM, CWM and processing speed in its specific analysis of the defined gestation group of LPT at the ages of 7 to 10 years old. However, it would be useful for this to be examined in other cohorts to further establish whether the results are generalizable.

5.4.1 Comparison with Previous Studies

Considering the executive function component findings in more detail, the study provided no evidence that a detrimental effect from birth at LPT gestation for VWM and the adjusted mean scores, shown in Figure 5-7, were very similar for all gestational groups. This is consistent with expectations from earlier studies in VWM in younger children born LPT (Baron et al., 2011; Hodel et al., 2019), and with studies (Cserjesi et al., 2012; Odd et al., 2019) in the wider moderately/LPT gestational group. Whilst the finding of no effect in the current study is contrary to that found by Brumbaugh et al. (2013), their study was with a smaller sample of younger children. However, it was surprising that no adverse effect was found from birth at VMPT gestation as this is contrary to previous studies (Anderson et al., 2004; Omizzolo et al., 2014; Wehrle et al., 2021).

There was a small adverse effect found in CWM in children born LPT, even after controlling for processing speed and background antenatal and SES characteristics. The adjusted mean score was lower for children born LPT than the other gestational groups, as seen in Figure 5-8. Whilst there were no existing studies in a similar age group, Baron et al. (2011) similarly found an adverse effect in younger children born LPT. This effect on children born LPT does not appear to subsist into adulthood (Suikkanen et al., 2021).

However, even a small effect could potentially have some impact on academic attainment as this is the area of working memory most often found predictive of such attainment (Alloway & Alloway, 2010; Gathercole et al., 2004; Gathercole & Pickering, 2000). Lower CWM is potentially an important finding for children in their primary education years where differences in education achievement have been shown in Chapter Three and several studies (Alterman et al., 2022; Chan & Quigley, 2014; Chyi et al., 2008; Pettinger et al., 2020; Quigley et al., 2012).

The current studies result of no statistically significant effect from VMPT birth for CWM was unexpected, as a number of studies have found children born VMPT have poorer CWM (Aarnoudse-Moens et al., 2012; Böhm et al., 2004; Omizzolo et al., 2014).

The current study found no predictive effect of LPT birth on VSWM scores at the ages of 7 to 10 years old. This was expected as studies by Baron et al. (2011) and Brumbaugh et al. (2013), in younger LPT born children also did not find an effect. There was also no adverse effect seen from VMPT for this variable, despite other studies suggesting such a deficit (Aarnoudse-Moens et al., 2012; Böhm et al., 2004; Mulder et al., 2011; Omizzolo et al., 2014).

The current chapter study also suggests that there is no effect from preterm birth on response inhibition at the age of 7 to 10 years old. There was no existing study identified investigating response inhibition in children born LPT within this age group. However, comparing this finding to studies of inhibition in children born very preterm (Aarnoudse-Moens et al., 2012), or in children born moderately/LPT (Hodel et al., 2016) results vary dependent on the type of inhibition task. The Flanker task (Eriksen & Eriksen, 1974), on which the current study's task was based, is considered a motor inference control inhibition task (Aarnoudse-Moens et al., 2012). It is notably that Aarnoudse-Moens et al. (2012) did not find a statistically significant detrimental effect even in children born very preterm children aged 4 to 11 years old within the Flanker task.

Whilst Brumbaugh et al. (2013) found an adverse effect on inhibition from LPT gestation in children at a younger age than the current chapter, they did so in a verbal inhibition task. Similarly, Cserjesi et al. (2012) found an adverse effect for moderately/LPT in verbal inhibition task. The evidence from this chapter's study does not suggest a detrimental effect on motor interference control inhibition (described in Section 5.1.1.2), the type of inhibition examined in the current study, between the ages of 7 to 10 years old for children born LPT.

Therefore, the current evidence suggests that children born preterm do not have issues with motor interference control inhibition as seen in this study and in Aarnoudse-Moens et al. (2012), but may have issues with other areas of inhibition such as hot inhibition tasks (described in Section 5.1.1.2) (Hodel et al., 2016) and verbal inhibition (Brumbaugh et al., 2013; Cserjesi et al., 2012). It would be useful to investigate a wider range of inhibition tasks in the same sample of children born LPT to explore this further.

Finally, there was no adverse effect found from LPT birth on processing speed. This finding was somewhat unexpected as previous studies have found increased processing times for LPT birth (Brumbaugh et al., 2016; Jin et al., 2020). However, all of these studies had samples of less than a quarter of the size of the current study for LPT births. A risk of small sample sizes is due to vagaries within the sample there can be an increased risk of finding an effect when one does not exist at population level (Knudson & Lindsey, 2014). Additionally, two previous studies have reported an adverse effect on processing speed within a combined moderately/LPT sample (Bogičević et al., 2020; Reijneveld et al., 2021). However this effect may have been the result of an adverse effect in the earlier gestation group (moderately preterm) being attributed to the overall moderately/LPT group.

More studies are needed to investigate processing speed in children born LPT to see if the results from the current study are replicated. The current study did not suggest a cascade of effects from poorer processing speed influencing executive function leading to worse levels of academic achievement seen in children born very preterm found by Rose et al. (2011). It does however certainly support processing speed being important to all executive functioning as it was a statistically significant predictor for *all* of the executive function variables.

5.4.2 Potential Explanations for the Findings in the Executive Function Study

Previous studies looking at neural differences between children born LPT and full term at the ages considered in the current study have found differences in the parietal lobe (Rogers et al., 2014), and the thalamus (Brumbaugh et al., 2016). Studies in the general population have suggested that these areas have a key role in CWM (X. Chen et al., 2023; Gomes et al., 2023; Koenigs et al., 2009; B. Lee et al., 2022). It is possible that this is a key factor in the current study’s findings of worsened CWM, but further studies are needed to investigate this potential link.

There are a number of explanations for no adverse effect in any of the outcome variables being found in children born VMPT. The study combined moderately preterm and very preterm children together, due to the low sample size for these two groups. There were more children in the moderately 32 to 33 gestational weeks' category than the very preterm category (< 32 weeks), and better outcomes in this group may have influenced the finding, reflecting the reverse gestational gradient of effect (Boyle et al., 2012). Additionally, the combined group size itself may have been too small to find an effect. It is notable that some of the studies that did find an adverse effect on children born very preterm had the benefit of a greater sample size in the VMPT category than the current study (e.g. Aarnoudse-Moens et al., 2012; Omizzolo et al., 2014). However, the mean scores in this chapter's results for the VMPT group were worse than the full term scores for four of the five outcome variables (VWM, VSWM, Inhibition and processing speed) as shown in Table 5-2 and Figures 5-5 to 5-9 (for the adjusted means).

5.4.3 Implications of the Findings

The study is the first to explore CWM in children born LPT at the ages of 7 to 10 years. It suggests that children born LPT may have poorer CWM at this age, but this was only a small effect.

CWM has been identified as being crucial in many aspects of learning, including mathematics (Bull et al., 2008; De Smedt et al., 2009; Geary, 2011); reading (Bull et al., 2008; Cortés Pascual et al., 2019; Gathercole & Pickering, 2000); and writing (De Vita et al., 2021; Gathercole & Pickering, 2000). These three key subjects have been highlighted as areas of lower attainment for children born preterm, as seen in Chapter Three and many studies (Alterman et al., 2022; Chan & Quigley, 2014; Copper et al., 2023; Quigley et al., 2012).

The Central Executive required for CWM, holds a significant role in cognition and is suggested to control encoding a retrieval; attention switching; and the mental manipulation of information (Baddeley, 1996). As such its involvement, in academic achievement is unsurprising. For example, in the subject area of mathematics, the learning of transcoding of number from words to figures requires the manipulating and maintenance of information in the brain when changes are required from the verbal form, such as in overwriting the zero place holder when writing numbers (e.g. 21 not 201), and inverting from the verbal order in writing teen numbers (e.g. 16 not 61) (Barrouillet et al., 2004; Camos, 2008). Furthermore, CWM has found to be important in manipulations for arithmetic such as 'carrying' numbers over in addition and in 'borrowing' in subtraction (Imbo & Vandierendonck, 2007; Iuculano et al., 2011). Similarly, learning to read requires alphabetic decoding, storage the letter in sound form and then blending, whilst recalling the correct sound form (Peng et al., 2018). Whilst in writing, text composition requires planning and idea generation; organization of ideas; transcription of thoughts to words and sentences; revision and monitoring the overall writing process (Hayes & Flower, 1980). Therefore, the impact of worse level of CWM can be far reaching in many areas of education.

A potential implication of the finding is that strategies already developed for teaching children with lower levels of CWM would be helpful, such as cognitive off-loading (Berry et al., 2019). There is also an existing suitable package available which has been shown to increase teacher knowledge in such strategies for children born preterm (S. Johnson et al., 2019).

Furthermore, children born preterm, including those born LPT have increased incidence of Attention Deficit Hyperactivity Disorder (Crump et al., 2023). Attention Deficit Hyperactivity Disorder is associated with increased difficulties in CWM (Fosco et al., 2020; Holmes et al., 2014; Kofler et al., 2020) and it maybe that the low-level non-clinical deficits observed in the current study reflect this more acute clinical finding.

Although the effect size of the deficit found is very small, the other areas found to be predictive are relatively commonplace, such as being male; being younger in the school year; and mother having not attended higher education. Therefore, this small effect would be cumulative for many of the children and would have further detrimental effect on their CWM.

5.4.4 Strengths and Limitations

The current study has several strengths. Firstly, it used data collected from a recent cohort data sweep with recruitment between 2007-2010 (J. Wright et al., 2013) and therefore represents contemporary effects in terms of health and education treatment on children born prematurely. The study had good statistical power (Button et al., 2013) to find effects in the LPT and early term gestational groups and benefited from being able to use a wide range of background characteristics as control variables collected as part of the BiB cohort study.

A limitation of the work is the small numbers in the VMPT group. This was due to recruitment to the cohort occurring at 26 weeks' gestation and thereby potentially missing children born at extremely preterm gestation, and to the extremely low occurrence of births below 34 weeks' gestation (Office for National Statistics, 2024). However, this group is not the main focus of this thesis and the effect of birth at VMPT gestation has already been well-examined in many previous studies (Aarnoudse-Moens et al., 2012; Anderson, 2003; Böhm et al., 2004; De Kieviet et al., 2014; Fraello et al., 2011; Gnigler et al., 2015; Loe et al., 2019; López Hernández et al., 2022; Mulder et al., 2010; Omizzolo et al., 2014; Reynold De Seresin et al., 2023; Rose et al., 2011; J. Sato et al., 2019; Wehrle et al., 2021). The current study seeks to make a substantial contribution to the research of LPT gestation and does so by making valid findings in this lesser researched gestational period.

A further limitation of the study is that there was only one test per construct, i.e. only one test of VWM, VSWM, CWM, inhibition and processing speed. It would be useful to repeat the study using different measures of this constructs to establish if the same results are reached.

Additionally, data was not available for some of cognitive aspects that would have been of interest, including IQ, which is often found to be one of the principal deficits for children born preterm (Karnati et al., 2020; Pettinger et al., 2023; Sejer et al., 2019). However, there are criticism of IQ testing in the great variation in test themselves, the abilities they measure, and whether they are truly tapping into mental functioning (Ganuthula & Sinha, 2019).

Furthermore, due to time out of the classroom being restricted, it was not possible to collect data on CWM in the visuospatial domain, nor on the differing aspects of inhibition. The findings are therefore only relevant for the specific aspects of executive function examined.

5.4.5 Suggestions for Next Steps in this Area of Research

In view of the effect size and that this is the only study to examine CWM in school-age children born LPT, more studies are needed to establish if the effect observed in the current study is generalizable.

It would also be advantageous for a study to examine other aspects of inhibition to establish if it is the type of inhibition that results in conflicting results for this construct. This is suggested by the results of Hodel et al. (2016), who found that hot (but not cold) inhibition tasks were negatively affected by moderately/LPT birth. Similarly, Aarnoudse-Moens et al. (2012) who found that response inhibition, but not interference control inhibition, was worse in children born very preterm compared to full term. The differing types of inhibition have not been well-explored in children born LPT and therefore more studies are required.

Furthermore, it was hoped to conduct a mediation analysis with gestational age at birth, working memory and educational outcome variables. However, very few children from the sample completed the statutory academic tests (Key Stage 2 testing) due to Covid-related closures in 2020 and 2021. Therefore, this mediation was not possible but would be useful to complete in the future. Additionally, greater exploration of the potential mediating role of decreased parietal volume, and thalamus size and premature birth and CWM would be useful in establishing the potential relationship in this area.

Finally, this area of research would also benefit from a longitudinal study to assess if the deficit in CWM seen in children born LPT are present at an earlier age, and whether this remains into adolescence and adulthood.

5.4.6 Conclusion

In conclusion, the findings from the study suggest that, relative to children born at full term, children born at LPT gestation perform at similar levels for VWM, VSWM, interference control inhibition, and processing speed. However, the study found a small but statistically significant effect from birth at LPT gestation for CWM. This could have some impact on academic performance and may partially explain the lower attainment seen in Chapters 3 and 4. Nevertheless, as this is the first study to make this finding for children born LPT aged 7 to 10 years, more studies are required to verify this finding.

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Chapter 6

Does Birth at Late Preterm Gestation Predict Graphomotor Skills at the Ages of 4 to 5 years and 7 to 10 Years Old?

Chapter Summary

This study investigates the impact of being born at LPT, VMPT, and early term gestation, compared to full term, at ages 4 to 5 years and 7 to 10 years in three graphomotor outcomes: tracking, aiming and tracing. All three of these outcomes have been shown to predict educational attainment (Giles et al., 2018). The outcomes in this study are measured using kinematic assessment. Such assessment focuses on the quality of the movements made, as opposed to the movement's completion (Barnett et al., 2020). The current study is the first to examine graphomotor outcomes using kinematic measures in children born LPT.

Using cross-sectional linear regression analysis, the results suggest that children born LPT have worse tracking skills at both ages considered, but no deficit in aiming or tracing skills. Whereas children born VMPT had poorer levels of aiming and tracing skills at age 4 to 5 years, but not at age 7 to 10 years. Children born VMPT also had worse tracking skills at age 7 to 10 years, in the covariate adjusted model. There was no deficit found for children born early term for any of the outcomes at any age.

6.1 Introduction

There is evidence that FMS, the “small muscle movements that require close hand-eye coordination” (Luo et al., 2007 p.596), are linked to the poorer cognition and academic attainment seen in children born very preterm (Hasler & Akshoomoff, 2019; Marlow et al., 2007; Oudgenoeg-Paz et al., 2017). A sub-division of FMS, “graphomotor skills” are the pen/pencil skills required in writing (Ghanamah et al., 2020; Suggate et al., 2016). Graphomotor skills are particularly predictive of academic attainment in the general population (Carlson et al., 2013; Dinehart & Manfra, 2013; Feder & Majnemer, 2007; Grissmer et al., 2010; Hasler & Akshoomoff, 2019; Malpique et al., 2020; Mayes & Calhoun, 2007; Pitcher et al., 2012; Suggate et al., 2019).

Graphomotor skills can be examined using “kinematic assessment”. These are computer-aided “process-oriented” assessments evaluating the quality of movement, as opposed to “product-oriented” assessments (further defined in Section 6.1.2) measuring task completion (An, 1984; Barnett et al., 2020). However, there has been no kinematic study examining the graphomotor skills focussed on children born LPT after the age of five years old: the start of compulsory education.

This is an age when minor developmental issues often become apparent (Astbury et al., 1990; Voss et al., 2007) and poorer graphomotor skills impact on many school-based tasks, such as learning to write (Sagnol et al., 2007). Therefore, evaluating if children born preterm at school age have worse graphomotor skills is important in addressing the lower educational achievement observed by many authors (Alterman et al., 2022; Chan & Quigley, 2014; Cheong et al., 2017; Copper et al., 2023; S. Johnson et al., 2011; Pettinger et al., 2020; Quigley et al., 2012). The current study addresses this gap by presenting for the first time, a kinematic examination of graphomotor skills by gestational group at two time-points: T1, at the ages of 4 to 5 years in this study, and T2, age 7 to 10 years in this study.

6.1.1 Neural Influences of Preterm Birth on Motor Skills

The effects of prematurity are found generally to have a gestational gradient of risk, with worse outcomes associated with earlier gestation (i.e. very preterm). This is due to shorter in-utero developmental time, with outcomes improving the closer the birth is to 40 weeks’ gestation (Boyle et al., 2012; Moore et al., 2012). As discussed in Chapter One (Section 1.5), in premature birth early extra-uterine exposure occurs at a time when the brain is still forming, and white matter injury may consequently result. Rates of white matter injury are much more prevalent in children born at lower gestational ages, (i.e. very preterm), due to their very early birth (Romero-Guzman & Lopez-Munoz, 2017). Therefore, children born LPT are less affected by white matter injury than those born very preterm, but are more affected than term births (Romero-Guzman & Lopez-Munoz, 2017). Such white matter injury has been found to predict motor skills impairment in children born very preterm (Spittle et al., 2011)

6.1.2 Assessing FMS and Graphomotor Skills

FMS and graphomotor skills are evaluated in either “product-oriented” or “process-oriented” assessments. Product-oriented assessments generally measure the completion of a task, and research using such assessments tend to yield a high sample size because they are usually quicker to complete and set up (Barnett et al., 2020). Conversely, process-oriented assessments are finer grained and include kinematic computer-based assessment (defined in Section 6.1.6). Thus process-oriented based studies typically are capable only of recruiting relatively small sample sizes (e.g. Bernhardt et al., 2002; Z.-J. Chen et al., 2021; Halek et al., 2015; Jeng et al., 2002; Murphy et al., 2011). Within the next section the results of studies of general FMS, and those specifically focussed on graphomotor skills, in children born preterm are considered within both types of assessment.

6.1.3 Graphomotor Skills Assessed using Product-Oriented Assessments in Children born Preterm

The evidence for poorer levels of FMS in childhood is strong for children born VMPT (J. Atkinson & Braddick, 2007; Bolk et al., 2018; Bracewell & Marlow, 2002; Dathe et al., 2020; De Rose et al., 2013; Evensen et al., 2020; Feder et al., 2007; Foulder-Hughes & Cooke, 2003; Marlow et al., 2007; Setänen et al., 2016). There have also been studies focussed specifically on the graphomotor skills of children born VMPT. These too have found lower levels of graphomotor skills throughout childhood (Bolk et al., 2018; Caravale et al., 2012; Constable et al., 2008; Cooke, 2003; Dathe et al., 2020; Feder et al., 2007; Fletcher et al., 1997; Luoma et al., 1998; Miranda-Herrero et al., 2021; Roze et al., 2021; van Veen et al., 2019). However, there are far fewer studies examining FMS in children born LPT, with studies even scarcer investigating graphomotor skills specifically (Z. Chen et al., 2022; Dusing & Tripathi, 2015).

6.1.4 FMS and Children Born at LPT Gestation

Before five years of age, most studies find worsened FMS in children who were born LPT (Baron, Weiss, Baker, et al., 2014; Z. Chen et al., 2022; Hua et al., 2022; Kerstjens et al., 2011; Morag et al., 2013; You, Shamsi, et al., 2019; You, Yang, et al., 2019). Conversely, worse FMS and graphomotor skills were not found in a large study (LPT *n* = 400) by Nepomnyaschy et al. (2012). However, a potential explanation for this result is that the tasks were assessed as pass or fail and may have lacked sufficient discriminatory ability to reveal more subtle differences in skills.

After the age of five years, studies often combine the moderately preterm and LPT groups, meaning that any effect found may be due to the influence of the difficulties experienced by children born moderately preterm reflecting the theorised gestational gradient of risk (Boyle, 2020). Baron, Weiss, Baker, et al. (2014, p. 439) caution against merging the LPT and moderately preterm categories, arguing these two gestational groups have “distinctly different developmental outcomes”.

Furthermore, most studies investigate the wider category of FMS and therefore do not report on graphomotor skills separately. There have also been contradictory results in these FMS studies. One study found poorer FMS in children born moderately/LPT (*n* = 331) at age 7 years (Odd et al., 2013); another smaller study found no difference in either children born moderately/LPT(*n* = 62), or very preterm (*n* = 38) (Pitcher et al., 2012); and a further small study found *only* children born very preterm (*n* = 29), but not moderately/LPT (*n* = 30), had poorer FMS scores (Rodríguez Fernández et al., 2016).

However, the sample sizes in the last two analyses (Pitcher et al., 2012; Rodríguez Fernández et al., 2016), were quite small and may not therefore have been able to detect the effects found in the larger study (*n* = 331) by Odd et al. (2013). Sufficient power in terms of number of participants is required to find statistically significant effects, with smaller effects requiring larger samples (Hackshaw, 2008). However, the effect size found by Odd (2013) (using a FMS coordination summary score from the ALSPAC[31] cohort data) of an OR of 1.39 equates to a small effect size (Sullivan & Feinn, 2012). Therefore, smaller studies such as the studies by Pitcher et al. (2012) and Rodríguez Fernández et al. (2016) may not be able to detect such effect.

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[31] Avon Longitudinal Study of Parents and Children

Additionally, Huddy et al. (2001) also found “below average” FMS in 7-year-old children born at the gestation of 32-35 weeks (covering moderately preterm and partially covering LPT gestation) in a teacher-reported questionnaire. However, this study relied on subjective teacher comparisons of the preterm child’s ability compared to the ‘average’ generic child (not specifically preterm), with the teacher being required to judge the level ‘average’ themselves.

Robson (2009) suggests that are potential methodological drawbacks with the use of questionnaires to obtain data. Firstly, results are potentially affected by the characteristics of the respondent in terms of their knowledge and experience; secondly, the respondent potentially won’t necessarily report accurately as they may be wanting to please the researcher; thirdly, the respondent may misunderstand the questions, and lastly, that the respondent may not take the questionnaire seriously, nor place importance on it. Therefore, the results in Huddy et al. (2001) may have differed using a more objective method of assessment.

6.1.4.1 Methodological Issues with Product-Oriented FMS Assessments

The studies reviewed above (Z. Chen et al., 2022; Hua et al., 2022; Huddy, 2001; Kerstjens et al., 2011; M.-X. Liu et al., 2023; Odd et al., 2013; Pitcher et al., 2012; Rodríguez Fernández et al., 2016) all used product-oriented assessments and such assessment do not offer any insight on movement quality (Barnett et al., 2020). There are also methodological issues associated with some of the specific assessments used in these investigations, which all investigated FMS in general, in extending the findings specifically to graphomotor skills.

Firstly, many of the above studies (M.-X. Liu et al., 2023; Pitcher et al., 2012; Rodríguez Fernández et al., 2016) used the MABC[32] (Henderson et al., 2007). Whilst this measure does investigate a graphomotor measure: “drawing”, it reports a combined score for three FMS tasks (drawing, threading, and posting) (Ke et al., 2021). Therefore, a high score on either the threading or posting task may result in the overall score indicating no deficit in FMS. However, it is still entirely possible that a poor score was reached in the drawing-based graphomotor task.

Similarly, the ALSPAC coordination test used in the study by Odd et al. (2013), utilized an adapted version of the MABC that did not measure graphomotor skills at all (C. M.

[32] Movement Assessment Battery for Children

Taylor et al., 2018). Therefore, whilst Odd et al. (2013) found that children born moderately/LPT have poorer FMS, this does not specifically extend our knowledge of their graphomotor skills.

Other studies examining FMS, have used a questionnaire-based method seeking teacher or parental responses (Benzies et al., 2017; Hua et al., 2022; Huddy, 2001; Kerstjens et al., 2011). Such questionnaires can result in different findings dependent on who completed the assessment and are therefore quite subjective (Ke et al., 2021). These assessments also report a general FMS score rather than reporting on graphomotor specific outcomes. Therefore, there is a risk again that the results seen in general FMS may not extend to the specific area of graphomotor skills.

6.1.4.2 Graphomotor Skills in the LPT Population

Only two studies explicitly look at the LPT population and graphomotor skills after the age of 5 years. Firstly, Ibrahimi et al. (2023) found poorer graphomotor skills at the age of 5 to 12 years old in children born LPT by Caesarean Section (LPT: n = 20). Babies delivered by Caesarean Section are regarded as having heightened risk of worsened health outcomes as they have greater intensive care admission rate and requirement for oxygen supplementation. This may change their subsequent development (Kamath et al., 2009). Babies born by Caesarean Section are also more likely to have lower white brain matter and functional connectivity at birth (Deoni et al., 2019). Therefore, these findings may not apply to the general population of children born LPT.

In contrast, Brumbaugh et al. (2016) found no negative impact of LPT birth (LPT: n = 52) on graphomotor skills in children aged 6 to 13 years old in a general sample. However, this study had a relatively low sample size and may therefore have been underpowered to find small effects (Button et al., 2013). It would therefore be useful for a study with a larger sample size to explore graphomotor outcomes in children born LPT to overcome the potential issues of sample size from Brumbaugh et al. (2016) and generalisability and sample size from Ibrahimi et al. (2023).

6.1.5 Age-Related Changes

A further issue in both of two existing graphomotor studies (Brumbaugh et al., 2016; Ibrahimi et al., 2023), is the wide age ranges examined (5 to 12 years and 6 to 13 years respectively). Motor deficits may be remedied over the course of development, and differences have been seen at one age but not at another in children born very preterm (Domellöf et al., 2018; M.-X. Liu et al., 2023; Sagnol et al., 2007). However, this would not be apparent if wide age ranges are used.

Furthermore, the period between the ages 4 to 6 years old has been described as a "transitional phase" for postural stability, which is "emergent" at 4 to 6 years but "mature" by age 7 to 10 years (Shumway-Cook & Woollacott, 1985). Such postural stability is required for good reaching and aiming skills (De Graaf-Peters et al., 2007; Hadders-Algra, 2013; Rachwani et al., 2015), and general FMS (Haddad et al., 2013; Rosenblum & Josman, 2003).

These reaching skills are considered a precursor to graphomotor aiming skills (Sagnol et al., 2007) and there is a significant correlation between postural stability and graphomotor skills (Flatters, Mushtaq, et al., 2014). This is suggested because postural stability provides the required steadiness to receive and produce accurate visual representations. Accordingly, Fallang, Saugstad, and Hadders-Algra (2003) found children born preterm who had worse postural stability as infants, also had poorer FMS. A systematic review has likewise demonstrated that children born preterm (less than 37 gestational weeks) have lower postural stability than their term-born peers (Tuñón-Domínguez et al., 2022).

In view of this theorised transitional period for postural stability, it has been posited that children born preterm may have a differing motor development trajectory between the ages of 4 to 6 years and 7 to 10 years old (L. Brown et al., 2015). Additionally, aiming and reaching motor skills, required for graphomotor movements, have been shown to develop from 4 years to 10 years old (Kuhtz-Buschbeck et al., 1998) and therefore developmental changes may be seen within these ages. Studies in children born LPT are therefore needed that use narrower age ranges than the existing studies (Brumbaugh et al., 2016; Ibrahimi et al., 2023), reflecting potential improved postural control and aiming development between the ages of 4 to 10 years old.

6.1.6 Kinematically Assessed Graphomotor Skills

All studies discussed above (Baron, Weiss, Baker, et al., 2014; Bolk et al., 2018; Brumbaugh et al., 2016; Dathe et al., 2020; De Rose et al., 2013; Ibrahimi et al., 2023; Kerstjens et al., 2011; Marlow et al., 2007; Miranda-Herrero et al., 2021; Morag et al., 2013; Nepomnyaschy et al., 2012; Odd et al., 2013; Rodríguez Fernández et al., 2016; You, Yang, et al., 2019) used product-oriented assessments rather than process-oriented 'kinematic' assessments.

Kinematic assessment can provide specific information on the movement patterns, quality and the movement strategies using computer analysis (Murphy et al., 2011). Such assessments have been argued to allow focused and precise examination of motor skills (Eddy et al., 2020; Logan et al., 2018). Furthermore, kinematic assessment of specific graphomotor outcomes have been shown to predict academic attainment in the general population (Giles et al., 2018; Shire et al., 2016).

6.1.6.1 Kinematic Assessment of Graphomotor Outcomes in Preterm Births

There are a limited number of studies using kinematic assessment to measure general FMS in children born preterm. These have tended to focus on children below the age of 5 years, born at very preterm gestation. Such studies have found poorer levels of reaching ability (Araújo Rohr et al., 2021; Fallang, Saugstad, Grøgaard, et al., 2003; Grönqvist et al., 2011; Kaul et al., 2019; Sagnol et al., 2007). Two studies have also found less mature reaching movement in LPT and moderately/LPT born children (Rönnqvist & Domellöf, 2006; N. T. D. S. Sato & Tudella, 2018).

There is only one existing graphomotor study which examines aiming graphomotor outcomes in a small sample of children born very preterm (*n* = 20) at two ages, aged around 3 years and 5 years old, by Sagnol et al. (2007). Sagnol and colleagues found children born very preterm had more fragmented aiming movement at age 3 years compared to children born at full term, but not by age 5 years. However, by age 5 years, children born very preterm made significantly more errors in reaching the target with greater movement time, when compared to children born at full term. The authors posit this early increased fragmented movement represents less mature movement control in very preterm children, compared to full term born children. However, they suggest that the preterm children used a correcting feedback mechanism by the age of 5 years, and this increased the fluidity of their movement, but this came at the cost of slower movement and less accuracy as the process was still being mastered. Their results therefore indicate a transition in graphomotor skills for children born very preterm at around the age of 5 years.

The kinematic examination of preterm children after the age of 5 years have examined FMS, but not specifically graphomotor skills. Furthermore, they have not examined specifically the LPT gestational group at all. Domellöf et al. (2013) used a kinematic assessment of FMS in children born 22 to 35 weeks' gestation (*M* = 31 weeks'), aged 6 to 8 years. They found being of overall preterm gestation did not predict poorer performance on a kinematically assessed picking and threading task but that increased gestational age in weeks within the preterm group was associated with better FMS skill levels.

Using the same FMS task, Johansson et al. (2014) examined children born before 35 weeks' gestation at 4 to 8 years. Johansson and colleagues found only children born very preterm had poorer levels of performance in the threading and picking tasks, compared to full term births. Children born moderately preterm (33 to 35 gestational weeks) were found to perform similarly to full term births, but had less defined handedness preference. Whilst again, in the same task, Domellöf et al. (2018) examined two time-points with predominantly very preterm children (*n* = 18) and found worse FMS compared to full term births at age 4 years but not by at age 8 years, thereby suggesting effects may change with age, and a differing trajectory of development for the preterm group.

A further kinematic study was conducted by Van Braekel et al. (2008) in children born VMPT (*n* = 45) aged 7 to 11 years, examining index finger pointing/aiming. This preterm group were found to have lower aiming skills including in movement speed and accuracy. In a follow-up study, using the same sample and task, Van Braekel et al. (2010) explored aiming quasi-longitudinally to establish whether the differences seen in children born very preterm represent a delay or deficit. They found a regression in movement time for children born full term at age 8 years that was not present in the children born very preterm. They conclude that this suggests there is a deficit in aiming skills in children born very preterm, rather than the delay (Van Braeckel et al., 2010). However, a potential criticism of the study is that the sample size for the very preterm group varied greatly, from 17 children at age 10 years old to 40 children at age 8 years old.

These existing kinematic assessments leave a profound research gap: there has been no graphomotor study examining outcomes in children born LPT at all and only one study of graphomotor skills, which considered the effect of very preterm birth on a sample of children aged 3 to 5 years old. Furthermore, that study (Sagnol et al., 2007) only looked at aiming skills and no other areas of graphomotor skills. It is, therefore, necessary for a study to be conducted using kinematic assessment focussed on graphomotor skills investigating the association of preterm birth in graphomotor outcomes after the age of 5 years. This needs to examine a range of graphomotor skills to examine if any difference applies to all or only particular skills.

This is a crucial area of research as there is evidence to suggest that graphomotor skills are related to lower academic achievement, which has been found to be a key deficit in children born preterm, including LPT (Alterman et al., 2022; Chan & Quigley, 2014; Copper et al., 2023; Pettinger et al., 2020).

6.1.7 FMS and Graphomotor Skills in Children Born at Early Term Gestation

There are currently few studies investigating the FMS skills of children born at early term gestation compared to full term births. Here, Espel et al. (2014) found children born at early term gestation had worse motor skills at the ages 3, 6 and 12 months compared to children born at full term. Similarly, Hua et al. (2022) found increased odds of parents reporting worse FMS in children born early term, compared to children born at full term, at the age of 3-5 years.

However, no adverse effect was found in later childhood by M.-X. Liu et al. (2023) who found no difference in the FMS of children born early term, compared to full term, at either age 3-6 years or 7-10 years in an assessment using the MABC. No studies in graphomotor skills specifically, either in a product oriented or process oriented assessment, were found examining differences between children born early term compared to full term. The current study is therefore believed to be the first examination of the graphomotor skills of children born early term compared to full term and therefore provides a unique contribution to this field.

6.1.8 Aim of the Study and Research Questions

This chapter adds a process-oriented assessment to the few existing product-oriented studies of the graphomotor skills of children born LPT (Brumbaugh et al., 2016; Ibrahimi et al., 2023). This is also the first study comparing the graphomotor skills of children born early term to those born at full term, and therefore presents new knowledge in this field.

It considers graphomotor skills in two age groups, given the suggestion of a ‘transitional phase’ (Shumway-Cook & Woollacott, 1985) in motor development for children at the ages 4 to 6 and 7 to 10 years by examining children at these age range separately. It also has the advantage of greater sample size than many of the previous kinematic assessments of preterm birth after the age of five years (Domellöf et al., 2013, 2018; Johansson et al., 2014; Sagnol et al., 2007; Van Braeckel et al., 2010), and therefore improved power in finding small effects (Button et al., 2013; Hackshaw, 2008).

The overall aim of the study was to investigate the association of being born at LPT, VMPT or early term gestation, compared to full term gestation, on the graphomotor outcome scores in aiming, tracing, and tracking at the ages of 4 to 5 years for T1, and 7 to 10 years for T2, whilst controlling for a comprehensive range of covariates.

6.1.8.1 Research Questions

Given the small number of studies currently in this area, much of this analysis was exploratory. The following research questions were defined.

RQ1: Do Children born LPT and VMPT have Different Levels of Tracking, Aiming, and Tracing Skills to Children Born at Full Term Gestation?

As this has not been examined before in children born LPT, this was an exploratory investigation. The indication from previous studies is that children born VMPT may have poorer graphomotor skills, but this only been looked at in in aiming when assessed kinematically (Sagnol et al., 2007).

RQ2: Are There Differing Effects of LPT, VMPT birth on Tracking, Aiming and Tracking skills at the Two Time-Points?

The second research question is are there different effects at the two time-points, with greater effect being seen at T1 (the younger age group). This is exploratory, but is somewhat suggested by the findings of Sagnol et al. (2007) that children born very preterm have emergent aiming skills at age 5 years. Therefore, these skills may be somewhat more mature by 7 to 10 years, T2 in this study. It is also perhaps inferred from the suggestion of a transitional age in postural development by Shumway-Cook and Woollacott (1985) and age-related changes suggested by Domellöf et al. (2018).

6.2 Methods

6.2.1 Participants and Study Setting

The sample was drawn from the BiB birth cohort, described in earlier chapters. As part of BiB, study participants were followed up in two school-based data sweeps. The ‘Starting School’ sweep (T1 in this study) took place between 2012 and 2014 with children aged 4 to 5 years, and the ‘Primary School Years’ sweep (T2 in this study), took place between 2016 and 2019 with children aged 7 to 10 years. A total of 967 participants had complete outcome data at both time-points. Further details of both sweeps are included in Chapter Two (the Methods Chapter: Sections 2.1.4 and 2.1.5). Details of the mean ages overall and by gestational group in both time-points are shown in Table 6-1.

The sample selection is shown in Figure 6-1. Participants were excluded from the study consistent with the criteria used in the other chapters of the thesis. There was also one additional exclusion criteria, shown in Figure 6-1: tracking, aiming and tracing scores greater than three standard deviations from the mean were removed. Sample characteristics by gestational group showing percentage proportions, before and after multiple imputation, are presented in Appendix M (Table M-1 for T1, Table M-2 for T2).

Table 6-1

Mean Ages in Months Overall and by Gestational Group in T1 and T2

Birth Category	T1 n = 2466		T2 n = 5864	
	M	SD	M	SD
Overall	**59.61**	**0.50**	**100.89**	**7.94**
By Gestational Group				
Full Term	59.51	4.43	100.82	7.97
Early Term	60.08	4.34	100.97	7.89
LPT	59.09	4.17	101.13	7.55
VMPT	58.74	5.14	102.47	8.16

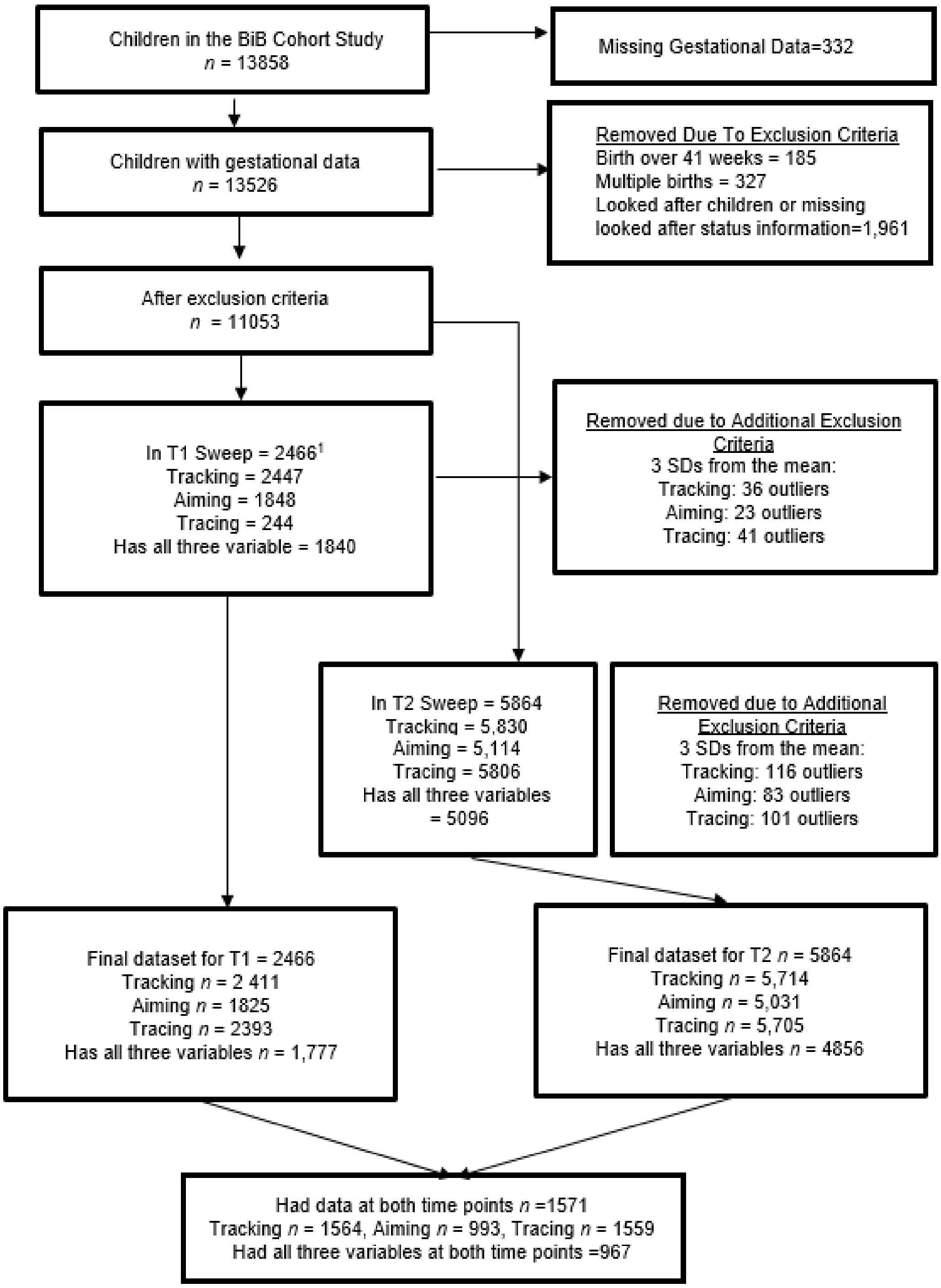
M = mean, SD = Standard Deviation

6.2.2 Procedures

The procedures were essentially the same at both time-points. The assessors were trained by staff from BiB or the Universities of York and Leeds. The child sat at a desk with laptop in front of them, which was situated 15 cm from the edge of the table. They completed the battery of computerised tasks with the stylus using their preferred hand. The order of presentation was consistently the tracking task; the aiming task; and then the tracing task. The child was instructed to complete each task as quickly and as accurately as possible and the assessment took between 15 to 20 minutes. Brief details of the procedures by task are explained in next section, with full details available for T1 (the Starting School Sweep) in Shire et al. (2020) and T2 (the Primary School Years sweep) in Hill et al. (2021).

Figure 6-1

Sample Selection for Graphomotor Study



Note. [1]BiB = Born in Bradford. [2] 1 child removed as aged 11 years, 1 child removed as age 6 years.

6.2.3 Missing Data

Missing data on any of the covariates were replaced with values computed using a multiple imputation by chained equations method implemented using the ice command in Stata 17 (StataCorp., 2021). There were 20 iterations of the data completed. As in Chapter Five, the analysis was repeated using complete case analysis (contained in Appendix N, Tables N-1 to N-6) and the results compared.

6.2.4 Measures

6.2.4.1 Outcome Measures

The outcome measures were drawn from the CKAT (Culmer et al., 2009). This tool was developed to allow rapid collection of kinematic data, outside the laboratory. The CKAT measures movement quality, velocity, acceleration, and form in uni-manual hand movement. It consists of three tasks examining tracking, aiming, and tracing graphomotor skills, described below. Table 6-2 provides a description of the variables collected within CKAT and further details are available in Culmer et al. (2009).

The CKAT is particularly suited as a measure of graphomotor skills in children born preterm. It is portable so data can be gathered in schools with high numbers of children and thereby sample size can be increased relative to requiring participants to attend the laboratory-based assessment more often seen in kinematic assessment (Barnett et al., 2020). This is an important factor in preterm studies, as preterm birth only occurs in around 7% of all births (Office for National Statistics, 2024). Therefore, datasets providing large amounts of data are useful in examining the potential impact of preterm birth, especially when the effect size may be relatively small.

The CKAT is also an established measure of graphomotor outcomes and has been used in several preceding papers (Flatters, Hill, et al., 2014; Shire, 2016; Shire et al., 2016; Waterman et al., 2015; Wood, 2021; Wood et al., 2024). As such, it is a well-established measure of graphomotor skills that will enable more precise understanding of where any graphomotor deficits in the preterm population occur.

Table 6-2

The Kinematic Variables Calculated in CKAT: Table adapted from Wood et al. (2024, p. 7)

Task	Variable	Indices	Description of Variable
All tasks	Path length	Spatial[a]	The distance travelled during the component movement.
Tracking (as 'All Tasks' plus the following)[1]	Path accuracy	Spatial[a]	The measurement of the spatial errors. The movement trajectory compared to the reference trajectory.
	X Gain	Dynamic[b]	The degree to which the movement corresponds to the target sine wave on the X axis.
	Y Gain	Dynamic[b]	The degree to which the movement corresponds to the target sine wave on the X axis.
	RMSE[4]	Dynamic[b]	The amount of error related to the temporal and spatial accuracy compared to the reference trajectory.
	Standard Deviation of RMSE[4]	Dynamic[b]	The standard deviation of the RMSE (the variability of the tracking errors)

Table 6.2 continued

Task	Variable	Indices	Description of Variable
Aiming (as 'all tasks' plus)[2]	Peak speed	Temporal[c]	Fastest speed reach within that movements (mm/s)
	Time to Peak Speed	Temporal[c]	The number of seconds taken to reach the peak speed
	Deceleration Time	Temporal[c]	The number of seconds from peak speed to the end of the movement.
	Reaction Time	Temporal[c]	The time taken between the presentation of the stimulus and reaching the speed threshold of 50mm/s.
	Movement Time	Temporal[c]	The time between the movements first exceeding the velocity threshold of 50mm/s and then falling below it.
Tracing (as 'all tasks' plus)[3]	Path Length Time	Temporal[c]	Time needed to generate the path length
	Path Accuracy	Spatial[a]	Measurement of the spatial errors.
	Path Length Time	Temporal[c]	Time needed to generate the path length

Note. [1] The tracking task was completed in two conditions: a visual guided trajectory of the sine wave, termed the 'guide' condition, and one without the guide he 'no guide' condition. There were three revolutions varying by speed between slow (42mm/s), medium (84mm/s) and fast (188 mm/s). Therefore, there were 36 variables for each participant (6x the 6 variables shown above). [2] The aiming task was complete in three conditions: baseline, jump and embedded baseline) therefore there were (3 x 6) 18 variables. [3] The tracing task was completed in Shape A and Shape B, therefore there were 6 variables per participant (2 x the 3 variables shown above). [4] RMSE = Root Mean Square Error [a] The Spatial indices provides information on the accuracy and efficiency a movement was made on a pathway (Culmer et al., 2009).[b] Some of the CKAT required following a moving trajectory and the degree to which the movement corresponded with the target here was measured in the dynamic indices [c] The temporal indices measured the time related aspects of the movement (Culmer et al., 2009).

6.2.4.1.1 The Validity and Reliability of the CKAT

The CKAT is an established measure of kinematics and has been used in many papers to examine graphomotor kinematic outcomes (e.g. Cunningham et al., 2019; Flatters, Hill, et al., 2014; Flatters, Mushtaq, et al., 2014; Hill et al., 2022; Preston et al., 2014; Shire et al., 2016). The accuracy and reliability of the CKAT was tested against a “gold standard” established kinematic assessment reference: the NDI Optotrak Certus (Culmer et al., 2009, p. 188). Culmer et al. (2009) demonstrated that the CKAT performed very similarly to this gold standard in test data, using the same variables. Culmer et al. (2009) also used this test data to confirm the CKAT’s ability to discriminate between ability and task difficulty by retesting individuals with their non-preferred hand. The results showed difference in ability between preferred and non-preferred hand [F (1, 11) = 23.756, $p < 0.05$; preferred = 23.512; non-preferred = 30.506] and in task difficulty [F (1, 11) = 80.104, $p < 0.05$; tracing = 14.844; copying = 39.175]. Thus, the CKAT has been shown to have good discrimination in ability, task difficulty and produces results at similar levels of accuracy to established “gold standard” kinematic tools.

The disassociations between tasks is further supported by the level of correlation seen between the three tasks observed Giles et al. (2018) in Hill et al. (2022), which showed only moderate associations (tracking-aiming r =.48, steering-tracking r =.40, steering-aiming r = .33, all $p < .01$), with similar levels of correlation seen in study by Shire (2016). It is also demonstrated by the different patterns of association between reading, writing and mathematics seen in Shire (2016) and Giles et al. (2018). Furthermore, the underlying CFA composition used by this study was first examined in a training data set (n = 1740) by Wood et al. (2024) and verified in larger verification data set from the BiB data sweeps (n = 22406).

6.2.4.1.2 Data Reduction of the CKAT Data

A potential barrier to the use of kinematic data is the vast volume of data collected which can potentially lead to complexity in the interpretation of the results. Dimension reduction techniques, such as PCA[33] and CFA[34] can help reduce the quantity and complexity of data.

[33] Principal Component Analysis

[34] Confirmatory Factor Analysis

PCA aims to reduce a large number of observed variables into components reflecting their underlying latent structure (Jolliffe & Cadima, 2016). Similarly, CFA aims to reduce observed variables into latent components but is also based on hypotheses drawn on previous theory of the structure the latent components (Babyak & Green, 2010; D. L. Jackson et al., 2009).

The CKAT weighted mean scores used in this Chapter were developed by Wood et al. (2024) who completed a PCA and CFA using the raw CKAT data from both T1 and T2. The results of the CFA were then tested to establish the best fitting model for each of the tasks in children aged 4 to 11 years. The data reduction is described briefly below, with details of the mapping of the original observed variables on to the CFA latent variables.

6.2.4.1.3 The Tracking Variable

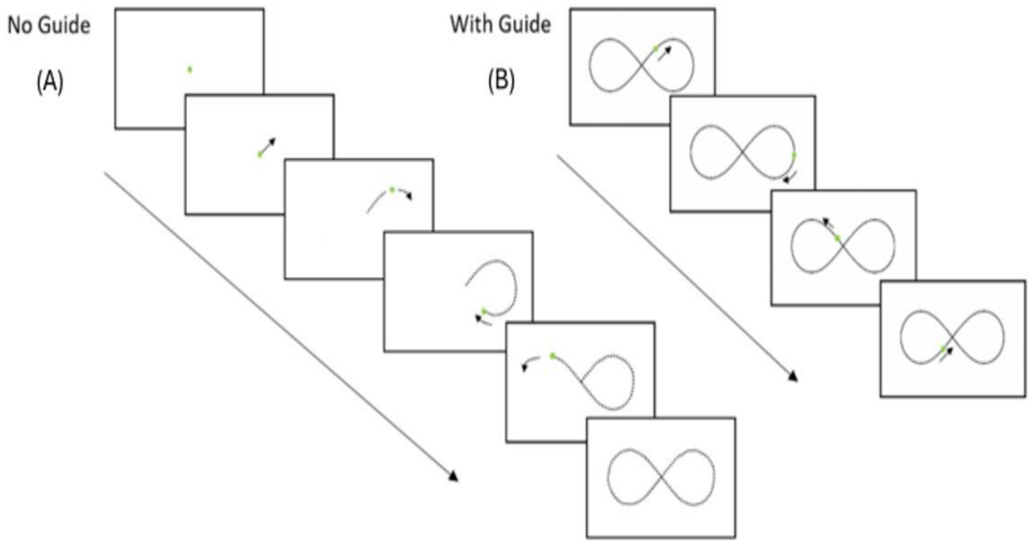
Tracking tasks typically require the tracking of a moving object with a stylus, based on received visual information (Miall et al., 1993; Russell & Sternad, 2001). Such movement involves the use of a feedforward (predictive) and feedback (reactive) motor control mechanism to estimate the trajectory of the object (Gritsenko et al., 2009).

There are thought to be three differing strategies used in such tracking: firstly, a compensatory control strategy using predictive forward models to predict the trajectory of the target and to make compensatory movements to amend the movement to minimise deviation (Davidson & Wolpert, 2005; Desmurget & Grafton, 2000; Miall & Wolpert, 1996); secondly, a corrective feedback strategy using consecutive smaller, corrective feedback movements as the target moves (Culmer et al., 2009; Davidson & Wolpert, 2005; Desmurget & Grafton, 2000); and lastly, a hybrid of the two (Desmurget & Grafton, 2000).

The CKAT tracking task required the participant to move the stylus to track a moving dot around the screen in a series of sinusoidal wave patterns, as shown in Figure 6-2. The task varied between two conditions: a with-guide condition displaying the upcoming trajectory of the dot; and without-guide condition. Each of the two conditions was presented at three speeds: slow (42 mm/s); medium (82 mm/s); and fast (168 mm/s). These speeds were presented three times each; making a total of nine presentations in the with-guide, and nine presentations in the without guide conditions (Wood et al., 2024). The without guide condition was completed first, followed by the with-guide condition. The presence of the guide is theorised to provide extra information in the direction of the dot (Flatters, Hill, et al., 2014).

Figure 6-2

A Schematic Illustration of the Tracking Task: *Figure Reproduced from Wood et al. (2024, p. 7)*



Note. The tracking task had two conditions: Condition A: no guide condition, and Condition B: with guide condition.

There were six variables collected for each of the 18 presentations. These variables are detailed in Table 6-2. A mean score was taken for each of the fast, medium and slow presentations within with-guide and without-guide conditions. This resulted in 36 data points for each participant (six variables multiplied by the six sub-conditions: fast, medium, and slow for both with and without-guide conditions). The results of the CFA completed by Wood et al. (2024) revealed a seven-factor latent model had the best fit for the tracking data, as shown in Figure 6-3. This model included items related to dynamic accuracy for each of the test conditions, as well as items related to path length.

6.2.4.1.4 The Aiming Variable

Aiming tasks are used to assess graphomotor control and coordination (Ishihara & Imanaka, 2007). These tasks require stylus movement towards a target and can examine both response speed and accuracy (Naber & Murphy, 2020). Aiming movement are believed to consist of two phases, a central ballistic acceleration phase and a feedback-based (honing) phase. This is referred to as the “Two-Component Model” (Elliott et al., 2001).

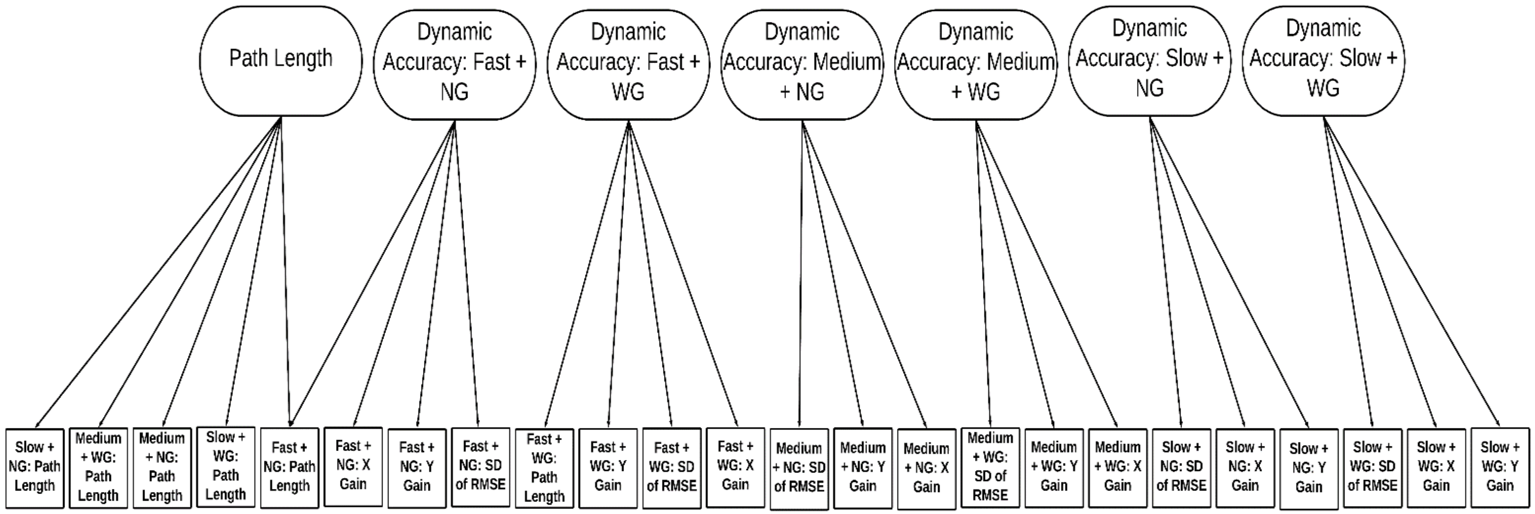
A “target jump” can be included to form a double-step paradigm. This occurs when the target moves as the participant draws near, requiring the participant to change course. This makes the task more difficult by requiring an online correction of movement (Sarlegna & Mutha, 2015).

The aiming task required the child to make a series of 75 aiming movements towards individual targets which appeared sequentially in a pseudorandomised order (Wood et al., 2024), as shown in Figure 6-4. Whilst the targets formed a pentagram, no visual guide was presented to the child. Once the target was reached it immediately disappeared and the next target was presented. The child was required to continuously keep the stylus in contact with the screen.

The first 50 of the 75 movements consisted of ten repetitions of the same pentagram-shaped presentation, whilst the next 25 incorporate a ‘jump’ condition. Twelve of these were jump conditions where the target changed to the next location in the sequence when the child reached 40mm from the original target. This required a corrective movement by the child to reach the new target (Flatters, Hill, et al., 2014).

Figure 6-3

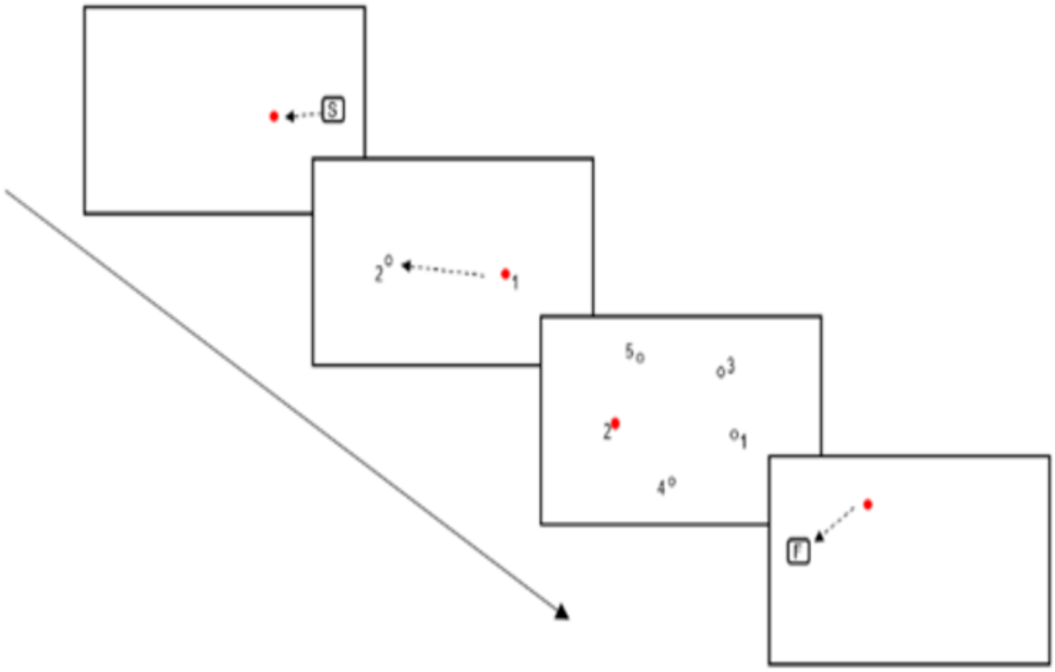
Path Diagram of the Final Model for the Tracking Task: *Reproduced from Wood et al. (2024, p. 11)*



Note. NG = No Guide, WG = With Guide, RMSE = Root Mean Squared Error, SD = Standard Deviation, PL = Path Length. The rectangular boxes represent observed variables. Ellipses show latent variables. X gain refers to movement on the horizontal path. Y gain refers to movement on the vertical path.

Figure 6-4

A Schematic Illustration of the Aiming Task: Diagram Reproduced from Wood et al. (2024, p. 8)



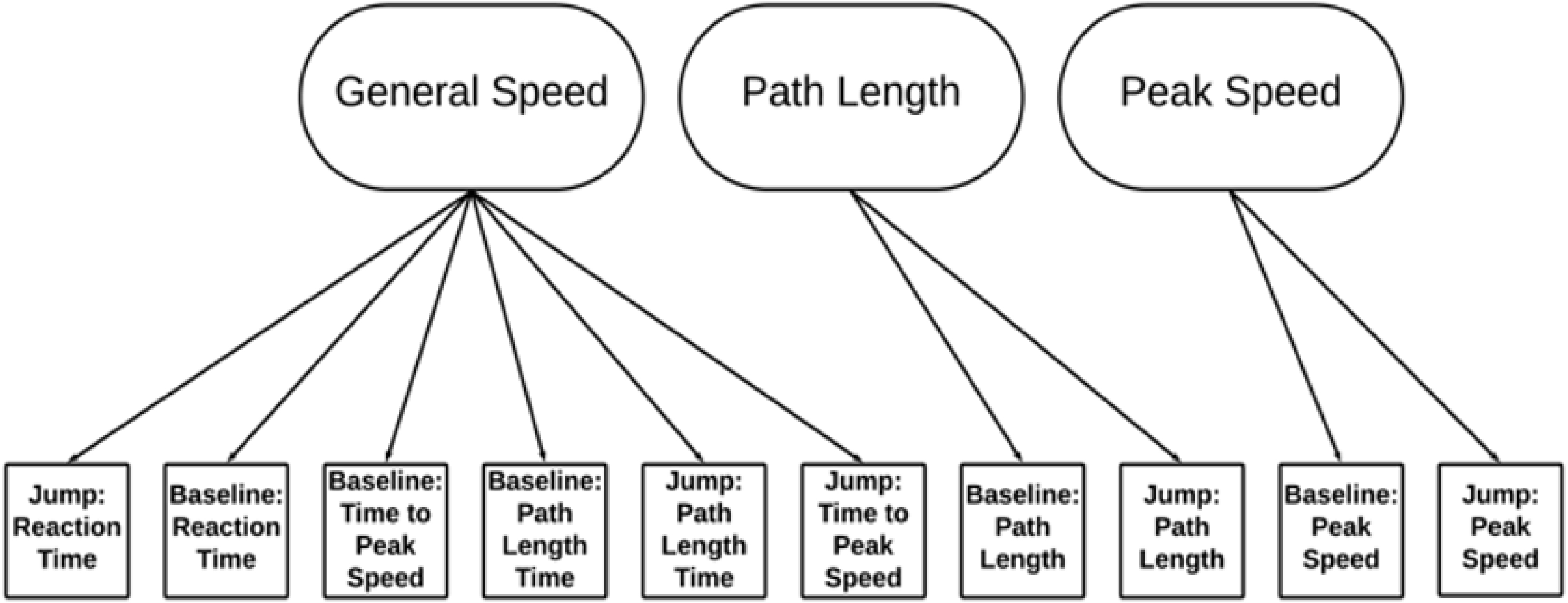
Note. The child was required to aim for the red dot with the stylus. Once the child reached the dot target, the target disappeared from view and the next target appeared. S = Start, F = Finish.

The purpose of these jump trails was to reduce the predictability of sequences for the participant. The jump trails were inserted pseudo-randomly between 13 standard aiming movements identical to the base line condition (where the target did not move as the child got closer to it, termed 'embedded baseline trails'). Therefore, the aiming task was divided into three conditions: baseline, jump and embedded baseline conditions (Wood et al., 2024).

The PCA by Wood et al. (2024) revealed a three-factor latent model, shown in Figure 6-5. The embedded baseline condition was not included in this modelling as it was used as purely to separate the jump trials. Movement time also did not load onto the PCA latent components.

Figure 6-5

Path Diagram of the Final Model for the Aiming Task: Reproduced from Wood et al. (2024, p. 13)



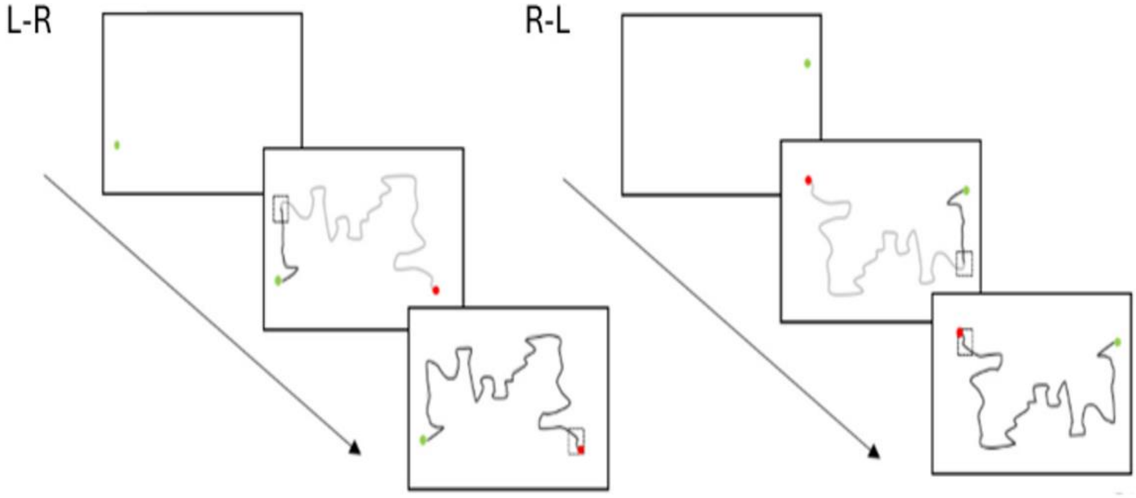
6.2.4.1.5 The Tracing Variable

Tracing tasks involve tracing a shape with a stylus (Carlson et al., 2013). Such tasks require a feedforward (predictive) and feedback (reactive) mechanism to control the stylus, apply the correct amount of stylus pressure and adjust the pressure and grip based on the sensory feedback (Culmer et al., 2009; Davidson & Wolpert, 2005).

The tracing task required the child to trace an abstract pathway form. The first form, “Shape A”, required this being done from the left-hand side of the screen to the right, whilst “Shape B” was the shape reversed horizontally, required tracing from the left-hand side to the right (both shown in Figure 6-6). Participants had to keep the stylus within a box that moved sequentially across the pathway every five seconds to contain the movement speed. This prevented participants engaging in a speed-accuracy trade off by encouraging them to standardise their pace (Flatters, Hill, et al., 2014). One trial of each presentation was completed (Shape A, then Shape B) (Wood et al., 2024). There were eight variables per data-point for this task. The PCA by Wood et al. (2024), suggested a four-factor model, as shown in Figure 6-7.

Figure 6-6

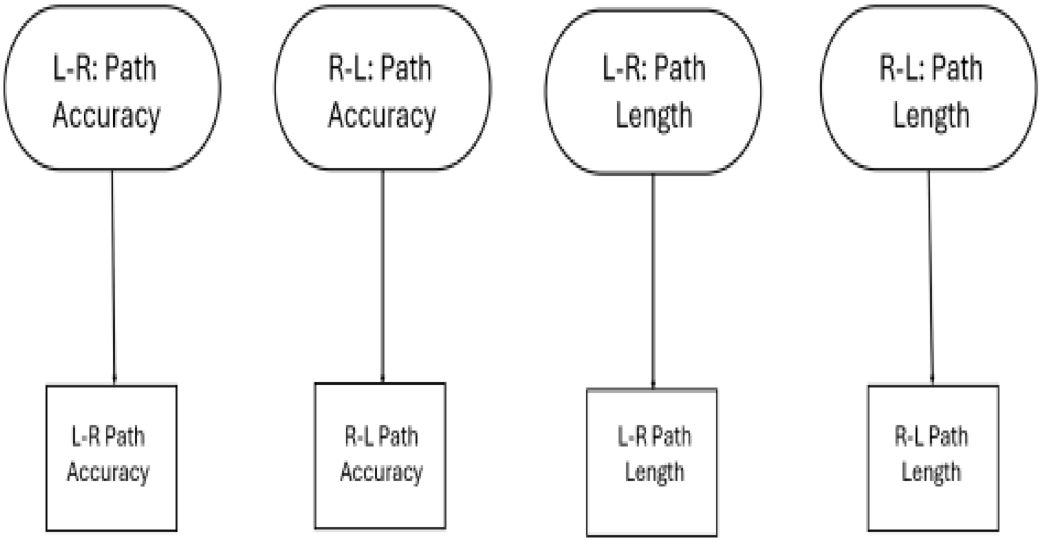
A Schematic Illustration of the Tracing Task: Reproduced from Wood et al. (2024, p. 8).



Note. The tracing task required the child to steer the stylus along the trajectory of two abstract shapes which were shown, as accurately and as quickly as possible. The second shape was the same shape as the first but reversed horizontally. This task is referred to as “steering” within Wood et al. (2024). L-R = Left to right, R-L = Right to Left.

Figure 6-7

Path Diagram of the Final Model for the Tracing Task: Reproduced from Wood et al. (2024, p. 13)



Note. L-R = Left to right; R-L = Right to left. The rectangular boxes indicate the observed variables. The ellipses indicate latent variables.

6.2.4.1.6 The Production of Weighted Mean Scores

From the CFA and PCA analysis, Wood et al. (2024) produced one weighted mean score for each of the three tasks (tracking, aiming and tracing). These weighted mean scores, produced by Wood et al. (2024), were drawn from the raw outcome variables found to explain the most variance, as indicated by the CFA and PCA testing completed by Wood et al. (2024).

To complete CFA and PCA analyses, Wood et al. (2024) initially produced a combined standardised score from the raw CKAT output data, for the outcomes shown in Table 6.2. The CFA and PCA analyses was then used to finalise models which best retained the variance seen in the data for each task (tracking, aiming and tracing).

For the tracking task, a seven component model as shown in Figure 6-3, represented the best fitting model from the CFA and PCA. These seven component outcomes were: path length; dynamic accuracy at fast speed with a guide; dynamic accuracy at fast speed without a guide; dynamic accuracy at medium speed with a guide; dynamic accuracy at medium speed without a guide; dynamic accuracy at slow speed with a guide; and dynamic accuracy at slow speed without a guide. A three-component model provided the best fit for the aiming task, as shown in Figure 6-5. Here, the three component outcomes were general speed; path length; and peak speed. Whilst four component outcomes (left to right path accuracy; right to left path accuracy, left to right path length and right to left path length) best fitted the tracing task, as shown in Figure 6-7.

Wood et al. (2024) used these seven (tracking); three (aiming); and four (tracing) component models to derive a weighted mean score for each of the three tasks that best encapsulated the components dimension seen in the final PCA models. This weighted mean score, was calculated by firstly multiplying the participants' score for each of the components identified in the PCA for that task by the corresponding factor weighting for that component observed in the PCA. This product was then summed. Finally, the weighted mean score was reached by dividing the sum products from the first stage, by the sum of the weights from the PCA for those components. For further details, see Wood et al. (2024).

6.2.4.1.7 Removal of Outliers and Standardisation

The weighted mean scores included several observations which were significant outliers, suggesting children may not have either understood or engaged in the task. The data was therefore trimmed to remove any scores more than three standard deviations from the mean for each outcome. This approach is consistent with that adopted by Hill et al. (2021) to the executive function data used in Chapter Five. To increase interpretability of results, the data was standardised around the mean for each of the two time-points.

6.2.4.2 Predictor Variable

Gestation was grouped into the following categories of completed gestational weeks: VMPT (33 weeks' or less gestation); LPT (34 to 36 weeks' gestation); early term (37 to 38 weeks' gestation); and full term (39 to 41 weeks' gestation), as used in other chapters of this thesis. Full term birth provided the comparator category to the other gestational groups.

6.2.4.3 Covariates

Control variables were consistent with those used elsewhere in this thesis, as detailed in the Methods Chapter Table 2-1, with the addition of two variables. Firstly, to reflect that children were at different ages when the tests were conducted “age in months” was included in all analyses. Secondly, handedness was included as studies in aiming skills have suggested that this is a key significant predictor (Aoki et al., 2016; Habibi & Chattopadhyay, 2021).

6.2.5 Statistical Analysis

Simple and multiple linear regression analyses tested group differences between the VMPT, LPT, early term gestational groups, compared to children born at full term, on the outcome variables at both time-points. The outcome variables of tracking, aiming and tracing standardised scores were treated as continuous variables. A higher score indicates a better result in all cases.

In order to leverage the most data, all observations with data after the application of the exclusion criteria were considered (not just those with data at both time-points). This was due to low number, especially in the preterm gestational categories having data at both time-points meaning restricting analyses to children with data at both time-points was unfeasible. Approximately 64% of children at T1 also had data at T2.

In the interest of parsimony, any covariate that was not statistically significant for all outcome variables at the time-point was removed from the analyses. Conversely, to allow a consistent comparison, if a covariate was statistically significant in at least one model, it was kept in other models for that time-point. This inclusion was checked to ensure it did not materially affect the outcome. Statistical significance for both hypotheses was measured by a p value of less than 0.05 (two tailed) and all analysis was performed using Stata 17.0 (StataCorp., 2021). Effect sizes were calculated in the Centre for Evaluation and Monitoring effect size calculator (Centre for Evaluation & Monitoring & Coe, 2000).

Effect size was estimated in terms of standardised mean differences divided by the shared standard deviation (Faraone, 2008). Effect sizes conformed to Cohen’s guidelines (small ($d = 0.2$), medium ($d = 0.5$), and large ($d \geq 0.8$) (Cohen, 2013; Sullivan & Feinn, 2012)

6.3 Results

The numbers of participants overall, and by gestational group, for each of the outcomes at each time-point is shown in Table 6.3. The mean scores and standard deviations for each gestational group against the CKAT graphomotor variables of tracking, aiming and tracing at the two time-points are shown in Table 6-4. Figure 6-8 shows the predicted means for the three outcome variables, adjusted for covariates, for each gestational groups at each time-points.

Table 6-3

Numbers of Participants Overall and by Gestational Group for each Outcome at T1 and T2

	Overall *n* =	Full Term *n* =	Early Term *n* =	LPT *n* =	VMPT *n* =
T1 (Age 4 to 5 years)					
Tracking	2411	1763	553	77	18
Aiming	1825	1326	433	51	15
Tracing	2393	1760	541	75	17
T2 (Age 7 to 10 years)					
Tracking	5714	4143	1294	209	68
Aiming	5031	3643	1144	187	57
Tracing	5705	4139	1292	206	68

Table 6-4

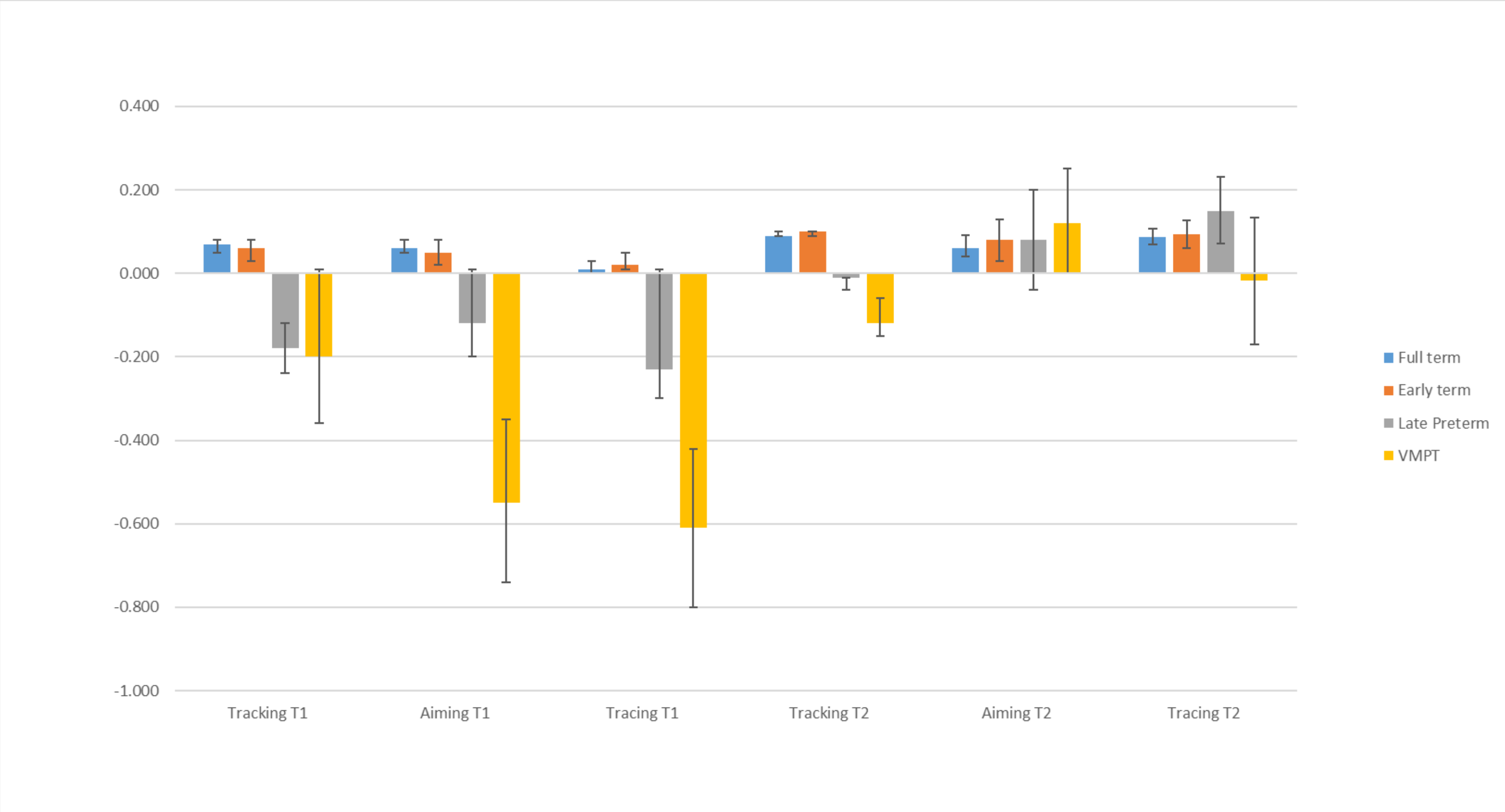
Mean Scores, for Tracking, Aiming and Tracing Variables at both Time-Points

	Full Term			Early Term			LPT			VMPT		
Variable	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL	M	SE	95% CI LL, UL
T1 (AGED 4 TO 5 YEARS)												
Tracking[1]	0.07	0.02	0.03, 0.11	0.06	0.04	-0.02, 0.13	-0.18	0.12	-0.41, 0.05	-0.20	0.21	-0.64, 0.24
Aiming[2]	0.06	0.02	0.02, 0.11	0.05	0.04	-0.03, 0.14	-0.12	0.13	-0.39, 0.15	-0.55	0.30	-1.20, 0.11
Tracing[3]	0.10	0.01	0.07, 0.12	0.05	0.03	-0.01, 0.10	0.16	0.06	0.04, 0.27	-0.30	0.17	-0.66, 0.06
T2 (AGED 7 TO 10 YEARS)												
Tracking[4]	0.10	0.01	0.07, 0.12	0.10	0.02	0.06, 0.14	0.01	0.05	-0.09, 0.11	-0.07	0.10	-0.09, 0.11
Aiming[9]	0.07	0.01	0.04, 0.09	0.09	0.06	0.04, 0.13	0.09	0.06	-0.03, 0.21	0.04	0.12	-0.20, 0.28
Tracing[10]	0.09	0.01	0.07, 0.11	0.09	0.02	0.07, 0.11	0.15	0.04	0.07, 0.22	-0.02	0.08	-0.17, 0.14

Note. M = mean, SE = standard error, 95% CI = 95% Confidence Interval, LL = Lower Limit, UL = Upper Limit.

Figure 6-8

Mean Scores for Tracking, Aiming and Tracing Graphomotor Skills, Adjusted for Covariates, at T1 and T2



Note. Mean scores at T1 were adjusted for the following covariates: age in months at time of testing, sex, ethnicity, maternal education, mother's age at child's birth, parity, IMD and handedness. Error bars show 95% confidence intervals. Mean scores at T2 were adjusted for the following covariates: age in months at time of testing, sex, ethnicity, maternal education, mother's age at child's birth, parity and handedness. (IMD not included as it was not a statistically significant predictor at this age group). Error bars show 95% confidence intervals. Abbreviations: LPT = Late Preterm; VMPT = Very and Moderately Preterm.

6.3.1.1 Regression Results by Outcome

6.3.1.1.1 Tracking at T1

At T1 (aged 4 to 5 years), the results of the baseline model, shown in Table 6-5, with the gestational groups as the only predictor, indicated that LPT birth (p = .019), but not early term (p = .780) nor VMPT birth (p = .209), was associated with worse levels of tracking skills. When adjusted for covariates, LPT birth (p = .029) continued to predict the tracking score, but again early term (p = .424) and VMPT (p = .241) were not significant predictors. The effect size of LPT birth, measured by Cohen's d was d = -.26, 95% CI [-0.49, -0.03] indicating a small effect (Cohen, 2013).

In the covariates, age, measured in months was a statistically significant predictor of the tracking outcome (p < .001) with children older in the school year achieving a higher score. Whilst male sex (p = .001) or being of Pakistani heritage (p < .001) were associated with a lower score. The child's mother's highest level education being five GCSEs (p = .006), or less (p = .001) were also associated with a poorer score.

6.3.1.1.2 Tracking at T2

At T2 (aged 7 to 10 years), in the baseline model none of the gestational predictors were statistically significant, as shown in Table 6-6 (early term: p = .830; LPT: p = .106; VMPT: p = .078). However, in the adjusted model, LPT (p = .046) and VMPT birth (p = .042) were both statistically significant, but not early term (p = .653), as shown in Table 6-6.

The effect size for the LPT gestational group, measured by Cohen's d was d = - 0.14, 95% CI [-028, 0.00] indicating a very small effect (Cohen, 2013). For the VMPT gestational group, the Cohen's d was d = - 0.25, 95% CI [-0.49, -0.01], also indicating a small effect (Cohen, 2013). This statistically significant result in the model adjusted for covariates, was principally due to the addition of age in months and ethnicity covariates for LPT birth, which when added resulted in both LPT and VMPT birth being statistically significant predictors (LPT: B = -.10, p = .049 and VMPT: B = -.18, p = .041, once ethnicity and age were added to the model). VMPT birth was statistically significant once age in months was included in the modelling (LPT: B = -.09, p = .086 and VMPT: B = -.18, p = .046, once age in months was added to the model).

Additionally, in the covariates, increased age in months was a statistically significant predictor of a better score (*p* < .001), as it was for all outcomes. Whereas Pakistani ethnicity (*p* < .001); left handedness (*p* = .006); and mother's highest educational qualification being 5 GCSEs (*p* = .001), or less (*p* < .001) predicted poorer scores. Child's biological sex was not significant in this model (*p* = .585).

6.3.1.1.3 Aiming at T1

In the aiming task at T1, in the baseline model being born VMPT was negatively associated with the aiming score (*p* = .009). The results for children born early term (*p* = .848) or LPT (*p* = .151) were not statistically significant, as shown in Table 6-7. In the adjusted model, also shown in Table 6-7, VMPT (*p* = .006), but not LPT (*p* = .135) nor early term birth (*p* = .627), were statistically significant predictors of the aiming score at T1. The effect size of VMPT birth on the aiming score, measured by Cohen's d was *d* = -.71, 95% CI [-1.22, -0.21], indicating a medium effect (Cohen, 2013).

In the covariates, age in months was a statistically significant predictor with increased age resulting in a better score (*p* < .001). Male sex (*p* < .001); Pakistani ethnicity (*p* = .001); left handedness (*p* = .009); mother's highest level of education being either 5 GCSEs (*p* = .003) or less (*p* = .001); and living in an area categorised as IMD 1 (the lowest level) (*p* = .027) were associated with a poorer score.

6.3.1.1.4 Aiming at T2

The baseline model for aiming at T2, shown in Table 6-8, found that none of the gestational groups were predictive of the aiming score at T2 (early term: *p* = .408; LPT: *p* = .699; VMPT: *p* = .811). In the adjusted model, the gestational groups continued to not be statistically significant predictors (early term: *p* = .326; LPT: *p* = .997; VMPT: *p* = .336).

In the covariates, increased age in months was predictive of a better score (*p* < .001). Whilst Pakistani ethnicity (*p* = .001) and left handedness (*p* = .005) predicted a poorer score, as did mother's highest qualification being A Levels (*p* = .031), 5 GCSEs (*p* < .001) or less than 5 GCSEs (*p* < .001) when compared to the mother having received higher education. Male sex was not statistically significant in the model (*p* = .935), unlike at T1.

Table 6-5

Linear Regression Table for Tracking at T1: Predicted by Gestational Group, Age in Months, Sex of Child, Maternal Education, Ethnicity and IMD

Variable	Tracking at T1 (age 4 to 5 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.07	0.02	-0.03, - 0.11		**.002**
Early Term[1]	-0.01	0.04	-0.10, -0.08	-.01	.780
LPT[1]	-0.25	0.10	-0.45, -0.04	-.05	**.019**
VMPT[1]	-0.27	0.21	-0.68, 0.15	-03	.209
Model 2: Model Adjusted for Covariates					
Intercept	-3.06	0.24	-3.53, -2.59		**< .001**
Early Term[1]	-0.03	0.04	-0.12, -0.05	-.02	.424
LPT[1]	-0.22	0.10	-0.41, -0.02	-.04	**.029**
VMPT[1]	-0.24	0.20	-0.64, 0.16	-.02	.241
Age in Months at testing	0.06	0.00	0.05, 0.07	.28	**< .001**
Male[2]	-0.12	0.03	-0.18, -0.05	-.07	**.001**
Pakistani Ethnicity[3]	-0.18	0.04	-0.26, -0.10	-.10	**< .001**
Other Ethnicity[3]	-0.08	0.06	-0.20, 0.03	-.03	.152
Maternal Education: A Levels[4]	-0.08	0.06	-0.21, 0.04	-.03	.175
Maternal Education: 5 GCSEs[4]	-0.14	0.05	-0.23, -0.04	-.07	**.006**
Maternal Education: < 5 GCSEs[4]	-0.17	0.05	-0.28, -0.07	-.08	**.001**
Maternal Education: Other[4]	0.01	0.07	-0.14, 0.15	.00	.936
IMD Category 1[5]	-0.05	0.04	-0.12, 0.02	-.03	.177
Left Handedness[6]	-0.03	0.05	-0.14, 0.07	-.01	.549

Note. n = 2,411. Baseline Model: R^2 = .00, F (3, 2407.00) = 2.33, p = .073. Adjusted Model: R2 = 0.10, F (13, 2394.90) = 20.87, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10; [6]Right handedness. The following variables were not statistically significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time One; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 6-6

Linear Regression Table for Tracking at T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity, Sex and Handedness

Variable	Tracking at T2 (aged 7 to 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.10	0.01	0.07, 0.12		**< .001**
Early Term[1]	0.01	0.02	-0.04, 0.05	.00	.830
LPT[1]	-0.09	0.05	-0.19, 0.02	-.02	.106
VMPT[1]	-0.16	0.09	-0.34, 0.02	-.02	.078
Model 2: Model Adjusted for Covariates					
Intercept	-1.24	0.13	-1.45, -0.98		**< .001**
Early Term[1]	0.01	0.02	-0.04, 0.06	.01	.653
LPT[1]	-0.10	0.05	-0.21, -0.00	-.03	**.046**
VMPT[1]	-0.18	0.09	-0.36, -0.01	-.03	**.042**
Age in Months at testing	0.01	0.00	0.01, 0.012	.15	**< .001**
Male[2]	-0.01	0.02	-0.05, 0.03	-.01	.585
Pakistani Ethnicity[3]	-0.09	0.02	-0.13, -0.04	-.06	**< .001**
Other Ethnicity[3]	0.07	0.03	0.01, 0.14	.03	**.023**
Maternal Education: A Levels[4]	-0.06	0.04	-0.13, 0.01	-.28	.107
Maternal Education: 5 GCSEs[4]	-0.10	0.03	-0.16, -0.04	-.06	**.001**
Maternal Education: < 5 GCSEs[4]	-0.13	0.03	-0.19, -0.07	-.07	**< .001**
Maternal Education: Other[4]	-0.04	0.05	-0.13, -0.05	-.01	.343
Left handedness[5]	-0.09	0.03	-0.15, -0.02	-.04	**.006**

Note. n = 5714. Baseline Model: $R^2 = 0.00$, $F(3, 5710) = 1.94$, $p = .121$. Adjusted Model: $R^2 = 0.04$, $F(12, 5250.40) = 17.91$, $p < .001$. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not statistically significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 = Time Two; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table 6-7

Linear Regression Table for Aiming at T1: Predicted by Gestational Group, Age in Months, Sex of Child, Maternal Education, Ethnicity and IMD Area of Residence

Variable	Aiming at T1 (aged 4 to 5 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.06	0.02	0.02, 0.11		**.010**
Early Term[1]	-0.01	0.05	-0.11, 0.09	-.01	.848
LPT[1]	-0.18	0.13	-0.43, 0.07	-.04	.151
VMPT[1]	-0.61	0.23	-1.06, -0.15	-.06	**.009**
Model 2: Model Adjusted for Covariates					
Intercept	-3.05	0.27	-3.57, -2.52		**< .001**
Early Term[1]	-0.02	0.05	-0.11, 0.07	-.11	.627
LPT[1]	-0.18	0.12	-0.41, 0.06	-.03	.135
VMPT[1]	-0.59	0.22	-1.02, -0.17	-.06	**.006**
Age in Months at testing	0.06	0.00	0.05, 0.07	.29	**< .001**
Male[2]	-0.31	0.04	-0.39, -0.24	-.18	**< .001**
Pakistani Ethnicity[3]	-0.14	0.05	-0.23, -0.06	-.08	**.001**
Other Ethnicity[3]	0.07	0.07	-0.06, 0.20	.03	.289
Maternal Education: A Levels[4]	-0.06	0.07	-0.20, 0.08	-.02	.403
Maternal Education: 5 GCSEs[4]	-0.16	0.05	-0.26, -0.05	-.09	**.003**
Maternal Education: 5 GCSEs[4]	-0.20	0.06	-0.32, -0.09	-.10	**.001**
Maternal Education: Other[4]	-0.12	0.08	-0.28, 0.05	-.04	.166
IMD Category 1[5]	-0.09	0.04	-0.17, -0.01	-.05	**.027**
Left Handedness[6]	-0.16	-0.06	-0.29, -0.04	-.06	**.009**

Note. *n* = 1,825. Baseline Model: $R^2 = 0.01$, $F\ (3, 1821) = 2.94$, $p = .032$. Adjusted Model $R^2 = 0.15$, $F\ (13, 1809.00) = 23.57$, $p < .001$. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10; [6]Right handedness. The following variables were not statistically significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time One; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 6-8

Linear Regression Table for Aiming in T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity and Handedness

Variable	Aiming at T2 (aged 7 to 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.06	0.01	0.04, 0.09		**< .001**
Early Term[1]	0.02	0.03	-0.03, 0.08	.01	.408
LPT[1]	-0.02	0.06	-0.10, 0.02	.01	.699
VMPT[1]	-0.03	0.11	-0.24, 0.19	.00	.811
Model 2: Model Adjusted for Covariates					
Intercept	-2.50	0.15	-2.79, -2.21		**< .001**
Early Term[1]	0.03	0.03	-0.03, 0.08	.01	.326
LPT[1]	0.00	0.06	-0.12, 0.12	00	.997
VMPT[1]	-0.10	0.11	-0.31, 0.10	-.01	.336
Age in Months at testing	0.03	0.00	0.02, 0.03	.26	**< .001**
Male[2]	0.00	0.02	-0.04, 0.05	.00	.935
Pakistani Ethnicity [3]	-0.08	0.03	-0.14, -0.03	-.05	**.001**
Other Ethnicity [3]	0.10	0.04	0.03, 0.17	.04	**.008**
Maternal Education: A Levels[4]	-0.09	0.04	-0.17, -0.01	-.04	**.031**
Maternal Education:5 GCSEs[4]	-0.12	(0.04)	-0.19, -0.05	-.07	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.16	(0.04)	-0.23, -0.09	-.08	**< .001**
Maternal Education: Other[4]	-0.06	(0.05)	-0.16, 0.04	-.02	.230
Left Handedness[5]	-0.10	(0.04)	-0.17, -0.03	-.04	**.005**

Note. n = 5031. Baseline Model: R^2 = 0.00, (F (3, 5025.00) = 0.29, p = .835. Adjusted Model: R^2 = 0.08, F (12, 4568.40) = 35.81, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not statistically significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 = Time Two; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

6.3.1.1.5 Tracing at T1

The baseline model for tracing at T1, shown in Table 6-9, found that birth at VMPT gestation (p = .005), but not early term (p = .083) or LPT birth (p = .379), was a statistically significant predictor of a worse tracing score. The model adjusted for inclusion of the covariates similarly found that being born at VMPT gestation (p = .004) was a statistically significant predictor of tracing at T1, unlike early term (p = .083) and LPT birth (p = .417). The effect size of VMPT birth on the tracing outcome at T1, measured by Cohen's d was d = - 0.69, *95*% CI [-1.16, -0.21], indicating a medium effect (Cohen, 2013).

In the covariates, in common with all the outcomes, age in months (p < .001) predicted a higher score. Whilst male sex (p < .001) and Pakistani ethnicity (p < .001) predicted lower scores. Whereas only mother's highest level of education being 5 GCSEs or equivalent predicted of a poorer score (p = .008), out of the maternal educational categories.

6.3.1.1.6 Tracing at T2

As shown in Table 6-10, in the baseline model for tracing at T2, none of the gestational groups were predictive of the tracing score (early term: p = .726; LPT p = .152; VMPT: p = .163). This pattern was replicated in the model adjusted for the inclusion of control variables with none of the gestational groups were predictive of the tracing score in the adjusted model at T2 (early term p = .332, LPT p = .171 and VMPT p = .094).

In the adjusted model, age in months was predictive of a better score (p < .001). Whilst Pakistani ethnicity (p < .001), maternal education level being less than 5 GCSEs (p = .009), male sex (p < .001) and left handedness (p = .044) were all also predictive of a poorer score.

Table 6-9

Linear Regression Table for Tracing at T1: Predicted by Gestational Group, Age in Months, Sex of Child, Maternal Education, Ethnicity and IMD

Variable	Tracing at T1 (aged 4 to 5 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.10	0.01	0.07, 0.13		**< .001**
Early Term[1]	-0.05	0.03	-0.11, 0.01	-.04	.083
LPT[1]	0.06	0.07	-0.08, 0.20	.02	.379
VMPT[1]	-0.40	0.14	-0.68, -0.12	-.06	**.005**
Model 2: Model Adjusted for Covariates					
Intercept	-0.50	0.16	-0.82, -0.18		**.002**
Early Term[1]	-0.05	0.03	-0.10, 0.01	-.04	.083
LPT[1]	0.05	0.07	-0.08, 0.19	.02	.417
VMPT[1]	-0.40	0.14	-0.68, -0.13	-.06	**.004**
Age in Months at testing	0.01	0.00	0.01, 0.02	.11	**< .001**
Male[2]	-0.14	0.02	-0.19, -0.09	-.12	**< .001**
Pakistani Ethnicity[3]	-0.21	0.03	-0.26, -0.16	-.18	**< .001**
Other Ethnicity[3]	-0.03	0.04	-0.11, 0.05	-.02	.466
Maternal Education: A Levels[4]	-0.04	0.04	-0.12, 0.04	-.02	.365
Maternal Education: 5 GCSEs[4]	-0.09	0.03	-0.15, -0.02	-.07	**.008**
Maternal Education < 5 GCSEs[4]	-0.05	0.04	-0.11, 0.02	-.03	.194
Maternal Education: Other[4]	0.01	0.05	-0.08, 0.11	.01	.772
IMD Category 1[5]	-0.03	0.02	-0.07, 0.02	-.02	.296
Left Handed[6]	-0.03	0.04	-0.11, 0.04	-.18	.354

Note: n = 2,393. Baseline Model: R^2 = 0.01, F (3, 2389.00) = 3.86, p = .004. Adjusted Model: R^2 = .07, F (13, 2377.00) = 12.97, p < 0.001. [a] The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10,[6]Right handedness. The following variables were not statistically significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time One; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

Table 6-10

Linear Regression Table for Tracing at T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity, and Handedness

Variable	Tracing at T2 (aged 7 – 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.09	0.01	0.07, 0.11		**< .001**
Early Term[1]	0.01	0.02	-0.03, 0.05	.01	.726
LPT[1]	0.06	0.04	-0.02, 0.15	.02	.152
VMPT[1]	-0.11	0.08	-0.25, 0.04	-.02	.163
Model 2: Model Adjusted for Covariates					
Intercept	-0.58	0.11	-0.79, -0.37		**< .001**
Early Term[1]	0.02	0.02	-0.02, 0.06	.01	.332
LPT[1]	0.06	0.04	-0.03, 0.14	02	.171
VMPT[1]	-0.12	0.07	-0.27, 0.02	-.02	.094
Age in Months at testing	0.01	0.00	0.01, 0.01	.10	**< .001**
Male[2]	-0.16	0.02	-0.19, -0.13	-.14	**< .001**
Pakistani Ethnicity[3]	-0.09	0.02	-0.12, -0.05	-.07	**< .001**
Other Ethnicity[3]	-0.01	0.03	-0.06, 0.05	.00	.783
Maternal Education: A Levels[4]	-0.03	0.03	-0.09, 0.03	-.02	.352
Maternal Education: 5 GCSEs[4]	-0.03	0.02	-0.08, 0.02	-.02	.214
Maternal Education: < 5 GCSEs[4]	-0.07	0.03	-0.12, -0.02	-.05	**.009**
Maternal Education Other[4]	0.03	0.04	-0.04, 0.11	.01	.423
Left Handedness[5]	0.05	0.03	0.00, 0.10	-.03	**.044**

Note. n = 5705. Baseline Model: R^2 = 0.00, F (3, 5701.00) = 1.40, p = .241. Adjusted Model: R^2 = .04, F (12, 5115.70) = 17.22, p < 0.001. [a] The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not statistically significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 = Time Two; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; IMD = Index of Multiple Deprivation of which category 1 is the most deprived areas and category 10 the least deprived.

6.4 Discussion

The study aimed to investigate the association of LPT and VMPT gestation group on three graphomotor outcomes: tracking, aiming, and tracing in children aged 4 to 5 years and 7 to 10 years. It is the first study to examine graphomotor outcomes measured kinematically in premature children after the age of 5 years. The study found a deficit in tracking for children born LPT at both T1 and T2, when compared to full term births. It also found wider deficits for children born VMPT, when compared to children born at full gestation, with statistically significant differences seen in aiming and tracing at T1 and in tracking at T2.Therefore, the study indicated different effects by age for the children born VMPT. Furthermore, children born at early term gestation performed at comparable levels to those born at full term. The next section reviews the findings in detail against the two research questions.

The first research question asked whether children born LPT or VMPT have worsened levels of tracking, aiming, and tracing skills compared to children born at full term. Children born LPT were found to have worse levels of tracking skills at T1, but this was only present in the covariate adjusted model by T2 (once both age and ethnicity had been added to the model). Children born LPT did not have poorer levels of aiming or tracing skills at any time-point. However, the study found that children born VMPT had a wider impact on their graphomotor skills, with worse aiming and tracing at T1 and worse tracking skills at T2, once the covariates were added. This pattern of results was also similar in the complete case analysis, completed for comparison, contained in Appendix N (Tables N-1 to N-6).

The second research question was are there different effects at the two time-points for the LPT and VMPT gestational group and if so, is the difference greater at T1. The results for children born LPT for tracking was statistically significant at T1 in both the baseline and adjusted model. Whilst at T2, the results were not statistically significant in the baseline model but were statistically significant once covariates were controlled. The results for the children born LPT reached statistical significance at T2 when age and ethnicity were included in the modelling. The results for aiming and tracing were not statistically significant at either time-point for the LPT. Therefore, results varied by age and suggested less effect at T2 for children born LPT.

In respect of children born at VMPT gestation, the children showed poorer aiming and tracing at T1, but not at T2. Thus, the results displayed a greater difference at T1 than T2 for these two graphomotor outcomes. However, the tracking result for children born VMPT was statistically significant at T2 in the model adjusted for covariates, becoming statistically significant when age in months was included in the model. The tracking result for VMPT gestation was not statistically significant at T1. Therefore, the results for this gestational group did suggest some time related changes.

The results suggest a wider impact on the VMPT gestational group at T1, whereas the impact on children born LPT was present at both time-points but only within the tracking variable. The results for each gestational group by outcome are discussed in more detail below.

6.4.1 Tracking in Children born at LPT Gestation Compared to Previous Studies

The tracking outcome was statistically significant at T1 (in both the baseline and covariate adjusted model) and T2 (in the model adjusted for covariates only) for children born LPT. The results of the tracking deficit for children born LPT seen at both time-points is supported by Ibrahimi et al. (2023) who found poorer general graphomotor skills in children born LPT between the ages of 5 to 12 years. The current study suggests that these graphomotor difficulties may be related to the child's tracking skills.

The current study differs from Brumbaugh et al. (2016) who did not find an adverse effect for children born LPT aged 6 to 13 years. However, it is notable that the current study was not statistically significant before the addition of the covariates at T2, with the addition of age in months for VMPT birth, and ethnicity and age in months for LPT birth rendering the result statistically significant. Whereas, in their study of the effect of LPT gestation, Brumbaugh et al. (2016) controlled for age and sex, but crucially *not* ethnicity which may potentially explain the differing result. Additionally, Brumbaugh et al. (2016) used a sample of slightly older children (LPT: M = 8.87 years) than the current study (LPT: M = 7.86 years) which may also partially explain the differing result. The current study had a larger sample of LPT births than either Ibrahimi et al. (2023), or Brumbaugh et al. (2016) and therefore increased likelihood of being able to detect a small effect (Hackshaw, 2008).

6.4.2 Tracking in Children born at VMPT Gestation Compared to Previous Studies

The tracking outcome was not statistically significant at T1 but was at T2 once covariates were added for children born VMPT. The finding that tracking skills were not significantly worse for children born VMPT at T1 was somewhat surprising, especially given the effect seen in other studies (Caravale et al., 2012; Dathe et al., 2020; van Veen et al., 2019) measuring graphomotor skills in product-oriented assessment at similar ages (aged 5 years or below) in children born VMPT. However, the coefficients for tracking in respect of children born VMPT displayed wide confidence intervals, suggesting that the result may be somewhat less reliable and reflecting the small group size for children born VMPT at T1. It is also notable that the adjusted mean scores at age 4 to 5 years, shown in Figure 6-8, were suggestive of a gestational gradient, with full term children scoring the best and children born VMPT scoring the worst adjusted mean score.

At T2, being born VMPT was associated with a poorer score in the adjusted model only. The addition of age in months was sufficient to result in statistically significant worse scoring. There is a gestational gradient for tracking at T2 in preterm groups when compared to term groups with full term and early term scoring the best scores, and children born VMPT scoring the worst score. This poorer result for children born VMPT accords with the results of product-oriented studies examining similar skills, such as copying shapes between the ages of 7 and 10 years (J. Atkinson & Braddick, 2007; Bolk et al., 2018; Feder et al., 2007; Miranda-Herrero et al., 2021; Roze et al., 2021). A comparable study had not been completed in kinematic assessment, and the current study helps fills this gap and suggests a detrimental effect in graphomotor tracking.

6.4.3 Aiming in Children born at LPT Gestation Compared to Previous Studies

The results for the aiming outcome were not statistically significant at T1 or T2 for children born LPT. The finding of no effect on the LPT-born children is supported by Rönnqvist and Domellöf (2006) in children born LPT reaching skill at 36 months, although differences had been seen before this age. However, their study was very small: considering only four children born LPT. Such reaching action is posited to be a precursor to graphomotor aiming tasks (Sagnol et al., 2007). The lack of effect is also suggested by Johansson et al. (2014) who found no adverse effect for children born moderately preterm in a threading FMS task but also within a small sample (n = 35). The current study similarly finds no evidence of an adverse effect from LPT birth on aiming skills in graphomotor context. It does so within a larger sample than these previous FMS studies but finds similar results.

6.4.4 Aiming in Children born at VMPT Gestation Compared to Previous Studies

The finding of an aiming deficit in children born VMPT at T1 is consistent with studies investigating the reaching action in children born VMPT before the age of 5 years (Araújo Rohr et al., 2021; Fallang, Saugstad, Grøgaard, et al., 2003; Grönqvist et al., 2011; Kaul et al., 2019; Roze et al., 2021), as well as the graphomotor aiming study by Sagnol et al. (2007). There was a medium effect size seen from VMPT gestation the aiming outcome at T1. However, the group size for children born VMPT for the aiming outcome in the current study at T1 was small and therefore caution should be used in drawing firm conclusions from this finding.

No adverse effect from VMPT birth was observed at the ages of 7 to 10 years at T2 for aiming skills. Whilst a similar study by Van Braeckel et al. (2008) in same age group found several elements of aiming statistically significant, such as reaction time and acceleration time, other elements were not significant such as pointing error and deceleration time. Their study did not report an overall aiming score as the current study does, which may account for the differing finding. The current study benefited from CFA and PCA analysis to establish the weighting z-scores that represented the most appropriate overall structure of the data.

Furthermore, the changes seen from an adverse effect observed at T1 to no significant effect by T2 is supported by Domellöf et al. (2018) who found a similar effect in children born below 35 weeks' gestation in a FMS task kinematically assessed at age 4 years and 8 years old.

6.4.5 Tracing in Children born at LPT Gestation Compared to Previous Studies

In the tracing outcome, there was no statistically significant effect at either time-point for children born LPT. Given the findings of Ibrahimi et al. (2023) it was somewhat surprising that no adverse effect was found for the LPT gestational group. Ibrahimi and colleagues used a copying graphomotor task which uses similar skills, with a small sample of children born LPT all born by Cesarean Section. They did not however, break down this task into different graphomotor skills as the current study does. The tracking task (where statistically significant results was seen in the current study) may be more similar to a copying based product-oriented assessment than the tracing task but this potential correlation needs to be verified in further research.

6.4.6 Tracing in Children born at VMPT Gestation Compared to Previous Studies

The current study found an adverse effect of VMPT birth in tracing at T1 only. Whilst a previous study using the same outcomes to the current one has not previously conducted, an adverse effect from VMPT birth is suggested by van Veen et al. (2019) and Caravale et al. (2012) in product-oriented copying based assessments in children aged 4 to 5 years, the same age as T1 in the current study.

However, the current study did not find a difference in children born VMPT by T2. Similar assessments using product assessments have generally found an adverse effect at 7 to 12 years in a copying-based product assessment task (Constable et al., 2008; Cooke, 2003; Fletcher et al., 1997). The difference in findings may be due to differences in whether the task is product-oriented or process-oriented (as used in the current study) or due to the differing nature of the task (e.g. tracing or copying). It would be useful to complete a similar study using both a product-oriented assessment and the process-oriented CKAT assessment with children born VMPT to investigate if differences are seen.

Additionally, the current study merged children born moderately preterm (32 to 33 weeks' gestation) and those born very preterm (less than 32 weeks' gestation) and the better results likely for children born moderately preterm may account for the different results when compared studies containing solely children born very preterm.

6.4.7 Implications of the Findings

The current study therefore found a small but persistent effect on tracking skills for children born LPT, which may contribute to the poorer educational achievement and educational scores seen in this thesis (Chapters 3 and 4). Giles et al. (2018) found tracking skills were associated with reading, writing and mathematics achievement, with reading being particularly affected. Therefore, the small effect observed may well be having some detrimental effect on the academic achievement. Whereas a wider adverse effect was observed for children born VMPT at T1 which is likely to also negatively affect their educational achievement.

Academic achievement at the start of school has been found to predict attainment later in education (A. L. Atkinson et al., 2022). The current study found both children born LPT and VMPT had poorer graphomotor outcomes at the start of school (T1). Therefore, such children having worse skills at age 4 to 5 years may still have an adverse effect on their learning even when their graphomotor skills have improved. However, more studies are needed to verify the effects observed, ideally examining the mediation effect of graphomotor skills on academic achievement for children born preterm.

6.4.8 Potential Explanations for the Findings in Graphomotor Outcomes

The study found an adverse effect from being born LPT for tracking at both time-points in the models adjusted for covariates. Children born VMPT had poorer outcomes than children born at full term on all three outcomes at differing time-points. There are a number of potential explanations why the children born preterm, and most particularly those born VMPT, may struggle with graphomotor skills, relative to children born at full term.

The "Preterm Infant Vulnerability to Neuro-morbidity Model" by Purdy et al. (2008) (discussed in Section 1.7) suggests a complex interplay of "resource availability" (e.g. healthcare, parental education, and other social resources) "health status" (maturity at birth, environmental exposure) and "relative risk" (neurobiological stress, steroid exposure and severity of illness at birth) on outcomes following preterm birth. In this model, children born very preterm are more exposed to both relative risk, e.g. they are more likely to have been prescribed steroids due to respiratory distress syndrome at birth (Kamath-Rayne et al., 2016), and risk from health status (as they are less mature at birth) than children born LPT. Children born VMPT are also more likely to have white matter injury than either children born LPT or term (Ou et al., 2017). Such white matter injury has been linked with poorer motor skills outcomes (Spittle et al., 2011). However, children born LPT are also at increased risk of vulnerability relative to term-births.

Furthermore, Sagnol et al. (2007) posit that children born VMPT may have early difficulties processing sensory information which leads to issues in visual motor coordination and graphomotor skills. Children born VMPT are also more likely to be diagnosed with visual problems, especially retinopathy of prematurity (Hellgren et al., 2016). This has been shown to significantly affect graphomotor skills at age 5 years (Zimmermann et al., 2023). Whilst these problems are more frequent in VMPT births, there is also a small increased incidence of visual problems in children born at moderately/LPT gestation (Pettinger et al., 2023).

A potential explanation for the differing effects seen in the current study at the two time-points in children born VMPT for aiming, and tracing is improvements in postural stability. Shumway-Cook and Woolcott (1985) suggest inputs required for postural control mature from age 4 to 6 years to 7 to 10 years old. Flatters, Mushtaq, et al. (2014) found postural stability and the tracking and tracing, but not the aiming, outcomes examined in this chapter were correlated. Additionally, children born very preterm have been shown to have poorer posture than children born at term, at least until the age of 6 years (Tuñón-Domínguez et al., 2022). However, whilst this provides a potential explanation it is somewhat speculative when applied to the current study: the children born VMPT also had lower scores for aiming which was not correlated with postural stability in the Flatter's study (Flatters, Mushtaq, et al., 2014). The VMPT group sizes in the current study at the T1 were also very small, meaning the sample size is also too low to draw definitive inferences (Hackshaw, 2008).

6.4.9 Underlying Factors Influencing the Deficit Seen in the Tracking Task in Children Born LPT

Children born LPT were found to have worse tracking skills at age 4 to 5 years in the unadjusted and adjusted models, and age 7 to 10 years in the adjusted model. There were 18 trials in tracking where children were required to track the stylus. Whereas the aiming required 75 rapid aiming movements and there were only two trials for tracing. Therefore, there was perhaps a greater attentional demand from the tracking task than the other two tasks. This is of interest as studies have suggested that children born LPT may have worse attention skills than children born at full term. This includes orienting attention (difficulty shifting attention to a new stimuli) and behavioural attention (Bogičević et al., 2020) at the ages in the current study. Children born LPT are also at increased risk of being diagnosed with attention deficit disorder (Crump et al., 2023; Pettinger et al., 2023). Thus the higher attentional demands from the tracking task may underlie the relatively poorer (when compared to children born full term) score from the children born LPT.

Attentional skills have also been found to associate with academic achievement, including in writing (Kent et al., 2014), maths and reading (Gallen et al., 2023). There is also arguably some overlap with the skills of letter formation and the tracking task. It is notable that children born LPT were at increased odds of not reaching expected levels of academic achievement in writing at three of the four academic assessments considered in chapter three. Interestingly, Visser (2003) points to a potential explanation using the dual-task paradigm, where worse performance in seen in a secondary task (e.g. writing composition) due to a lack of automatization of the primary task (potentially graphomotor letter formation skills). This is referred to as the "automazation deficit".

6.4.10 Strengths and Limitations of the Study

The current study makes a substantial contribution to the sparse evidence on the predictiveness of gestational group on graphomotor outcomes measured kinematically. There has only one previous kinematically measured graphomotor study in children born VMPT and this only considered children to age 5 years. Furthermore, there have been no kinematically measured graphomotor studies of children born at LPT gestation. The current study had relatively good sample size in the LPT group for a study of this nature as kinematic studies have tended to have small samples (Barnett et al., 2020).

The study utilised data from the BiB cohort, which draws on participants from an area that experience higher than UK average SES deprivation and also a higher number of children from ethnic minorities than typical for a large UK city. This diversity provides a strength of the study in showing that preterm birth is still a statistically significant factor in graphomotor skills even when influences such as ethnicity, maternal education and area of residence are controlled.

It is accepted that there are somewhat low number of children born VMPT, especially at age 4 to 5 years old at T1. However, this is typical of studies in preterm birth, as this birth at VMPT preterm gestation is relatively unusual at less than 1% of births in the UK (Office for National Statistics, 2024). A further limitation of the study is that there was only one test per construct as there was only one test at each time-point for tracking, aiming and tracing. It would therefore be useful to repeat the study to establish if the same results are reached.

Additionally, in reviewing the results against previous findings, it is important to note that, due to the novelty using kinematic outcomes against gestation, there are limited comparative studies, therefore comparison is made with product-oriented assessments and reaching/pointing kinematic assessments. However, it is possible that these results yielded differing findings, reflecting their different domains and assessment methods.

6.4.11 Suggestions for Next Steps in this Area of Research

A mediation study using educational variables was not possible due to low numbers also having educational data collected after the T2 sweep took place and this would be useful in obtaining greater understanding of adverse effects.

Additionally, more studies are needed examining prematurity and graphomotor outcomes, especially longitudinal studies with good sample size, to verify the small/medium and temporal effects seen in this current study and establish the link to academic attainment.

Furthermore, it would be useful to explore the suggested link between very preterm birth, postural stability and graphomotor skills as a mediation study. There are very few studies of preterm children and postural stability after the age of 5 years (Tuñón-Domínguez et al., 2022) and greater knowledge would help identify where intervention might be useful.

6.4.12 Conclusion

In conclusion, this study makes a substantial contribution to the literature on prematurity being the first study to investigate preterm birth and graphomotor skills after the start of school using process-oriented measures. The study found birth at LPT was predictive of lower tracking skill at the outset of school, but this was only statistically significant towards to end of primary education when other covariates such as age and ethnicity were included in the model. The effect size on the tracking outcome for children born LPT was a small effect (Cohen, 2013). Whereas the effect on VMPT gestation was wider and affected all three elements of graphomotor skills, but varied with age. The results also pointed to age-related differences for children born VMPT and further kinematic studies are needed to examine their graphomotor attainment at school age and its relation both to academic attainment and postural stability. No adverse effects were found of early term birth on any graphomotor outcome.

The results in this study for children born VMPT and LPT suggest that educational professionals should be vigilant to a possible deficit in graphomotor outcomes at the outset of schooling. Such awareness is supported by training such as Premature Infants' Skills in Mathematics (University of Nottingham, 2024), which also suggests classroom based strategies to support children born prematurely with graphomotor activities.

There has not been a large randomised control trial investigating whether graphomotor skills intervention in the preterm population is effective. However, there is some evidence from studies in the general population that intervention produced improved graphomotor fluidity and accuracy, in children at the start of education (Ratzon et al., 2007) and this early graphomotor intervention would be useful to children born VMPT and LPT who are identified as having difficulties in this area.

Chapter 7 Discussion

Preterm birth has been found to adversely affect neurodevelopment into adulthood (Chung et al., 2020; Mitha et al., 2024; Moster et al., 2008; Song, 2023). However, as discussed in the preceding chapters, most of the studies making this finding have studied outcomes in children born at very preterm gestation (Martínez-Nadal & Bosch, 2020; P. E. Shah et al., 2016; Townley Flores et al., 2021). Outcomes for children born at LPT gestation are less investigated, reflecting a previously prevalent view that children born at this gestation had similar outcomes to children born at full term gestation (Adams-Chapman, 2006; W. A. Engle et al., 2007). Whilst this view is now changed, it was apparent on reviewing the pre-existing literature that there were still many areas where the effect of being born at LPT gestation was either not yet known or the findings were currently inconclusive.

This thesis fills these research gaps by providing evidence on the effect of LPT birth on children's educational, executive function and graphomotor outcomes at school age, comparing their attainment and skills with the results for children born at full term. This chapter discusses the main conclusions drawn from these empirical findings and reviews the policy implications and potential directions for future research.

7.1 Key Findings and Implications

7.1.1 Educational Achievement

The key finding from the cross-sectional studies in Chapter Three was that LPT birth was associated with increased odds of not reaching expected standards of overall educational achievement at every age examined (5, 7, and 11 years) in the unadjusted models, and to age 7 years in the models adjusted for covariates. It was also associated with a higher likelihood of not reaching expected levels in reading at age 5 and 6 years old but not thereafter; of not reaching expected levels in mathematics at every age investigated (age 5, 7 and 11 years); and of not reaching expected levels in writing at two of the three ages considered (ages 5 and 11 years). There was also increased odds of not reaching expected levels in EGPS skills which was tested at age 11 years.

Other cross-sectional studies in this area have varied between finding an adverse effect from being born at LPT gestation (Chan & Quigley, 2014; Louis et al., 2022; Quigley et al., 2012; Woythaler et al., 2015), or not (Alterman et al., 2022; Crockett et al., 2022; Morse et al., 2009). Studies which do not find an adverse effect on education achievement for children born LPT generally examine outcomes in children aged 8 years or over (Alterman et al., 2022; Chyi et al., 2008; Crockett et al., 2022). Some authors have suggested that the disparity is due to the influence of SES, with statistically significant results seen in the unadjusted models, but not in the SES covariate adjusted models (Crockett et al., 2022; P. E. Shah et al., 2016). Similar to the results in these studies (Crockett et al., 2022; P. E. Shah et al., 2016), the result for overall educational achievement in Chapter Three showed children born LPT had increased odds of not reaching expected levels at age 11 years, compared to full term births, in the unadjusted model but not once covariates were included. Whereas the study in Chapter Three found an increased odds for poorer overall educational achievement in *both* the unadjusted and adjusted models at age 5 and 7 years.

Disadvantaged SES itself is associated with preterm birth (McHale et al., 2022; Ruiz et al., 2015; K. Thomson et al., 2021). Whilst SES (controlled for by maternal education, IMD, and receipt of means tested benefit covariates) influenced both educational achievement and the underlying educational scores in the studies within this thesis, it is somewhat debatable how this transmission from SES to education occurs (S. Thomson, 2018). One view is that SES effects operate through cognitive factors that are genetically transmitted. This view is somewhat supported by empirical evidence showing that the effect of SES is small once previous achievement or IQ are controlled (Marks, 2017). However, the more prevalent view is that the effects of SES operate through home environmental factors, e.g. home literacy environment (Evans et al., 2010; Tamis-LeMonda et al., 2019; van Steensel, 2006); higher level of parental educational skills; and parental motivation towards education (Østbø & Zachrisson, 2022). To account for the confounding effect of SES, the studies in this thesis included a good range of SES factors (i.e. mother's highest education, IMD, and receipt of means tested benefits) but still often found an adverse effect of LPT birth within the BiB cohort when these were controlled. The children born LPT still had increased odds of poorer achievement in the subjects of writing and mathematics (but not reading) in the covariate adjusted models at age 11 years.

The study in the thesis also examined educational outcomes for children born early term. Meta-analysis of cognitive and academic studies in children born LPT and early term has demonstrated that there is little research on the effect of early term gestation on educational achievement (Chan et al., 2016). However, there are some findings of increased odds of children born at early term not reaching expected levels in educational achievement (Alterman et al., 2022; Hedges et al., 2021; Quigley et al., 2012). Nevertheless, the study in this thesis found no evidence of increased odds of not reaching expected levels of overall educational achievement for children born at early term gestation, when compared to full term. This was replicated in the analysis by school subject, with children born at early term gestation did not have increased adjusted odds of failing to reach expected levels in reading, writing and mathematics (other than writing at age 11 years), when compared to full term gestation.

Within the preceding studies, it is notable that the odds ratios for the early term gestation not reaching expected levels of educational achievement tend to hover close to an odds ratio of around one, even in studies that find an adverse effect (Alterman et al., 2022; Quigley et al., 2012). This is also the level of odds ratio observed in the study in this thesis (however the result was not statistically significant). Thus, the effect on educational achievement appears to be very small, verging on negligible, even for the studies finding a statistically significant effect for the early term gestational group.

As expected from other studies (Aarnoudse-Moens et al., 2011; Alenius et al., 2023; Alterman et al., 2022; Chan et al., 2016; Jansen et al., 2020; S. Johnson et al., 2009; Pritchard et al., 2009; Quigley et al., 2012), children born at VMPT gestation had increased odds of not reaching expected levels in most assessments of overall attainment (age 5 and 11 years but not age 7 years), and in assessments by individual subject. They also had generally higher odds ratios of not reaching expected levels of development than the LPT gestational group.

7.1.2 Longitudinal Analysis of Educational Scores

Chapter Four examined longitudinally the trajectory of educational scores in children born LPT between three time-points (between age 5 to 11 years; age 5 to 7 years; and age 7 and 11 years), compared to the trajectory for children born at full term. It did so to evaluate if there was an interaction between time and gestational group which would indicate that any difference in educational scores by children born LPT and children born at full term narrowed, widened or stayed consistent. The results for children born early term and VMPT were also included for comparison purposes.

Results found that there was no evidence of a differing trajectory for children born LPT or VMPT compared to children born at full term, despite some suggestions of this in findings from cross-sectional studies (Alterman et al., 2022; Crockett et al., 2022). The educational scores for the children born at LPT gestation were at a similar consistently poorer level compared to children born at full term gestation at each time, with the children born at VMPT gestation having the worst mean scores.

However, there was an interaction between early term gestation and time at T2 (when the children were aged around 7 years) to T3 (when the children were aged around 11 years). This indicated the early term gestation group had a group-level increase in scores statistically significantly greater than the change seen in the full term gestational group. This suggests that children born early term experience some catch up in their educational scores relative to those born at full term between the ages 7 and 11 years. The early term gestational group completed primary school with similar level educational scores to the children born full term, but this was not the case for the children born VMPT or LPT.

Here, as in the Chapter Three study, the study in thesis of educational scores controlled for a good range of SES covariates (IMD, Mother's education, receipt of means tested benefits). The finding of no group differences for the LPT gestational group was different to that of the one existing longitudinal study (Odd et al., 2019) examining the same construct in children born moderately/LPT. However, there are key differences between the demographics between the two cohorts. Firstly, the BiB cohort used in this thesis and the ALSPAC cohort used by Odd et al. (2019) differ in terms of ethnicity: the ALSPAC cohort is predominately of White British origin (Fraser et al., 2013) and the BiB cohort is predominately of Pakistani origin (J. Wright et al., 2013). Secondly, there are greater poverty levels in Bradford than the Avon and Somerset (The Health Foundation, 2023). Whilst SES and ethnicity were controlled for in both studies, an additional third factor is that Odd et al. (2019) study examined older curricular no longer in place for children aged 11 years in the UK.

The findings are at odds with the cross-sectional study conducted in Chapter Three, where, once the model was adjusted for covariates , the children born LPT were not at statistically significant increased odds of failing to reach expected levels of overall development at the age of 11 years. This difference is likely to be driven by the lack of increased odds of failing to reach expected levels of development in reading in children born LPT, as the writing result and mathematics result at age 11 years for children born LPT showed increased odds of not reaching expected levels of development. The assessment in reading migrates from decoding skills at below the age of 7 years to increasingly comprehension based after this age.

There are also methodological differences between the studies in chapter 3 and 4. The study in chapter 3 was cross-sectional (and therefore did not consider the same children throughout) and based on a binary outcome of whether the child failed to reach expected levels or not. Whereas the study in chapter 4 was longitudinal and considered the same children throughout their primary school years was based on continuous scores. Dichotomisation, as used in the chapter 3 study, may simplify interpretation but it is argued to lead to a loss of power in showing the underlying relationship. Additionally, it can underestimate the variation in outcome in the groups (Altman & Royston, 2006). Furthermore, as discussed in Section 4.1.4, there are considerable advantages in longitudinal studies, over cross-sectional methods, including improved recognition of the dynamic nature of development within individuals (Durrant et al., 2020; van Beek et al., 2021; improved accounting for the influence of time in examining potential underlying causal factors (Vignoles, 2021); and improved modelling of the intra-and inter-personal factors in the participants (Karmiloff-Smith, 1998). For these reasons, it is likely that the analysis in Chapter Four, the longitudinal analysis, is more robust in examining the long-term educational effects of LPT birth.

Therefore, the thesis finding of no catching up in educational scores represent a more recent examination of the trajectory of educational scores and is the first time that this has been studied longitudinally specifically in the LPT gestational group. Such longitudinal studies are argued to provide better evidence of developmental changes in children than cross-sectional studies (Durrant et al., 2020; Vignoles, 2021).

7.1.3 Executive Function

Given the findings of a persistent deficit in both overall educational achievement and underlying educational scores, potential mediating factors were examined that could be an underlying mechanism for the lower educational performance. Chapter Five investigated executive function and processing speed (both defined in Section 5.1.1) in children born LPT, VMPT and early term compared to full term born children at the ages of 7 to 10 years old.

Executive function is associated with educational achievement in the general population (Blair & Razza, 2007; Cortés Pascual et al., 2019; Espy et al., 2004; McClelland & Cameron, 2019), as is processing speed (Berg, 2008; Bull & Johnston, 1997; Formoso et al., 2018; Kail & Hall, 1994; Rindermann et al., 2011). Therefore, poorer levels of executive function in children born at preterm gestation could be related to their poorer educational achievement and underlying education scores observed in a number of studies (e.g. Chan & Quigley, 2014; Crockett et al., 2022; S. Johnson et al., 2009; Morse et al., 2009; Pettinger et al., 2020; Quigley et al., 2012) and Chapters Three and Four of this thesis.

In the study in Chapter Five, the following components of executive function were examined: VWM; CWM; VSWM and inhibition, together with processing speed. The only statistically significant finding was a small adverse effect in CWM for children born LPT, when compared to children born at full term.

Surprisingly, given previous findings (Loe et al., 2019; López Hernández et al., 2022; Reynold De Seresin et al., 2023), no effect was found in children born VMPT on any of the executive function outcomes. The numbers in VMPT gestational group were small and the study potentially did not have the power to find a small effect within this group (Button et al., 2013; Hackshaw, 2008).

G*Power (Faul et al., 2007) was used to evaluate the statistical power of the sample sizes throughout the studies in this thesis. The G*power result for the executive function data suggested that the sample size of the VMPT gestational group, relative to the full term group, was only sufficient to reliably detect a medium to large effect. Therefore, it is possible a small effect exists that was not seen in the thesis' results. Whilst this is a limitation of the study on this thesis, the VMPT gestational group have been comparatively well-examined previously in their executive function skills (Anderson, 2002; Fraello et al., 2011; Loe et al., 2019; López Hernández et al., 2022; Omizzolo et al., 2014; Reynold De Seresin et al., 2023; J. Sato et al., 2019; Wehrle et al., 2021).

There were also no statistically significant differences at all for children born early term. Here the sample size G*Power (Faul et al., 2007) calculation showed sufficient power to reliably observe a small effect. No previous studies were identified investigating executive function in children born early term and this finding therefore represents new knowledge in suggesting no effect present in the early term gestational group.

The lack of a widespread impact of children born LPT between the ages of 7 and 11 years agrees with many of the previous studies. Whilst there was no existing study specifically focussed on children born LPT in VWM, evidence from the wider moderately/LPT combined group suggests no effect (Cserjesi et al., 2012; Odd et al., 2012). Similarly, previous studies have also suggested a lack of effect for VSWM (Baron, Weiss, Litman, et al., 2014; Fitzpatrick et al., 2016).

The finding of a small deficit in CWM is of interest as this is the component of executive function most closely linked to educational achievement. CWM has been particularly closely linked to mathematics (Cragg et al., 2017; Cragg & Gilmore, 2014; Ji & Guo, 2023; Raghubar et al., 2010). This is a subject, as seen in Chapter Three and other studies, that children born prematurely frequently have difficulty (Chyi et al., 2008; Copper et al., 2023; Lipkind et al., 2012; Quigley et al., 2012; Richards, Drews-Botsch, et al., 2016).

CWM is also associated with more complex writing tasks (Berninger & Chanquoy, 2012; De Vita et al., 2021; Olive, 2012). Whilst there has been less research here, previous studies and the study in Chapter Three, have also indicated that children born LPT have poorer writing skills (Chan & Quigley, 2014; Copper et al., 2023; Lipkind et al., 2012). The study in Chapter Three found increased odds of not reaching expected levels of development for writing for the children born LPT, compared to the outcomes for children born at full term at three of the four assessments reviewed.

Therefore, it is possible that CWM may mediate the relationship between LPT birth and mathematics and writing but further studies are required to establish this. Additionally, preceding studies have suggested that this adverse effect on children born LPT may change over the course of development, with poorer CWM seen in children born LPT at age 3 to 4 years (Baron et al., 2011; Hodel et al., 2016) but not by age 23 years (Suikkanen et al., 2021). The current thesis study suggests the deficit seen at age 3 to 4 years in studies by Baron et al. (2011) and Hodel et al. (2016) is still present at ages 7 to 10 years.

7.1.4 Graphomotor Outcomes

A further area of skills highly associated with academic achievement are graphomotor skills (Carlson et al., 2013; Dinehart & Manfra, 2013; Feder & Majnemer, 2007; Grissmer et al., 2010; Hasler & Akshoomoff, 2019; Malpique et al., 2020; Mayes & Calhoun, 2007; Pitcher et al., 2012; Suggate et al., 2019). This thesis is the first to examine these graphomotor skills in children born LPT, compared to those of children born at full term, using process-oriented assessment. This was examined at two time-points within primary school (T1: age 4 to 5 years; and T2: age 7 to 10 years).

The study did not find a wide impact on the graphomotor outcomes of children born LPT. The only statistically significant result for this group was the tracking task which required the tracking of a moving object with a stylus, and this was only significant in the covariate adjusted model by T2, when the children were aged 7 to 10 years. As with the small effect seen in CWM for children born LPT, it is unlikely that the small deficit found in tracking skills for children LPT is highly responsible for the differences seen in their educational outcomes in chapters 3 and 4. However, it would potentially be contributory, as graphomotor skills have been found to be predictive of educational attainment (Giles et al., 2018; Shire, 2016).

There was stronger evidence of children born VMPT having graphomotor deficits with the result for aiming and tracing statistically significant at age 4 to 5 years and for tracking at age 7 to 8 years (once age in months was included in the modelling). This finding is consistent with previous product-oriented graphomotor assessments in children born VMPT (Bolk et al., 2018; Caravale et al., 2012; Constable et al., 2008; Cooke, 2003; Dathe et al., 2020; Feder et al., 2007; Fletcher et al., 1997; Luoma et al., 1998; Miranda-Herrero et al., 2021; Roze et al., 2021; van Veen et al., 2019), and the one process-oriented graphomotor study by Sagol et al. (2007). This is potentially linked to the poorer educational achievement and scores often observed in children born VMPT (e.g. Alterman et al., 2022; Chan & Quigley, 2014; Copper et al., 2023; Quigley et al., 2012), including the results seen in Chapters 3 and 4.

The results also indicated that the impact on graphomotor skills may change during development, with the children born VMPT delayed in their aiming and tracing development at age 4 to 5 years, but having caught up with children born full term by age 7 to 8 years (as VMPT birth was no longer a statistically significant predictor). However, more studies are needed to establish if the findings of different effects from VMPT birth are present at differing ages is generalizable, especially due to the low numbers in this group in the current study. The results for children born early term were not statistically significant for any of the outcomes at either age.

Motor skills are suggested to partially rely on the CWM examined in Chapter Five. This is because of the involvement of CWM in the application of declarative knowledge to generate rules and guide motor performance. This declarative knowledge requires CWM in making decisions on the application of these rules (Maxwell et al., 2003; Sagnol et al., 2007). Thus, two underlying constructs reviewed in Chapters Four and Five are somewhat interwoven.

The impact of poorer graphomotor skills in children born LPT and VMPT may result in a reduction of cognitive resources for other aspects of writing such as planning and composition due to the attention having to be given to the mechanistic elements of writing. This view of cognitive resources as finite is known as the “capacity theory of writing” (McCutchen, 1996). Such lack of writing automacity is associated with a poorer writing composition skills because of the cognitive resources required to complete the mechanical graphomotor writing process leaving less cognitive resources available for composition (Medwell et al., 2009).

Likewise, skill levels in copying a figure, similar to the skills required in the tracking CKAT task, have been shown to predict both mathematics and writing educational achievement in the general population (Carlson et al., 2013). Similarly, being able to write and form numerical digits accurately has been found to predict mathematics scores in school (Clayton et al., 2020). Additionally, variance in presentation with school-based work has been shown to result in differing educational scores, with poorly presented work graded worse, even when the content is the same (Graham et al., 2011). Therefore, previous studies have linked lower graphomotor skills directly to lower writing and mathematical achievement in the general population. Thus, this thesis' finding of poorer graphomotor skills in LPT, and especially in the VMPT gestational group, are potentially linked to the poorer educational results seen in Chapters 3 and 4. However, a mediation study is needed to more firmly establish this.

7.2 Potential Explanations for the Overall Findings

The results from the thesis' studies suggest children born LPT have a small but significant difference in their educational achievement, educational scores, CWM and graphomotor tracking outcomes. A potential explanation for this is the suggestion of a sub-optimal LPT phenotype, similar to that seen in children born very preterm (S. Johnson & Marlow, 2011, 2017) and a higher rate of a general sub-optimal phenotype than present in full term born children.

Latent class analysis by S. Johnson et al. (2018) found the majority of children born moderately/LPT (67% compared to 84% of term-born children) were in the optimal Class One phenotype group. However, 26% of children born moderately/LPT (compared to 16% of term-born children) fell into a non-optimal general Class Two group. Additionally, around 7% of children born moderately/LPT were found to be phenotype non-optimal Class Three: a phenotype only found in children born prematurely.

Membership of the Class Two phenotype was associated with delayed social and emotional skills; greater behavioural problems; and increased rates of autism symptoms. Whilst Class Three phenotype presented with cognitive issues; delayed language; poorer social and emotional skills; and increased autism symptoms (S. Johnson et al., 2018). Hence, the indication of a LPT Class Three phenotype and higher incidence of the Class Two phenotype would provide a partial explanation of the educational, CWM and graphomotor deficits seen within this thesis.

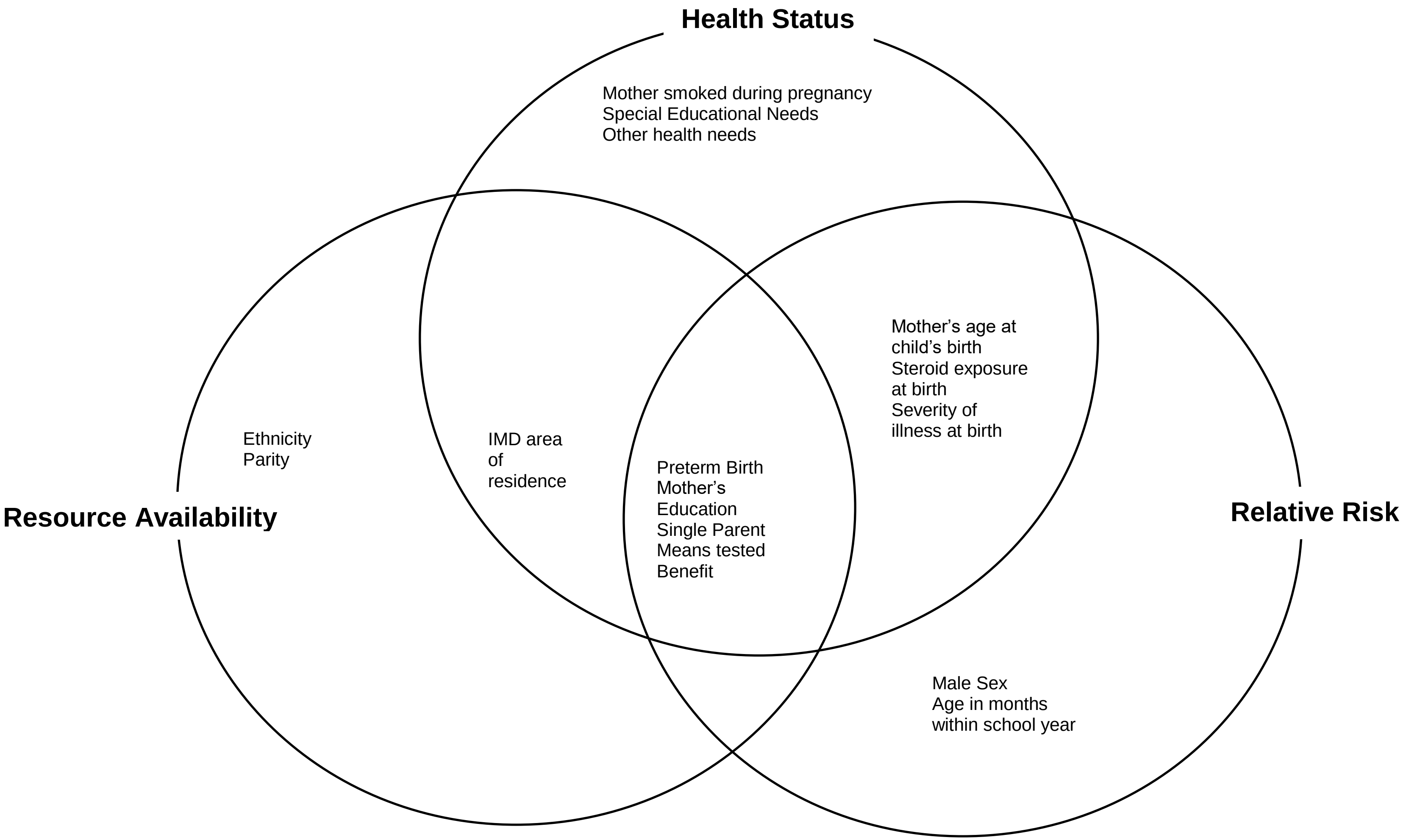
Furthermore, SES factors were found to predict group membership of both the Class Two and Class Three phenotype. Further statistically significant predictors were having a non-white mother, and the baby not being breast fed (S. Johnson et al., 2018). This phenotype research took place in Derbyshire and the rates of a number of the predictors, including SES disadvantage (Department for Work and Pensions, 2023), and non-white ethnicity are higher in Bradford (City of Bradford MDC, 2022; Office for National Statistics, 2023b). Therefore, it would be expected that children born LPT within the BiB cohort are perhaps even more likely to fall into phenotype Classes Two and Three than those in the original research by S. Johnson et al. (2018), as the levels within the predictors would be higher.

This inter-connection between SES, ethnicity, and health is also suggested by the Preterm Infant Vulnerability to Neuro-morbidity Model proposed by Purdy et al. (2008), discussed in Chapter One (Section 1.8). This inter-connectivity is shown in the Venn diagram in Figure 7.1. Here, the child's prematurity poses relative risk due to the reverse gestational gradient of improved outcomes (Boyle et al., 2012), but is also associated with less resource availability as preterm birth is associated with lower SES (McHale et al., 2025), and with increased risk for worse health outcomes after birth (Boyle et al., 2012). Therefore, it is shown at the union of the three elements of the Purdy et al. (2008) model. Similarly, the child's mother's education, single parenthood and receipt of means tested benefit also represents a relative risk to cognitive outcomes, but are additionally associated with less resource availability (M.I. Jackson et al., 2017) and worsened health status for the child (Prickett & Augustine, 2016). Male sex (Ibbotson & Roque-Gutierrez, 2023; Liutsko et al., 2020; Ogden et al., 2023), and being younger in the school year (Copper et al., 2023; Oosterbeek et al., 2021; Pettinger et al., 2020) are hypothesised as an increased relative risk in cognitive outcomes, in Figure 7.1. Whilst increased parity is often seen to be associated with decreased financial resource availability (Jalovaara et al., 2022), as is Pakistani ethnicity (Fairley et al., 2014), due to lower SES. IMD area of residence is presented intersecting with health status and (financial) resource availability (Skarda et al., 2025). Whilst the mother's age at birth intersects both relative risk and later health needs (Fall et al., 2015). Thus, the Preterm Infant Vulnerability to Neuro-morbidity Model by Purdy et al. (2008) illustrates the interplay between the predictor variables and covariates grouped as factors from health status, relative risk and resource availability. These factors form stressors or protectors within the child's system and thereby increase or decrease their risk to adverse outcomes.

Furthermore, these poorer levels of educational achievement, educational scores, CWM and graphomotor outcomes in children born LPT may be due to the many developments taking place in the brain during the LPT birth period, reviewed in the Introduction Section 1.5, that leads the child born at LPT gestation more prone to brain injury than a full term birth (Kinney, 2006; Walsh et al., 2014).

Figure 7-1

Venn Diagram Illustrating the Author's Hypothesised Interactions Between the Predictor Variable of Preterm Birth and the Covariates as Resource Availability, Health Status and Relative Risk Factors, as Suggested in the Preterm Infant Vulnerability to Neuro-morbidity Model by Purdy et al.(2008)



7.3 Policy Implications

The thesis demonstrated that children born LPT, as well as those born VMPT have worsened outcomes in educational achievement and educational scores. The LPT gestational group were shown to have lower CWM and poorer tracking graphomotor skills. The VMPT gestational group had a wider range of deficits in graphomotor skills. There are several policy implications in terms of support and surveillance; preventing premature birth; teacher knowledge; and parental support that would help mitigate these poorer outcomes.

The LPT gestational group is a large group and any detrimental effect on this group of children is likely to be costly at a societal level, for example it is estimated that in England the societal cost is more than double for a child born LPT compared to term-born, in the period between the child's birth to age 24 months (Khan et al., 2015). Early intervention for educational or neurodevelopmental disorder, as suggested by this thesis, is argued to reduce later educational costs to society and increase future attainment for the child (Grus, 2001). The following suggested policy measures would therefore help reduce the societal costs to society and improve outcomes for children born LPT.

7.3.1 Efforts to Reduce Preterm Births

Given the subtle but detrimental effects seen from LPT and VMPT birth, efforts to reduce the number of preterm births could have a public health impact in terms of improved cognition and social and emotional health for a large number of children. Potential health risks can be managed to reduce the threat of preterm pregnancy. These include regular maternal attendance of prenatal care services (Requejo et al., 2013; Tayebi et al., 2013; Vintzileos et al., 2002); management and treatment of conditions associated with preterm birth, such as maternal diabetes, thyroid disease, heart disease and asthma (Requejo et al., 2013); efforts to reduce maternal smoking (which is associated with preterm birth) (Ion & Bernal, 2015); the mother avoiding second-hand smoke (Requejo et al., 2013); and avoiding short inter-pregnancy intervals of less than 6 months (Smith, 2003).

Therefore, a public information campaign covering these factors may help bring down rates of preterm birth, for example by encouraging mothers to ensure that they attend all antenatal appointments and take part in any health surveillance offered during their pregnancy.

7.3.2 Increased Parental Knowledge

In addition to the recommendations regarding parental knowledge prior to the birth above, it would be useful to increase parental knowledge of the longer-term effects of LPT birth. Previous research has suggested that parents are unaware of any increased risks (Premji et al., 2017), and parents of children born LPT often feel that their children being preterm is only a relevant factor in the first year of the child's life (Jaworski et al., 2022). Increased knowledge would enable the parent to better advocate for their children in educational and school settings, as the results in this thesis suggest that the adverse effect can continue into childhood. Social media and parental forums are a useful tool in raising awareness of preterm issues and could be used for this (Thoren et al., 2013).

7.3.3 Medical Practitioner Knowledge

It is useful for medical practitioners to be aware of the potential impact of LPT birth longer term when advising the preterm child's parents. This was partly achieved by the research in Chapter Three being published in a medical journal (Archives of Disease in Childhood). However, greater dissemination of the findings to medical practitioners via conference presentations and CPD sessions would be beneficial.

7.3.4 Targeted Automated Surveillance

Children born before 30 weeks' gestation are eligible for enhanced development support and surveillance until age 2 years in England, with those children born before 28 weeks' gestation eligible for additional specific developmental assessment at age 4 years (National Institute for Health and Care Excellence, 2017). However, children born LPT do not have any enhanced assessed relative to children born at full term (National Institute for Health and Care Excellence, 2017).

Whilst non-automated surveillance of such a large group is unlikely to be practical, linking routine educational and health data may make "behind the scenes" data surveillance possible for children born LPT. This could thereby support the child's cognitive and educational development by identifying children requiring educational support at an earlier age, using a risk-matrix approach. This has been trialled for children with autism using data from the Connected Bradford research database (B. Wright et al., 2019) and could potentially be extended to other health risks, including preterm birth.

7.3.5 Educational Professional Awareness

Studies surveying schools have demonstrated that teaching staff receive little training on the longer term impacts of preterm birth (Elvert et al., 2021; S. Johnson et al., 2015). There is an e-learning resource for education staff that has been shown to increase their knowledge of the long-term consequences of preterm birth and how best to support children born preterm (S. Johnson et al., 2019). It would therefore be beneficial for more schools to use this resource and to increase school awareness of the resource.

Similarly, schools should ensure that they are cognizant if the child is born preterm and at what gestational week birth occurred in order to evaluate the likely risk to the child. Additionally, there is a “PremAware School” scheme available from the Smallest Things charity (The Smallest Things, 2017), which shows the teachers in school are trained on teaching children born prematurely, as well as evidencing that the school generally is aware of the issues surrounding prematurity. Schools should be encouraged to apply for this award and to fulfil its requirements to help serve the educational needs of children born at preterm gestation.

7.3.6 Interventions for Education, Executive Function and Graphomotor Development

Interventions designed to increase working memory capacity have been proposed by some authors and tested in children born very preterm. Whilst some of these studies observed initial success in increased working memory (C. S. C. Lee et al., 2017; van Houdt et al., 2019), significant increases have not been shown to be consistently maintained (Kelly et al., 2020; van Houdt et al., 2019). Therefore, it is suggested that efforts may be more effectively invested in subject-specific remediation (Jaekel et al., 2021).

Specific mathematics intervention has been trialled in children born generally preterm (i.e. before 37 weeks’ gestation), using XtraMaths ® (Jaekel et al., 2021). In this study, although initial results suggested improved performance, this was not maintained 12 months later. However, more studies are needed to examine this further, as the initial results showed some potential (Jaekel et al., 2021).

Teaching handwriting, including individual tuition and technology based in instruction, has been shown to improve writing legibility in studies within the general population (Santangelo & Graham, 2016). Interventions have resulted in a small to medium sized improvement in legibility, but there is less evidence on whether these interventions improve writing speed or writing fluency (Engel et al., 2018). There are several writing based intervention packages that may be of use to teaching staff, e.g. Helping Handwriting Shine which was found to increase writing progress for children in school Year 5 (Stone et al., 2020). However, no studies have examined handwriting/graphomotor interventions specifically in children born preterm as yet and this an area for future research.

Therefore, schools should be advised to commence subject-specific intervention for children born LPT that are working below expected levels of educational attainment, but the evidence of the efficacy of many of these potential interventions at present is somewhat limited.

7.4 Strengths and Limitations of the Studies within the Thesis

The BiB cohort dataset was well suited to the thesis research questions as it provided a large dataset of children. This is important given that preterm birth is a comparatively rare occurrence at around 7.4% of births in England (Office for National Statistics, 2022). The sample provided adequate power in the LPT gestational group, with G*power (Faul et al., 2007) showing around 80% chance of being able to observe a small effect. The BiB data also provided a good range of covariates that had been shown influence outcomes after preterm birth (as discussed in Section 1.3). The data was also available at a number of time-points for educational achievement, educational scores, and graphomotor outcomes.

Whilst it is acknowledged that the BiB cohort and Bradford itself is more ethnically and socio-economically diverse than the UK in general, the results from the studies are likely to generalise well to other UK cities with a large ethnic minorities and relatively high levels of deprivation. Studies featuring this demographic examining preterm birth are very rare as most preterm studies are in predominately White ethnicities (Pettinger et al., 2023). The studies in this thesis are therefore valuable in extending our knowledge to such diverse communities.

Limitations include missing data in the covariates, but this is an acknowledged feature of longitudinal cohort studies (Vignoles, 2021). Covariates with very high rates of missing data, e.g. father's employment, were not used as covariates in this thesis as these may not be missing at random and may therefore lead to selection bias (Mack & Westreich, 2018). The amount of missing outcome data in educational variables at age 11 years, due to Covid-related school closures, also meant that mediation studies were not possible with the data. However, this is more than balanced by being the first study to investigate the effect on children born preterm in most up-to-date curriculum at this age.

The low numbers in the VMPT gestational group meant that the research often only had the statistically power to reliably observe a medium to large effect in this group. Whilst this is a limitation, the VMPT group have been more examined within previous studies and this was therefore not the selected focus of the thesis, but is included for comparison purposes, with the caveat that the sample size is often relatively small.

7.5 Recommendations for Future Research

Whilst this thesis provides many novel findings in regard to birth at LPT and early term gestation, there are areas where it became clear during the research that require further investigation. The following research areas would benefit from additional studies.

7.5.1 Educational Overall Achievement to Age 16 and 18 Years

As the children born LPT had a small but statistically significant increase in odds of not reaching expected levels of development at age 11 years, it would be of interest to evaluate whether they are also at an educational disadvantage to age 16 years and 18 years. This would enable examination of whether this adverse effect is sustained. If possible, this should be done within longitudinal analysis to provide the most reliable evidence (Alterman et al., 2022).

Achievement at the end of compulsory education provides a pathway to further academic study, with results at age 16 years shown to be particularly influential for university attendance, even when controlling for later ‘A’ level results (Crawford & Greaves, 2023). Furthermore, attainment at age 16 years also predicts occupational, financial, and social emotional outcomes later in life (Starr et al., 2024). Greater knowledge of outcomes of children born LPT at the age of 16 years, and 18 years, would further help define the appropriate level of support and monitoring in the years preceding these time-points, by showing any lasting effect of birth at LPT gestation. This would potentially be of great interest to parents of children born LPT.

7.5.2 Inhibition Study

The results of the study on executive function in Chapter Five showed that there was no adverse effect in inhibition, supporting the previous findings in the wider moderately/LPT gestational group (Cserjesi et al., 2012; Reijneveld et al., 2021) However, studies within the very preterm gestational group (Aarnoudse-Moens et al., 2012) and by Hodel et al. (2016) in children born moderately/LPT at age 4 years suggest that the effect of preterm birth on inhibition may vary by the type of inhibition. “Hot” inhibition, that is inhibition related to motivation, was shown to be poorer in children born moderately/ LPT who were tested at age 4 years (Hodel et al., 2016). Therefore, it is recommended that testing take place to establish if hot inhibition is detrimentally affected in children born LPT at school age.

There are a small number of interventions available for hot inhibition with some reported success in improving outcomes (Chavez-Arana et al., 2018). If this area is shown to be a deficit within children born LPT, such interventions would be worth exploring to see if these are effective in children born LPT.

Interestingly, children whose mothers smoked during pregnancy have also been shown to have poorer hot inhibition, but not cold inhibition (non-motivation related) (Huijbregts et al., 2008). Maternal smoking is also associated with preterm birth (Kallen, 2001; Lawder et al., 2019; B. Liu et al., 2020). Therefore, it could be that preterm birth is on the mediation pathway between smoking and hot inhibition. However, neither of the papers that examined hot inhibition in children born preterm controlled for maternal smoking (Aarnoudse-Moens et al., 2012; Hodel et al., 2016). Furthermore, Huijbregts et al. (2008) did not control for prematurity in investigating differences in hot inhibition in children whose mother’s smoked during pregnancy. Therefore, an analysis of inhibition in children born at preterm gestation could be extended to also examine this potential mediation. This would enable greater knowledge of this pathway that is implicated in lower achievement.

7.5.3 Mediation Study of CWM and Educational Scores

Children born LPT were found to have a small deficit in their CWM. This area of working memory has been shown to predict academic attainment (Alloway & Alloway, 2010; Blankenship et al., 2015; Gathercole et al., 2004). A study investigating whether working memory mediates the psycho-educational test results (the Weschler Individual Achievement Test) in reading and mathematics for children born extremely preterm (Trickett et al., 2022), found that the relationship between reading and extremely preterm birth was fully mediated by CWM and that of mathematics and extremely preterm birth partially mediated. However, a similar study in children born LPT has not taken place, and such an examination would usefully expand knowledge in this area.

A mediational examination of gestational groups, CWM and educational outcomes was not possible within this thesis as there were relatively low numbers of children that had educational data collected after the executive function data was collected (as educational testing in schools was suspended during the Covid pandemic). However, it may be possible in the future within the BiB cohort using the children's executive function scores and GCSE results.

7.5.4 Teacher Understanding of the Impact of Prematurity

There have been a few studies that have investigated teachers' understanding of the potential impact of prematurity on later educational outcomes. However, there has not been a study that examines the extent to which schools collect information of prematurity and the medical and neurodevelopmental history connected to this, during the child's school entry.

The Bliss Charity (a charity for babies born prematurely or sick) suggest that parents of children born prematurely make sure that the school is aware that the child was born prematurely and the known health and cognitive impact (Bliss, 2024). However, ideally schools themselves should seek out this information actively and routinely (as discussed in Section 7.3.4). No study was identified that examined the extent to which this is currently occurring, nor how this information was used within schools, and whether the information was routinely passed on to the succeeding teachers. Identifying whether schools are routinely obtaining and using this information would help identify whether policy needs to change to ensure this occurs.

7.5.5 Social and Emotional Impacts of Preterm Birth

Studies have found adverse social and emotional outcomes into adulthood for the very preterm gestational group (Gray et al., 2018; S. Johnson & Wolke, 2013; Montagna & Nosarti, 2016) However there are very few studies examining any social and emotional impact of LPT birth in childhood (Bilgin et al., 2021). There is, however, some evidence of increased rates of Attentional Deficit Hyperactivity Disorder in children born LPT relative to full term births (Lindström et al., 2011; Pettinger et al., 2023; Tso et al., 2023). There has also been an increase in mother's reporting emotional problems issues in children born moderately/LPT over the last fifty years (Bilgin et al., 2021).

These social and emotional aspects of behaviour would have an effect on the child's learning (Kanopka et al., 2024) and therefore also affect their education. They may therefore be contributory to increase in not reaching expected levels of development and lower educational scores seen in children born LPT. This is therefore an area where a detailed study is required, as it would help identify where interventions may be useful. Although BiB collected data using the Strength and Difficulties Questionnaire, there were very low numbers in respect of children born preterm that had this data and therefore investigating this within this thesis was not possible.

7.6 Concluding Remarks

To conclude, the overall aim of the thesis was to investigate the impact of being born LPT, compared to full term birth, in childhood in educational, executive function and graphomotor outcomes. The key takeaway result is a sustained, small educational impact both in terms of increased likelihood of not reaching expected development levels and persistent lower educational scores, with no evidence of significant catching up with those born at full term gestation.

The thesis also investigated two potential underlying factors within this: executive function and graphomotor skills. There were small adverse effects on CWM and on tracking graphomotor skills. Both of these skills are also predictors of educational achievement (Alloway & Alloway, 2010; Blankenship et al., 2015; Gathercole et al., 2004; Giles et al., 2018; Shire, 2016).

As the LPT group is large (Office for National Statistics, 2022), even small levels of adverse effects would have societal consequences. It is imperative medical practitioners have knowledge of outcomes when advising parents of children born LPT, for example, on the importance on ensuring the child's school are aware of the child's gestation. It is also of vital importance that schools have regard to the child's gestation as factors that may influence achievement, both at the outset of school *and* also during the subsequent years. Additionally, it is essential that teaching staff are trained in pedagogical practices known to benefit children born preterm.

This thesis has contributed to the sparse knowledge of outcomes for children born LPT, demonstrating some evidence of poorer educational outcomes, executive function and graphomotor skills in this large group of children. It has also suggested potential systematic improvements that would help ameliorate the detrimental effects seen.

7.7 Chapter Summary

In this final chapter, I have reviewed the key findings from the thesis and how they inter-relate. The key findings from the thesis are that children born LPT have small but persistent poorer results in education both measured in terms of reaching expected levels of educational development and in educational scores. They also have worse CWM and tracking graphomotor skills than children born at full term gestation, but again these effects are small. My research contributes to provide empirical evidence on the effect of being born LPT on educational and cognitive outcomes, enhancing the understanding in an area where knowledge was scarce (Martínez-Nadal & Bosch, 2020). Within this chapter, I have explained some potential reasons for the poor results seen in some children born LPT and the policy and practice implications of the results. I have also discussed the strengths and weaknesses of the studies in the thesis and recommendations for future research.

References

Aarnoudse-Moens, C. S. H., Duivenvoorden, H. J., Weisglas-Kuperus, N., van Goudoever, J. B., & Oosterlaan, J. (2012). The profile of executive function in very preterm children at 4 to 12 years: Executive function in very preterm children. *Developmental Medicine & Child Neurology*, *54*(3), 247–253. https://doi.org/10.1111/j.1469-8749.2011.04150.x

Aarnoudse-Moens, C. S. H., Oosterlaan, J., Duivenvoorden, H. J., van Goudoever, J. B., & Weisglas-Kuperus, N. (2011). Development of preschool and academic skills in children born very preterm. *The Journal of Pediatrics*, *158*(1), 51–56. https://doi.org/10.1016/j.jpeds.2010.06.052

Aarnoudse-Moens, C. S. H., Weisglas-Kuperus, N., van Goudoever, J. B., & Oosterlaan, J. (2009). Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*, *124*(2), 717–728. https://doi.org/10.1542/peds.2008-2816

ACOG. (2021). *Medically indicated late-preterm and early-term deliveries*. The American College of Obstetricians. https://www.acog.org/clinical/clinical-guidance/committee-opinion/articles/2021/07/medically-indicated-late-preterm-and-early-term-deliveries

Adams, S. J. (2002). Educational attainment and health: Evidence from a sample of older adults. *Education Economics*, *10*(1), 97–109. https://doi.org/10.1080/09645290110110227

Adams-Chapman, I. (2006). Neurodevelopmental outcome of the late preterm infant. *Clinics in Perinatology*, *33*(4), 947–964. https://doi.org/10.1016/j.clp.2006.09.004

Ahlsson, F., Kaijser, M., Adami, J., Lundgren, M., & Palme, M. (2015). School performance after preterm birth. *Epidemiology*, *26*(1), 106–111. https://doi.org/10.1097/EDE.0000000000000171

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, *18*(3), 91–93. https://doi.org/10.1016/j.tjem.2018.08.001

Alenius, S., Kajantie, E., Sund, R., Nurhonen, M., Haaramo, P., Näsänen-Gilmore, P., Lemola, S., Räikkönen, K., Schnitzlein, D. D., Wolke, D., Gissler, M., & Hovi, P.

(2023). School grades and educational attainments of adolescents and young adults born preterm. *Scientific Reports*, *13*(1), 231. https://doi.org/10.1038/s41598-022-27295-4

Allen, R. J., & Waterman, A. H. (2015). How does enactment affect the ability to follow instructions in working memory? *Memory & Cognition*, *43*(3), 555–561. https://doi.org/10.3758/s13421-014-0481-3

Allotey, J., Zamora, J., Cheong-See, F., Kalidindi, M., Arroyo-Manzano, D., Asztalos, E., van der Post, J., Mol, B., Moore, D., Birtles, D., Khan, K., & Thangaratinam, S. (2018). Cognitive, motor, behavioural and academic performances of children born preterm: A meta-analysis and systematic review involving 64 061 children. *BJOG: An International Journal of Obstetrics & Gynaecology*, *125*(1), 16–25. https://doi.org/10.1111/1471-0528.14832

Alloway, T. P., & Alloway, R. G. (2010). Investigating the predictive roles of working memory and IQ in academic attainment. *Journal of Experimental Child Psychology*, *106*(1), 20–29. https://doi.org/10.1016/j.jecp.2009.11.003

Als, H. (1986). A synactive model of neonatal behavioral organization: Framework for the assessment of neurobehavioral development in the premature infant and for support of infants and parents in the neonatal intensive care environment. *Physical & Occupational Therapy in Pediatrics*, *6*(3), 3–53. https://doi.org/10.1300/J006v06n03_02

Altman, D. G., & Royston, P. (2006). The cost of dichotomising continuous variables. *BMJ,* 332(7549), 1080.1. https://doi.org/10.1136/bmj.332.7549.1080

Alterman, N., Johnson, S., Carson, C., Petrou, S., Kurinzcuk, J. J., Macfarlane, A., Boyle, E., & Quigley, M. A. (2022). Gestational age at birth and academic attainment in primary and secondary school in England: Evidence from a national cohort study. *PLoS ONE*, *17*(8), e0271952. https://doi.org/10.1371/journal.pone.0271952

Alterman, N., Johnson, S., Carson, C., Petrou, S., Rivero-Arias, O., Kurinczuk, J. J., Macfarlane, A., Boyle, E., & Quigley, M. A. (2021). Gestational age at birth and child special educational needs: A UK representative birth cohort study. *Archives of Disease in Childhood*, *106*(9), 842–848. https://doi.org/10.1136/archdischild-2020-320213

Althabe, F., Howson, C. P., Kinney, M., Lawn, J., & World Health Organization. (2012). *Born too soon: The global action report on preterm birth*. http://www.who.int/pmnch/media/news/2012/201204%5Fborntoosoon-report.pdf

An, K. N. (1984). Kinematic analysis of human movement. *Annals of Biomedical Engineering*, *12*(6), 585–597. https://doi.org/10.1007/BF02371451

Ananth, C. V., & Vintzileos, A. M. (2006). Maternal-fetal conditions necessitating a medical intervention resulting in preterm birth. *American Journal of Obstetrics and Gynecology*, *195*(6), 1557–1563. https://doi.org/10.1016/j.ajog.2006.05.021

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology*, *8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724

Anderson, P. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. *JAMA*, *289*(24), 3264. https://doi.org/10.1001/jama.289.24.3264

Anderson, P., Doyle, L. W., & Victorian Infant Collaborative Study Group. (2004). Executive functioning in school-aged children who were born very preterm or with extremely low birth weight in the 1990s. *Pediatrics*, *114*(1), 50–57. https://doi.org/10.1542/peds.114.1.50

Andrade, C. (2018). Internal, external, and ecological validity in research design, conduct, and evaluation. *Indian Journal of Psychological Medicine*, *40*(5), 498–499. https://doi.org/10.4103/IJPSYM.IJPSYM_334_18

Aoki, T., Rivlis, G., & Schieber, M. H. (2016). Handedness and index finger movements performed on a small touchscreen. *Journal of Neurophysiology*, *115*(2), 858–867. https://doi.org/10.1152/jn.00256.2015

Araújo Rohr, L., Cabral, T. I., Moraes, M. M. D., & Tudella, E. (2021). Reaching skills in six-month-old infants at environmental and biological risk. *PLoS ONE*, *16*(7), e0254106. https://doi.org/10.1371/journal.pone.0254106

Arnaud, C., Daubisse-Marliac, L., White-Koning, M., Pierrat, V., Larroque, B., Grandjean, H., Alberge, C., Marret, S., Burguet, A., Ancel, P.-Y., Supernant, K., & Kaminski, M. (2007). Prevalence and associated factors of minor neuromotor dysfunctions at age 5 years in prematurely born children: The EPIPAGE study.

Archives of Pediatrics & Adolescent Medicine, *161*(11), 1053. https://doi.org/10.1001/archpedi.161.11.1053

Astbury, J., Orgill, A. A., Bajuk, B., & Yu, V. Y. H. (1990). Neurodevelopmental outcome, growth and health of extremely low-birthweight survivors: How soon can we tell? *Developmental Medicine & Child Neurology*, *32*(7), 582–589. https://doi.org/10.1111/j.1469-8749.1990.tb08542.x

Atkinson, A. L., Hill, L. J. B., Pettinger, K. J., Wright, J., Hart, A. R., Dickerson, J., & Mon-Williams, M. (2022). Can holistic school readiness evaluations predict academic achievement and special educational needs status? Evidence from the Early Years Foundation Stage Profile. *Learning and Instruction*, *77*, 101537. https://doi.org/10.1016/j.learninstruc.2021.101537

Atkinson, J., & Braddick, O. (2007). Visual and visuocognitive development in children born very prematurely. In *Progress in Brain Research* (Vol. 164, pp. 123–149). Elsevier. https://doi.org/10.1016/S0079-6123(07)64007-2

Babyak, M. A., & Green, S. B. (2010). Confirmatory factor analysis: An introduction for psychosomatic medicine researchers. *Psychosomatic Medicine*, *72*(6), 587–597. https://doi.org/10.1097/PSY.0b013e3181de3f8a

Back, S. A., Luo, N. L., Borenstein, N. S., Levine, J. M., Volpe, J. J., & Kinney, H. C. (2001). Late oligodendrocyte progenitors coincide with the developmental window of vulnerability for human perinatal white matter injury. *The Journal of Neuroscience*, *21*(4), 1302–1312. https://doi.org/10.1523/JNEUROSCI.21-04-01302.2001

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology Section A*, *49*(1), 5–28. https://doi.org/10.1080/713755608

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, *4*(11), 417–423. https://doi.org/10.1016/S1364-6613(00)01538-2

Baddeley, A. (2001). Is working memory still working? *American Psychologist*, *56*(11), 851–864. https://doi.org/10.1037/0003-066X.56.11.851

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual Review of Psychology*, *63*(1), 1–29. https://doi.org/10.1146/annurev-psych-120710-100422

Baddeley, A. (2019). *Working Memory: Ambling and stumbling towards a multicomponent model*. https://vle.york.ac.uk/webapps/blackboard/execute/announcement?method=search&context=course_entry&course_id=_91577_1&handle=announcements_entry&mode=view

Baddeley, A., & Hitch, G. (1974). Working memory. In *Psychology of Learning and Motivation* (Vol. 8, pp. 47–89). Elsevier. https://doi.org/10.1016/S0079-7421(08)60452-1

Baddeley, A., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology*, *8*(4), 485–493. https://doi.org/10.1037/0894-4105.8.4.485

Baer, R. J., Chambers, C. D., Ryckman, K. K., Oltman, S. P., Rand, L., & Jelliffe-Pawlowski, L. L. (2019). Risk of preterm and early term birth by maternal drug use. *Journal of Perinatology*, *39*(2), 286–294. https://doi.org/10.1038/s41372-018-0299-0

Baggetta, P., & Alexander, P. A. (2016). Conceptualization and operationalization of executive function: Executive Function. *Mind, Brain, and Education*, *10*(1), 10–33. https://doi.org/10.1111/mbe.12100

Baghdadi, G., Towhidkhah, F., & Rajabi, M. (2021). *Neurocognitive mechanisms of attention: Computational models, physiology, and disease states*. Academic Press. https://doi.org/10.1016/C2020-0-02386-8

Bamber, D., Gilmore, C., & Johnson, S. (2019). Improving educational outcomes for children born preterm: A new approach. *Education*. https://barrycarpentereducation.files.wordpress.com/2021/10/bamber-et-al_infant-2019_prism2-paper.pdf

Barnett, L. M., Stodden, D. F., Hulteen, R. M., & Sacko, R. S. (2020). Motor competence assessment. In T. A. Brusseau, S. J. Fairclough, & D. R. Lubans (Eds.), *The Routledge Handbook of Youth Physical Activity* (1st ed., pp. 384–408). Routledge. https://doi.org/10.4324/9781003026426-24

Baron, I. S., Erickson, K., Ahronovich, M. D., Coulehan, K., Baker, R., & Litman, F. R. (2009). Visuospatial and verbal fluency relative deficits in ‘complicated’ late-preterm preschool children. *Early Human Development*, *85*(12), 751–754. https://doi.org/10.1016/j.earlhumdev.2009.10.002

Baron, I. S., Kerns, K. A., Müller, U., Ahronovich, M. D., & Litman, F. R. (2011). Executive functions in extremely low birth weight and late-preterm preschoolers: Effects on working memory and response inhibition. *Child Neuropsychology*, *18*(6), 586–599. https://doi.org/10.1080/09297049.2011.631906

Baron, I. S., Litman, F. R., Ahronovich, M. D., & Baker, R. (2012). Late preterm birth: A review of medical and neuropsychological childhood outcomes. *Neuropsychology Review*, *22*(4), 438–450. https://doi.org/10.1007/s11065-012-9210-5

Baron, I. S., Weiss, B. A., Baker, R., Khoury, A., Remsburg, I., Thermolice, J. W., Litman, F. R., & Ahronovich, M. D. (2014). Subtle adverse effects of late preterm birth: A cautionary note. *Neuropsychology*, *28*(1), 11–18. https://doi.org/10.1037/neu0000018

Baron, I. S., Weiss, B. A., Litman, F. R., Ahronovich, M. D., & Baker, R. (2014). Latent mean differences in executive function in at-risk preterm children: The delay-deficit dilemma. *Neuropsychology*, *28*(4), 541–551. https://doi.org/10.1037/neu0000076

Barrouillet, P., Camos, V., Perruchet, P., & Seron, X. (2004). ADAPT: A developmental, asemantic, and procedural model for transcoding from verbal to Arabic numerals. *Psychological Review*, *111*(2), 368–394. https://doi.org/10.1037/0033-295X.111.2.368

Bathelt, J., Scerif, G., Nobre, A. C., & Astle, D. E. (2019). Whole-brain white matter organization, intelligence, and educational attainment. *Trends in Neuroscience and Education*, *15*, 38–47. https://doi.org/10.1016/j.tine.2019.02.004

Bayless, S., & Stevenson, J. (2007). Executive functions in school-age children born very prematurely. *Early Human Development*, *83*(4), 247–254. https://doi.org/10.1016/j.earlhumdev.2006.05.021

Beauchamp, M. H., Thompson, D. K., Howard, K., Doyle, L. W., Egan, G. F., Inder, T. E., & Anderson, P. J. (2008). Preterm infant hippocampal volumes correlate with later working memory deficits. *Brain*, *131*(11), 2986–2994. https://doi.org/10.1093/brain/awn227

Benzies, K. M., Magill-Evans, J., Ballantyne, M., & Kurilova, J. (2017). Longitudinal patterns of early development in Canadian late preterm infants: A prospective cohort study. *Journal of Child Health Care*, *21*(1), 85–93. https://doi.org/10.1177/1367493516689167

Berg, D. H. (2008). Working memory and arithmetic calculation in children: The contributory roles of processing speed, short-term memory, and reading. *Journal of Experimental Child Psychology*, *99*(4), 288–308. https://doi.org/10.1016/j.jecp.2007.12.002

Bernhardt, J., Matyas, T., & Bate, P. (2002). Does experience predict observational kinematic assessment accuracy? *Physiotherapy Theory and Practice*, *18*(3), 141–149. https://doi.org/10.1080/09593980290058535

Berninger, V. W., & Chanquoy, L. (2012). What writing is and how it changes across early and middle childhood development. In E. L. Grigorenko, E. Mambrino, & D. D. Preiss (Eds.), *Writing* (1st ed., p. Chapter 3). Psychology Press. https://doi.org/10.4324/9780203808481

Berry, E. D. J., Allen, R. J., Mon-Williams, M., & Waterman, A. H. (2019). Cognitive offloading: Structuring the environment to improve children’s working memory task performance. *Cognitive Science*, *43*(8). https://doi.org/10.1111/cogs.12770

Berry, E. D. J., Waterman, A. H., Baddeley, A. D., Hitch, G. J., & Allen, R. J. (2018). The limits of visual working memory in children: Exploring prioritization and recency effects with sequential presentation. *Developmental Psychology*, 54(2), 240–253. https://doi.org/10.1037/dev0000427

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive functions after age 5: Changes and correlates. *Developmental Review*, *29*(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002

Bilgin, A., Mendonca, M., & Wolke, D. (2018). Preterm birth/low birth weight and markers reflective of wealth in adulthood: A meta-analysis. *Pediatrics*, *142*(1), e20173625. https://doi.org/10.1542/peds.2017-3625

Bilgin, A., Wolke, D., Baumann, N., Trower, H., Brylka, A., Räikkönen, K., Heinonen, K., Kajantie, E., Schnitzlein, D., & Lemola, S. (2021). Changes in emotional problems, hyperactivity and conduct problems in moderate to late preterm children and adolescents born between 1958 and 2002 in the United Kingdom. *JCPP Advances*, *1*(2), e12018. https://doi.org/10.1111/jcv2.12018

Billiards, S. S., Haynes, R. L., Folkerth, R. D., Trachtenberg, F. L., Liu, L. G., Volpe, J. J., & Kinney, H. C. (2006). Development of microglia in the cerebral white matter of the human fetus and infant. *The Journal of Comparative Neurology*, *497*(2), 199–208. https://doi.org/10.1002/cne.20991

Bird, P. K., McEachan, R. R. C., Mon-Williams, M., Small, N., West, J., Whincup, P., Wright, J., Andrews, E., Barber, S. E., Hill, L. J. B., Lennon, L., Mason, D., Shire, K. A., Waiblinger, D., Waterman, A. H., Lawlor, D. A., & Pickett, K. E. (2019). Growing up in Bradford: Protocol for the age 7–11 follow up of the Born in Bradford birth cohort. *BMC Public Health*, *19*(1), 939. https://doi.org/10.1186/s12889-019-7222-2

Biswal, B. (2015). Resting-state functional connectivity. In *Brain mapping* (pp. 581–585). Elsevier. https://doi.org/10.1016/B978-0-12-397025-1.00335-3

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Blankenship, T. L., O'Neill, M., Ross, A., & Bell, M. A. (2015). Working memory and recollection contribute to academic achievement. *Learning and Individual Differences*, *43*, 164–169. https://doi.org/10.1016/j.lindif.2015.08.020

Blencowe, H., Cousens, S., Oestergaard, M. Z., Chou, D., Moller, A.-B., Narwal, R., Adler, A., Vera Garcia, C., Rohde, S., Say, L., & 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. *The Lancet*, *379*(9832), 2162–2172. https://doi.org/10.1016/S0140-6736(12)60820-4

Bliss. (2024). *Supporting your child when they start school*. Bliss for Babies Born Premature or Sick. https://www.bliss.org.uk/parents/growing-up/starting-primary-school/supporting-your-child#:~:text=Through%20the%20school's%20admissions%20process,that%20you're%20aware%20of.

Bloom, H. S., Richburg-Hayes, L., & Black, A. R. (2007). Using covariates to improve precision for studies that randomize schools to evaluate educational interventions. *Educational Evaluation and Policy Analysis*, *29*(1), 30–59. https://doi.org/10.3102/0162373707299550

Bogičević, L., Verhoeven, M., & van Baar, A. L. (2020). Distinct profiles of attention in children born moderate-to-late preterm at 6 years. *Journal of Pediatric Psychology*, *45*(6), 685–694. https://doi.org/10.1093/jpepsy/jsaa038

Böhm, B., Smedler, A., & Forssberg, H. (2004). Impulse control, working memory and other executive functions in preterm children when starting school. *Acta Paediatrica*, *93*(10), 1363–1371. https://doi.org/10.1111/j.1651-2227.2004.tb02938.x

Bolk, J., Padilla, N., Forsman, L., Broström, L., Hellgren, K., & Åden, U. (2018). Visual–motor integration and fine motor skills at 6½ years of age and associations with neonatal brain volumes in children born extremely preterm in Sweden: A population-based cohort study. *BMJ Open*, *8*(2), e020478. https://doi.org/10.1136/bmjopen-2017-020478

Borghans, L., Golsteyn, B. H. H., Heckman, J. J., & Humphries, J. E. (2016). What grades and achievement tests measure. *Proceedings of the National Academy of Sciences*, *113*(47), 13354–13359. https://doi.org/10.1073/pnas.1601135113

Borsboom, D., Mellenbergh, G. J., & van Heerden, J. (2004). The concept of validity. *Psychological Review*, *111*(4), 1061–1071. https://doi.org/10.1037/0033-295X.111.4.1061

Boyle, E. M. (2020). Early outcomes in babies born close to term. In E. M. Boyle & Cusack (Eds.), *Emerging topics and controversies in neonatology*. https://doi.org/10.1007/978-3-030-28829-7

Boyle, E. M., Poulsen, G., Field, D. J., Kurinczuk, J. J., Wolke, D., Alfirevic, Z., & Quigley, M. A. (2012). Effects of gestational age at birth on health outcomes at 3 and 5 years of age: Population based cohort study. *BMJ*, *344*(mar01 2), e896–e896. https://doi.org/10.1136/bmj.e896

Bracewell, M., & Marlow, N. (2002). Patterns of motor disability in very preterm children. *Mental Retardation and Developmental Disabilities Research Reviews*, *8*(4), 241–248. https://doi.org/10.1002/mrdd.10049

Bramham, K., Parnell, B., Nelson-Piercy, C., Seed, P. T., Poston, L., & Chappell, L. C. (2014). Chronic hypertension and pregnancy outcomes: Systematic review and meta-analysis. *BMJ*, *348*(apr15 7), g2301–g2301. https://doi.org/10.1136/bmj.g2301

Breeman, L. D., Jaekel, J., Baumann, N., Bartmann, P., & Wolke, D. (2015). Preterm cognitive function into adulthood. *Pediatrics*, *136*(3), 415–423. https://doi.org/10.1542/peds.2015-0608

British Association for Early Childhood Education. (2012). Development matters in the early years foundation stage (EYFS). https://dera.ioe.ac.uk/id/eprint/14042/7/development%20matters%20in%20the%20early%20years%20foundation%20stage_Redacted.pdf

Brown, H. K., Speechley, K. N., Macnab, J., Natale, R., & Campbell, M. K. (2014). Mild prematurity, proximal social processes, and development. *Pediatrics*, *134*(3), e814–e824. https://doi.org/10.1542/peds.2013-4092

Brown, L., Burns, Y. R., Watter, P., Gibbons, K. S., & Gray, P. H. (2015). Motor performance, postural stability and behaviour of non-disabled extremely preterm or extremely low birth weight children at four to five years of age. *Early Human Development*, *91*(5), 309–315. https://doi.org/10.1016/j.earlhumdev.2015.03.003

Brumbaugh, J., Conrad, A. L., Lee, J. K., DeVolder, I. J., Zimmerman, M. B., Magnotta, V. A., Axelson, E. D., & Nopoulos, P. C. (2016). Altered brain function, structure, and developmental trajectory in children born late preterm. *Pediatric Research*, *80*(2), 197–203. https://doi.org/10.1038/pr.2016.82

Brumbaugh, J., Hodel, A., & Thomas, K. (2013). The impact of late preterm birth on Executive function at preschool age. *American Journal of Perinatology*, *31*(04), 305–314. https://doi.org/10.1055/s-0033-1348950

Brydges, C. R., Fox, A. M., Reid, C. L., & Anderson, M. (2014). The differentiation of executive functions in middle and late childhood: A longitudinal latent-variable analysis. *Intelligence*, *47*, 34–43. https://doi.org/10.1016/j.intell.2014.08.010

Brydges, C. R., Landes, J. K., Reid, C. L., Campbell, C., French, N., & Anderson, M. (2018). Cognitive outcomes in children and adolescents born very preterm: A meta-analysis. *Developmental Medicine & Child Neurology*, *60*(5), 452–468. https://doi.org/10.1111/dmcn.13685

Brydges, C. R., Reid, C. L., Fox, A. M., & Anderson, M. (2012). A unitary executive function predicts intelligence in children. *Intelligence*, *40*(5), 458–469. https://doi.org/10.1016/j.intell.2012.05.006

Budday, S., Steinmann, P., & Kuhl, E. (2015). Physical biology of human brain development. *Frontiers in Cellular Neuroscience*, *9*. https://doi.org/10.3389/fncel.2015.00257

Bui, T., & Das, J. (2023). Neuroanatomy, cerebral hemisphere. In *StatPearls [Internet]*. StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK549789/

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology*, *33*(3), 205–228. https://doi.org/10.1080/87565640801982312

Bull, R., & Johnston, R. S. (1997). Children's arithmetical difficulties: Contributions from processing speed, item identification, and short-term memory. *Journal of Experimental Child Psychology*, *65*(1), 1–24. https://doi.org/10.1006/jecp.1996.2358

Bull, R., & Lee, K. (2014). Executive functioning and mathematics achievement. *Child Development Perspectives*, *8*(1), 36–41. https://doi.org/10.1111/cdep.12059

Bulut, C., Gursoy, T., & Ovali, F. (2016). Short-term outcomes and mortality of late preterm infants. *Balkan Medical Journal*, *33*(2), 198–203. https://doi.org/10.5152/balkanmedj.2016.16721

Button, K. S., Ioannidis, J. P. A., Mokrysz, C., Nosek, B. A., Flint, J., Robinson, E. S. J., & Munafò, M. R. (2013). Power failure: Why small sample size undermines the reliability of neuroscience. *Nature Reviews Neuroscience*, *14*(5), 365–376. https://doi.org/10.1038/nrn3475

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement: Fine motor and kindergarten achievement. *Child Development*, *83*(4), 1229–1244. https://doi.org/10.1111/j.1467-8624.2012.01768.x

Cameron, C. E., Cottone, E. A., Murrah, W. M., & Grissmer, D. W. (2016). How are motor skills linked to children's school performance and academic achievement? *Child Development Perspectives*, *10*(2), 93–98. https://doi.org/10.1111/cdep.12168

Camos, V. (2008). Low working memory capacity impedes both efficiency and learning of number transcoding in children. *Journal of Experimental Child Psychology*, *99*(1), 37–57. https://doi.org/10.1016/j.jecp.2007.06.006

Caravale, B., Mirante, N., Vagnoni, C., & Vicari, S. (2012). Change in cognitive abilities over time during preschool age in low risk preterm children. *Early Human Development*, *88*(6), 363–367. https://doi.org/10.1016/j.earlhumdev.2011.09.011

Carlson, A. G., Rowe, E., & Curby, T. W. (2013). Disentangling fine motor skills' Relations to academic achievement: The relative contributions of visual-spatial integration and visual-motor coordination. *The Journal of Genetic Psychology*, *174*(5), 514–533. https://doi.org/10.1080/00221325.2012.717122

Caruana, E. J., Roman, M., Hernández-Sánchez, J., & Solli, P. (2015). Longitudinal studies. *Journal of Thoracic Disease*, *7*(11), E537-540. https://doi.org/10.3978/j.issn.2072-1439.2015.10.63

Centre for Evaluation & Monitoring, & Coe, R. (2000). *Effect size calculator* [Computer software]. Cambridge University Press & Assessment. https://www.cem.org/effect-size-calculator.

Cerella, J., & Hale, S. (1994). The rise and fall in information-processing rates over the life span. *Acta Psychologica*, *86*(2–3), 109–197. https://doi.org/10.1016/0001-6918(94)90002-7

Cermakova, P., Chlapečka, A., Csajbók, Z., Andrýsková, L., Brázdil, M., & Marečková, K. (2023). Parental education, cognition and functional connectivity of the salience network. *Scientific Reports*, *13*(1), 2761. https://doi.org/10.1038/s41598-023-29508-w

Chan, E., Leong, P., Malouf, R., & Quigley, M. A. (2016). Long-term cognitive and school outcomes of late-preterm and early-term births: A systematic review: Review: Neurodevelopment in late-preterm and early-term births. *Child: Care, Health and Development*, *42*(3), 297–312. https://doi.org/10.1111/cch.12320

Chan, E., & Quigley, M. A. (2014). School performance at age 7 years in late preterm and early term birth: A cohort studya. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *99*(6), F451–F457. https://doi.org/10.1136/archdischild-2014-306124

Chavez-Arana, C., Catroppa, C., Carranza-Escárcega, E., Godfrey, C., Yáñez-Téllez, G., Prieto-Corona, B., De León, M. A., & Anderson, V. (2018). A systematic review of interventions for hot and cold executive functions in children and adolescents with acquired brain injury. *Journal of Pediatric Psychology*, *43*(8), 928–942. https://doi.org/10.1093/jpepsy/jsy013

Chawanpaiboon, S., Vogel, J. P., Moller, A.-B., Lumbiganon, P., Petzold, M., Hogan, D., Landoulsi, S., Jampathong, N., Kongwattanakul, K., Laopaiboon, M., Lewis, C., Rattanakanokchai, S., Teng, D. N., Thinkhamrop, J., Watananirun, K., Zhang, J., Zhou, W., & Gülmezoglu, A. M. (2019). Global, regional, and national estimates of levels of preterm birth in 2014: A systematic review and modelling analysis. *The Lancet Global Health*, *7*(1), e37–e46. https://doi.org/10.1016/S2214-109X(18)30451-0

Chen, X., Sorenson, E., & Hwang, K. (2023). Thalamocortical contributions to working memory processes during the n-back task. *Neurobiology of Learning and Memory*, *197*, 107701. https://doi.org/10.1016/j.nlm.2022.107701

Chen, Z., Xiong, C., Liu, H., Duan, J., Kang, C., Yao, C., Chen, K., Chen, Y., Liu, Y., Liu, M., & Zhou, A. (2022). Impact of early term and late preterm birth on infants' neurodevelopment: Evidence from a cohort study in Wuhan, China. *BMC Pediatrics*, *22*(1), 251. https://doi.org/10.1186/s12887-022-03312-3

Chen, Z.-J., He, C., Xia, N., Gu, M.-H., Li, Y.-A., Xiong, C.-H., Xu, J., & Huang, X.-L. (2021). Association between finger-to-nose kinematics and upper extremity motorfunction in subacute stroke: A principal component analysis. *Frontiers in Bioengineering and Biotechnology*, *9*, 660015. https://doi.org/10.3389/fbioe.2021.660015

Cheng, Y., Kaimal, A., Bruckner, T., Hallaron, D., & Caughey, A. (2011). Perinatal morbidity associated with late preterm deliveries compared with deliveries between 37 and 40 weeks of gestation: Later preterm delivery and associated perinatal outcomes. *BJOG: An International Journal of Obstetrics & Gynaecology*, *118*(12), 1446–1454. https://doi.org/10.1111/j.1471-0528.2011.03045.x

Cheong, J. L., Doyle, L. W., Burnett, A. C., Lee, K. J., Walsh, J. M., Potter, C. R., Treyvaud, K., Thompson, D. K., Olsen, J. E., Anderson, P. J., & Spittle, A. J. (2017). Association between moderate and late preterm birth and neurodevelopment and social-emotional development at age 2 years. *JAMA Pediatrics*, *171*(4), e164805. https://doi.org/10.1001/jamapediatrics.2016.4805

Cheong, J. L. Y., & Doyle, L. W. (2012). Increasing rates of prematurity and epidemiology of late preterm birth: Epidemiology of late preterm birth. *Journal of Paediatrics and Child Health*, *48*(9), 784–788. https://doi.org/10.1111/j.1440-1754.2012.02536.x

Cheong, J. L. Y., & Doyle, L. W. (2020). Long term outcomes in moderate and late preterm Infants. In E. M. Boyle & J. Cusack (Eds.), *Emerging Topics and Controversies in Neonatology*. Springer International Publishing. https://doi.org/10.1007/978-3-030-28829-7

Choi, E. K., Kim, H., Je, B.-K., Choi, B. M., & Kim, S.-D. (2023). Morbidity and mortality trends in preterm infants of <32 weeks gestational age with severe intraventricular hemorrhage: A 14-year single-center retrospective study. *Journal of Korean Neurosurgical Society*, *66*(3), 316–323. https://doi.org/10.3340/jkns.2022.0264

Chung, E. H., Chou, J., & Brown, K. A. (2020). Neurodevelopmental outcomes of preterm infants: A recent literature review. *Translational Pediatrics*, *9*(S1), S3–S8. https://doi.org/10.21037/tp.2019.09.10

Chyi, L. J., Lee, H. C., Hintz, S. R., Gould, J. B., & Sutcliffe, T. L. (2008). School outcomes of late preterm infants: Special needs and challenges for infants born at 32 to 36 weeks gestation. *The Journal of Pediatrics*, *153*(1), 25–31. https://doi.org/10.1016/j.jpeds.2008.01.027

City of Bradford MDC. (2020a). *Indices of deprivation 2019*. City of Bradford Metropolitan District Council. https://ubd.bradford.gov.uk/media/1533/indices-of-deprivation-2019-on-the-day-alert.pdf

City of Bradford MDC. (2020b). *Poverty and deprivation*. City of Bradford Metropolitan District Council; 29/02/2024. https://ubd.bradford.gov.uk/media/1580/poverty-and-deprivation-jan-2020-update.pdf

City of Bradford MDC. (2022). *2021 Census: Ethnic group, religion and language spoken*. Office of the Chief Executive. https://ubd.bradford.gov.uk/media/1682/2021-census-ethnic-group-religion-and-language.pdf

Clayton, F. J., Copper, C., Steiner, A. F., Banfi, C., Finke, S., Landerl, K., & Göbel, S. M. (2020). Two-digit number writing and arithmetic in Year 1 children: Does number word inversion matter? *Cognitive Development*, *56*, 100967. https://doi.org/10.1016/j.cogdev.2020.100967

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Routledge. https://doi.org/10.4324/9780203771587

Collins, J. W., & Hawkes, E. K. (1997). Racial differences in post-neonatal mortality in Chicago: What risk factors explain the black infant's disadvantage? *Ethnicity & Health*, *2*(1–2), 117–125. https://doi.org/10.1080/13557858.1997.9961820

Constable, R. T., Ment, L. R., Vohr, B. R., Kesler, S. R., Fulbright, R. K., Lacadie, C., Delancy, S., Katz, K. H., Schneider, K. C., Schafer, R. J., Makuch, R. W., & Reiss, A. R. (2008). Prematurely born children demonstrate white matter microstructural differences at 12 years of age, relative to term control subjects: An investigation of group and gender effects. *Pediatrics*, *121*(2), 306–316. https://doi.org/10.1542/peds.2007-0414

Cooke, R. W. I. (2003). Growth impairment in the very preterm and cognitive and motor performance at 7 years. *Archives of Disease in Childhood*, *88*(6), 482–487. https://doi.org/10.1136/adc.88.6.482

Cooperstock, M., & Campbell, J. (1996). Excess males in preterm birth: Interactions with gestational age, race, and multiple birth. *Obstetrics & Gynecology*, *88*(2), 189–193. https://doi.org/10.1016/0029-7844(96)00106-8

Copper, C., Amanda Waterman, Cheti Nicoletti, Katherine Pettinger, Lee Sanders, & Liam J B Hill. (2023). Educational achievement to age 11 years in children born at late preterm and early term gestations. *Archives of Disease in Childhood*, *108*(12), 1019. https://doi.org/10.1136/archdischild-2023-325453

Cornish, R. P., Macleod, J., Boyd, A., & Tilling, K. (2021). Factors associated with participation over time in the Avon Longitudinal Study of Parents and Children:

A study using linked education and primary care data. *International Journal of Epidemiology*, *50*(1), 293–302. https://doi.org/10.1093/ije/dyaa192

Cortés Pascual, A., Moyano Muñoz, N., & Quílez Robres, A. (2019). The relationship between executive functions and academic performance in primary education: Review and meta-analysis. *Frontiers in Psychology*, *10*, 1582. https://doi.org/10.3389/fpsyg.2019.01582

Cowan, N. (2017). The many faces of working memory and short-term storage. *Psychonomic Bulletin & Review*, *24*(4), 1158–1170. https://doi.org/10.3758/s13423-016-1191-6

Coxon, J. P., Stinear, C. M., & Byblow, W. D. (2006). Intracortical inhibition during volitional inhibition of prepared action. *Journal of Neurophysiology*, *95*(6), 3371–3383. https://doi.org/10.1152/jn.01334.2005

Cragg, L., & Gilmore, C. (2014). Skills underlying mathematics: The role of executive function in the development of mathematics proficiency. *Trends in Neuroscience and Education*, *3*(2), 63–68. https://doi.org/10.1016/j.tine.2013.12.001

Cragg, L., Richardson, S., Hubber, P. J., Keeble, S., & Gilmore, C. (2017). When is working memory important for arithmetic? The impact of strategy and age. *PLoS ONE*, *12*(12), e0188693. https://doi.org/10.1371/journal.pone.0188693

Crawford, C., & Greaves, E. (2023). *Socio-economic, ethnic and gender differences in HE participation. London: Department for Business, Innovation and Skills.* Crown Copyright. https://ifs.org.uk/publications/socio-economic-ethnic-and-gender-differences-he-participation

Crawford, C., MacMillan, L. A., & Vignoles, A. (2014). *High-attaining children from disadvantaged backgrounds*. Social Mobility and Child Poverty Commission. https://dera.ioe.ac.uk/id/eprint/20433

Crockett, L. K., Ruth, C. A., Heaman, M. I., & Brownell, M. D. (2022). Education outcomes of children born late preterm: A retrospective whole-population cohort study. *Maternal and Child Health Journal*. https://doi.org/10.1007/s10995-022-03403-8

Crump, C., Sundquist, J., & Sundquist, K. (2023). Preterm or early term birth and risk of attention-deficit/hyperactivity disorder: A national cohort and co-sibling study.

Annals of Epidemiology, *86*, 119-125.e4. https://doi.org/10.1016/j.annepidem.2023.08.007

Crump, C., Sundquist, K., Winkleby, M. A., & Sundquist, J. (2013). Early-term birth (37–38 Weeks) and mortality in young adulthood: *Epidemiology*, *24*(2), 270–276. https://doi.org/10.1097/EDE.0b013e318280da0f

Cserjesi, R., Van Braeckel, K. N. J. A., Butcher, P. R., Kerstjens, J. M., Reijneveld, S. A., Bouma, A., Geuze, R. H., & Bos, A. F. (2012). Functioning of 7-year-old children born at 32 to 35 Weeks' gestational age. *Pediatrics*, *130*(4), e838–e846. https://doi.org/10.1542/peds.2011-2079

Culmer, P. R., Levesley, M. C., Mon-Williams, M., & Williams, J. H. G. (2009). A new tool for assessing human movement: The kinematic assessment tool. *Journal of Neuroscience Methods*, *184*(1), 184–192. https://doi.org/10.1016/j.jneumeth.2009.07.025

Cunningham, A. C., Hill, L., Mon-Williams, M., Peall, K. J., Linden, D. E. J., Hall, J., Owen, M. J., & Van Den Bree, M. B. M. (2019). Using kinematic analyses to explore sensorimotor control impairments in children with 22q11.2 deletion syndrome. *Journal of Neurodevelopmental Disorders*, *11*(1), 8. https://doi.org/10.1186/s11689-019-9271-3

Daamen, M., Bäuml, J. G., Scheef, L., Meng, C., Jurcoane, A., Jaekel, J., Sorg, C., Busch, B., Baumann, N., Bartmann, P., Wolke, D., Wohlschläger, A., & Boecker, H. (2015). Neural correlates of executive attention in adults born very preterm. *NeuroImage: Clinical*, *9*, 581–591. https://doi.org/10.1016/j.nicl.2015.09.002

Dai, D. W. T., Wouldes, T. A., Brown, G. T. L., Tottman, A. C., Alsweiler, J. M., Gamble, G. D., & Harding, J. E. (2020). Relationships between intelligence, executive function and academic achievement in children born very preterm. *Early Human Development*, *148*, 105122. https://doi.org/10.1016/j.earlhumdev.2020.105122

Dathe, A.-K., Jaekel, J., Franzel, J., Hoehn, T., Felderhoff-Mueser, U., & Huening, B. M. (2020). Visual perception, fine motor, and visual motor skills in very preterm and term-born children before school entry-observational cohort study. *Children (Basel, Switzerland)*, *7*(12), 276. https://doi.org/10.3390/children7120276

Davidoff, M. J., Dias, T., Damus, K., Russell, R., Bettegowda, V. R., Dolan, S., Schwarz, R. H., Green, N. S., & Petrini, J. (2006). Changes in the gestational age distribution among U.S. singleton births: Impact on rates of late preterm birth, 1992 to 2002. *Seminars in Perinatology*, *30*(1), 8–15. https://doi.org/10.1053/j.semperi.2006.01.009

Davidson, P. R., & Wolpert, D. M. (2005). Widespread access to predictive models in the motor system: A short review. *Journal of Neural Engineering*, *2*(3), S313–S319. https://doi.org/10.1088/1741-2560/2/3/S11

De Graaf-Peters, V. B., Bakker, H., van Eykern, L. A., Otten, B., & Hadders-Algra, M. (2007). Postural adjustments and reaching in 4- and 6-month-old infants: An EMG and kinematical study. *Experimental Brain Research*, *181*(4), 647–656. https://doi.org/10.1007/s00221-007-0964-6

de Jong, M., Verhoeven, M., & van Baar, A. L. (2012). School outcome, cognitive functioning, and behaviour problems in moderate and late preterm children and adults: A review. *Seminars in Fetal and Neonatal Medicine*, *17*(3), 163–169. https://doi.org/10.1016/j.siny.2012.02.003

De Jong, P. F. (1998). Working memory deficits of reading disabled children. *Journal of Experimental Child Psychology*, *70*(2), 75–96. https://doi.org/10.1006/jecp.1998.2451

De Kieviet, J. F., Heslenfeld, D. J., Pouwels, P. J. W., Lafeber, H. N., Vermeulen, R. J., van Elburg, R. M., & Oosterlaan, J. (2014). A crucial role for white matter alterations in interference control problems of very preterm children. *Pediatric Research*, *75*(6), 731–737. https://doi.org/10.1038/pr.2014.31

De Rose, P., Albamonte, E., Laganà, V., Sivo, S., Pisoni, S., Gallini, F., Serrao, F., Tinelli, F., Purpura, G., Ometto, A., Sacco, A., Quintiliani, M., De Clemente, V., Graziano, A., Romeo, D. M., Frezza, S., Papacci, P., Mosca, F., Vicari, S., … Ricci, D. (2013). Perceptual-motor abilities in pre-school preterm children. *Early Human Development*, *89*(10), 809–814. https://doi.org/10.1016/j.earlhumdev.2013.07.001

De Smedt, B., Janssen, R., Bouwens, K., Verschaffel, L., Boets, B., & Ghesquière, P. (2009). Working memory and individual differences in mathematics achievement: A longitudinal study from first grade to second grade. *Journal of*

Experimental Child Psychology, *103*(2), 186–201. https://doi.org/10.1016/j.jecp.2009.01.004

De Vita, F., Schmidt, S., Tinti, C., & Re, A. M. (2021). The role of working memory on writing processes. *Frontiers in Psychology*, *12*, 738395. https://doi.org/10.3389/fpsyg.2021.738395

Décaillet, M., Denervaud, S., Huguenin-Virchaux, C., Besuchet, L., Bickle-Graz, M., Fischer-Fumeaux, C. J., & Schneider, J. (2023). Executive functions assessment in very preterm children at school age: A pilot study about a clinical and experimental approach. *Applied Neuropsychology: Child*, 1–12. https://doi.org/10.1080/21622965.2023.2287059

Degnan, A. J., Wisnowski, J. L., Choi, S., Ceschin, R., Bhushan, C., Leahy, R. M., Corby, P., Schmithorst, V. J., & Panigrahy, A. (2015). Alterations of resting state networks and structural connectivity in relation to the prefrontal and anterior cingulate cortices in late prematurity. *NeuroReport*, *26*(1), 22–26. https://doi.org/10.1097/WNR.0000000000000296

Demestre, X. (2017). Prematuros tardíos, los ‘olvidados’: Una visión personal. *Revista Chilena de Pediatría*, *88*(3), 315–317. https://doi.org/10.4067/S0370-41062017000300001

Deoni, S. C., Adams, S. H., Li, X., Badger, T. M., Pivik, R. T., Glasier, C. M., Ramakrishnaiah, R. H., Rowell, A. C., & Ou, X. (2019). Cesarean delivery impacts infant brain development. *American Journal of Neuroradiology*, *40*(1), 169–177. https://doi.org/10.3174/ajnr.A5887

Department for Children, Schools and Families. (2008). *Statutory framework for the early years foundation stage*. Crown Copyright. https://dera.ioe.ac.uk/id/eprint/6413/7/statutory-framework_Redacted.pdf

Department for Communities and Local Government. (2010). *The English indices of deprivation 2010*. Crown Copyright.

Department for Education. (2012). Statutory framework for the early years foundation stage: Setting the standards for learning, development and care for children from birth to five. http://www.educationengland.org.uk/documents/pdfs/2012-eyfs-statutory-framework.pdf

Department for Education. (2013). *Education reform: New national curriculum for schools*. https://www.gov.uk/government/speeches/education-reform-new-national-curriculum-for-schools

Department for Education. (2014). *The national curriculum in England: Framework document*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/381344/Master_final_national_curriculum_28_Nov.pdf

Department for Education. (2015a). *Key stage 1 return 2015: Guide to the collection of results at the end of KS1*. https://assets.publishing.service.gov.uk/media/5a7f26d3ed915d74e6228b48/KS1_2015_Guidance__v1.0_web.pdf

Department for Education. (2015b). *Phonics screening check and national curriculum assessments at Key Stage 1 in England, 2015*. Crown Copyright. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/463002/SFR32_KS1_2015_Text.pdf

Department for Education. (2016a). *New primary school tests show schools rising to the challenge: Key stage 2 results for 2016 published*. https://www.gov.uk/government/news/new-primary-school-tests-show-schools-rising-to-the-challenge

Department for Education. (2016b). *Phonics screening check and Key stage 1 assessments in England, 2016*. Crown Copyright. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/577806/SFR42_Phonics_KS1_2016.pdf

Department for Education. (2017). *National curriculum assessments at key stage 2 in England, 2017 (revised)*. National Statistics. https://assets.publishing.service.gov.uk/media/5a7590cd40f0b6360e47514e/SFR69_2017_text.pdf

Department for Education. (2019a). *National curriculum assessments at key stage 2 in England, 2019 (revised)*. Crown Copyright. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/851798/KS2_Revised_publication_text_2019_v3.pdf

Department for Education. (2019b). *Primary school accountability in 2019: A technical guide for primary maintained schools, academies and free schools*. Crown Copyright. https://dera.ioe.ac.uk/id/eprint/34088/1/Primary_school_accountability_technical_guide.pdf

Department for Work and Pensions. (2023). *Children in low income families: Local area statistics, financial year ending 2022*. https://www.gov.uk/government/statistics/children-in-low-income-families-local-area-statistics-2014-to-2022/children-in-low-income-families-local-area-statistics-financial-year-ending-2022

Desmurget, M., & Grafton, S. (2000). Forward modeling allows feedback control for fast reaching movements. *Trends in Cognitive Sciences*, *4*(11), 423–431. https://doi.org/10.1016/S1364-6613(00)01537-0

Dhamrait, G. K., Christian, H., O'Donnell, M., & Pereira, G. (2021). Gestational age and child development at school entry. *Scientific Reports*, *11*(1), 14522. https://doi.org/10.1038/s41598-021-93701-y

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Digitale, J. C., Martin, J. N., & Glymour, M. M. (2022). Tutorial on directed acyclic graphs. *Journal of Clinical Epidemiology*, *142*, 264–267. https://doi.org/10.1016/j.jclinepi.2021.08.001

Dinehart, L., & Manfra, L. (2013). Associations between low-income children's fine motor skills in preschool and academic performance in second grade. *Early Education & Development*, *24*(2), 138–161. https://doi.org/10.1080/10409289.2011.636729

Domellöf, E., Johansson, A.-M., Farooqi, A., Domellöf, M., & Rönnqvist, L. (2013). Relations among upper-limb movement organization and cognitive function at school age in children born preterm. *Journal of Developmental & Behavioral Pediatrics*, *34*(5), 344–352. https://doi.org/10.1097/DBP.0b013e318287ca68

Domellöf, E., Johansson, A.-M., & Rönnqvist, L. (2018). Developmental progression and side specialization in upper-limb movements from 4 to 8 years in children born preterm and full term. *Developmental Neuropsychology*, *43*(3), 219–234. https://doi.org/10.1080/87565641.2018.1426765

Dong, Y., & Yu, J.-L. (2011). An overview of morbidity, mortality and long-term outcome of late preterm birth. *World Journal of Pediatrics*, *7*(3), 199–204. https://doi.org/10.1007/s12519-011-0290-8

Dowding, I., & Haufe, S. (2018). Powerful statistical inference for nested data using sufficient summary statistics. *Frontiers in Human Neuroscience*, *12*, 103. https://doi.org/10.3389/fnhum.2018.00103

Drayton, E., Farquharson, C., Ogden, K., Sibieta, L., Tahir, I., & Waltmann, B. (2023). *Annual report on education spending in England: 2023*. Institute for Fiscal Studies. https://ifs.org.uk/sites/default/files/2023-12/IFS-Annual-report-on-education-spending-in-England-2023-new.pdf

Durrant, C., Wong, H. S., Cole, T. J., Hutchon, B., Collier, L., Wright, A., George, C., De Haan, M., & Huertas Ceballos, A. (2020). Developmental trajectories of infants born at less than 30 weeks' gestation on the Bayley-III Scales. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *105*(6), 623. https://doi.org/10.1136/archdischild-2019-317810

Dusing, S., & Tripathi, T. (2015). Long-term neurodevelopmental outcomes of infants born late preterm: A systematic review. *Research and Reports in Neonatology*, 91. https://doi.org/10.2147/RRN.S44062

Eagle, D. M., Bari, A., & Robbins, T. W. (2008). The neuropsychopharmacology of action inhibition: Cross-species translation of the stop-signal and go/no-go tasks. *Psychopharmacology*, *199*(3), 439–456. https://doi.org/10.1007/s00213-008-1127-6

Ebert, S., Lockl, K., Weinert, S., Anders, Y., Kluczniok, K., & Rossbach, H.-G. (2013). Internal and external influences on vocabulary development in preschool children. *School Effectiveness and School Improvement*, *24*(2), 138–154. https://doi.org/10.1080/09243453.2012.749791

Eddy, L. H., Bingham, D. D., Crossley, K. L., Shahid, N. F., Ellingham-Khan, M., Otteslev, A., Figueredo, N. S., Mon-Williams, M., & Hill, L. J. B. (2020). The validity and reliability of observational assessment tools available to measure fundamental movement skills in school-age children: A systematic review. *PLoS ONE*, *15*(8), e0237919. https://doi.org/10.1371/journal.pone.0237919

El Marroun, H., Zeegers, M., Steegers, E. A., van Der Ende, J., Schenk, J. J., Hofman, A., Jaddoe, V. W., Verhulst, F. C., & Tiemeier, H. (2012). Post-term birth and the risk of behavioural and emotional problems in early childhood. *International Journal of Epidemiology*, *41*(3), 773–781. https://doi.org/10.1093/ije/dys043

Elliott, D., Helsen, W. F., & Chua, R. (2001). A century later: Woodworth's (1899) two-component model of goal-directed aiming. *Psychological Bulletin*, *127*(3), 342–357. https://doi.org/10.1037/0033-2909.127.3.342

Elvert, C., Johnson, S., & Jaekel, J. (2021). Teachers' knowledge and approaches to supporting preterm children in the classroom. *Early Human Development*, *159*, 105415. https://doi.org/10.1016/j.earlhumdev.2021.105415

Engel, C., Lillie, K., Zurawski, S., & Travers, B. G. (2018). Curriculum-based handwriting programs: A systematic review with effect sizes. *The American Journal of Occupational Therapy*, *72*(3), 7203205010p1-7203205010p8. https://doi.org/10.5014/ajot.2018.027110

Engle, R. W., Cantor, J., & Carullo, J. J. (1992). Individual differences in working memory and comprehension: A test of four hypotheses. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *18*(5), 972–992. https://doi.org/10.1037/0278-7393.18.5.972

Engle, W. A., Tomashek, K. M., Wallman, C., & and the Committee on Fetus and Newborn. (2007). "Late-preterm" infants: A population at risk. *Pediatrics*, *120*(6), 1390–1401. https://doi.org/10.1542/peds.2007-2952

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143–149. https://doi.org/10.3758/BF03203267

Eryigit Madzwamuse, S., Baumann, N., Jaekel, J., Bartmann, P., & Wolke, D. (2015). Neuro-cognitive performance of very preterm or very low birth weight adults at 26 years. *Journal of Child Psychology and Psychiatry*, *56*(8), 857–864. https://doi.org/10.1111/jcpp.12358

Espel, E. V., Glynn, L. M., Sandman, C. A., & Davis, E. P. (2014). Longer gestation among children born full term influences cognitive and motor development. *PLoS ONE*, *9*(11), e113758. https://doi.org/10.1371/journal.pone.0113758

Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology*, *26*(1), 465–486. https://doi.org/10.1207/s15326942dn2601_6

Evans, M. D. R., Kelley, J., Sikora, J., & Treiman, D. J. (2010). Family scholarly culture and educational success: Books and schooling in 27 nations. *Research in Social Stratification and Mobility*, *28*(2), 171–197. https://doi.org/10.1016/j.rssm.2010.01.002

Evensen, K. A. I., Ustad, T., Tikanmäki, M., Haaramo, P., & Kajantie, E. (2020). Long-term motor outcomes of very preterm and/or very low birth weight individuals without cerebral palsy: A review of the current evidence. *Seminars in Fetal and Neonatal Medicine*, *25*(3), 101116. https://doi.org/10.1016/j.siny.2020.101116

Fairchild, A. J., & McQuillin, S. D. (2010). Evaluating mediation and moderation effects in school psychology: A presentation of methods and review of current practice. *Journal of School Psychology*, *48*(1), 53–84. https://doi.org/10.1016/j.jsp.2009.09.001

Fairley, L., Cabieses, B., Small, N., Petherick, E. S., Lawlor, D. A., Pickett, K. E., & Wright, J. (2014). Using latent class analysis to develop a model of the relationship between socioeconomic position and ethnicity: Cross-sectional analyses from a multi-ethnic birth cohort study. *BMC Public Health*, *14*(1), 835. https://doi.org/10.1186/1471-2458-14-835

Fall, C. H. D., Sachdev, H. S., Osmond, C., Restrepo-Mendez, M. C., Victora, C., Martorell, R., Stein, A. D., Sinha, S., Tandon, N., Adair, L., Bas, I., Norris, S., & Richter, L. M. (2015). Association between maternal age at childbirth and child and adult outcomes in the offspring: A prospective study in five low-income and middle-income countries (COHORTS collaboration). *The Lancet Global Health*, *3*(7), e366–e377. https://doi.org/10.1016/S2214-109X(15)00038-8

Fallang, B., Saugstad, O. D., Grøgaard, J., & Hadders-Algra, M. (2003). Kinematic quality of reaching movements in preterm infants. *Pediatric Research*, *53*(5), 836–842. https://doi.org/10.1203/01.PDR.0000058925.94994.BC

Fallang, B., Saugstad, O. D., & Hadders-Algra, M. (2003). Postural adjustments in preterm infants at 4 and 6 months post-term during voluntary reaching in supine position. *Pediatric Research*, *54*(6), 826–833. https://doi.org/10.1203/01.PDR.0000088072.64794.F3

Faraone, S. V. (2008). Interpreting estimates of treatment effects: Implications for managed care. *P & T: A Peer-Reviewed Journal for Formulary Management*, *33*(12), 700–711.

Farbu, J., Haugen, M., Meltzer, H. M., & Brantsæter, A. L. (2014). Impact of singlehood during pregnancy on dietary intake and birth outcomes- a study in the Norwegian Mother and Child Cohort Study. *BMC Pregnancy and Childbirth*, *14*(1), 396. https://doi.org/10.1186/s12884-014-0396-9

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Feder, K. P., & Majnemer, A. (2007). Handwriting development, competency, and intervention. *Developmental Medicine & Child Neurology*, *49*(4), 312–317. https://doi.org/10.1111/j.1469-8749.2007.00312.x

Feder, K. P., Majnemer, A., Bourbonnais, D., Platt, R., Blayney, M., & Synnes, A. (2007). Handwriting performance in preterm children compared with term peers at age 6 to 7 years. *Developmental Medicine & Child Neurology*, *47*(3), 163–170. https://doi.org/10.1111/j.1469-8749.2005.tb01110.x

Fernández De Gamarra-Oca, L., Ojeda, N., Loureiro, B., Sierra-Ibarbia, A., García-Guerrero, M. A., Peña, J., Ibarretxe-Bilbao, N., & Zubiaurre-Elorza, L. (2022). Maternal care and general cognitive functioning in moderate and late preterm-born children. *Cognitive Development*, *64*, 101247. https://doi.org/10.1016/j.cogdev.2022.101247

Field, A. (2017). *Discovering statistics using IBM SPSS statistics* (5th edition). SAGE Publications.

Field, D., Boyle, E., Draper, E., Evans, A., Johnson, S., Khan, K., Manktelow, B., Marlow, N., Petrou, S., Pritchard, C., Seaton, S., & Smith, L. (2016). Towards reducing variations in infant mortality and morbidity: A population-based approach. *Programme Grants for Applied Research*, *4*(1), 1–218. https://doi.org/10.3310/pgfar04010

Fischer, M. H. (2001). Probing spatial working memory with the Corsi blocks task. *Brain and Cognition*, *45*(2), 143–154. https://doi.org/10.1006/brcg.2000.1221

Fishman, S. H., & Min, S. (2018). Maternal age and offspring's educational attainment. *Journal of Marriage and Family*, *80*(4), 853–870. https://doi.org/10.1111/jomf.12490

Fitzpatrick, A., Carter, J., & Quigley, M. A. (2016). Association of gestational age with verbal ability and spatial working memory at age 11. *Pediatrics*, *138*(6), e20160578. https://doi.org/10.1542/peds.2016-0578

Flatters, I., Hill, L. J. B., Williams, J. H. G., Barber, S. E., & Mon-Williams, M. (2014). Manual control age and sex differences in 4 to 11 year old children. *PLoS ONE*, *9*(2), e88692. https://doi.org/10.1371/journal.pone.0088692

Flatters, I., Mushtaq, F., Hill, L. J. B., Holt, R. J., Wilkie, R. M., & Mon-Williams, M. (2014). The relationship between a child's postural stability and manual dexterity. *Experimental Brain Research*, *232*(9), 2907–2917. https://doi.org/10.1007/s00221-014-3947-4

Fletcher, J. M., Landry, S. H., Bohan, T. P., Davidson, K. C., Brookshire, B. L., Lachar, D., Kramer, L. A., & Francis, D. J. (1997). Effects of intraventricular hemorrhage and hydrocephalus on the long-term neurobehavioral development of preterm very-low-birthweight infants. *Developmental Medicine & Child Neurology*, *39*(9), 596–606. https://doi.org/10.1111/j.1469-8749.1997.tb07495.x

Ford, R. M., Neulinger, K., O'Callaghan, M., Mohay, H., Gray, P., & Shum, D. (2011). Executive function in 7-9-year-old children born extremely preterm or with extremely low birth weight: Effects of biomedical history, age at assessment, and socioeconomic status. *Archives of Clinical Neuropsychology*, *26*(7), 632–644. https://doi.org/10.1093/arclin/acr061

Formoso, J., Barreyro, J.-P., Injoque-Ricle, I., Calero, A., Jacubovich, S., & Burin, D. I. (2018). Mathematical cognition, working memory, and processing speed in children. *Cognition, Brain, Behavior. An Interdisciplinary Journal*, *22*(2), 59–84. https://doi.org/10.24193/cbb.2018.22.05

Fosco, W. D., Kofler, M. J., Groves, N. B., Chan, E. S. M., & Raiker, J. S. (2020). Which ‘working’ components of working memory aren’t working in youth with ADHD? *Journal of Abnormal Child Psychology*, *48*(5), 647–660. https://doi.org/10.1007/s10802-020-00621-y

Foulder-Hughes, L. A., & Cooke, R. W. I. (2003). Motor, cognitive, and behavioural disorders in children born very preterm. *Developmental Medicine and Child Neurology*, *45*(2), 97–103.

Fraello, D., Maller-Kesselman, J., Vohr, B., Katz, K. H., Kesler, S., Schneider, K., Reiss, A., Ment, L., & Spann, M. N. (2011). Consequence of preterm birth in early adolescence: The role of language on auditory short-term memory. *Journal of Child Neurology*, *26*(6), 738–742. https://doi.org/10.1177/0883073810391904

Francis-Devine, B. (2020). *Which ethnic groups are most affected by income inequality?* House of Commons Library. https://commonslibrary.parliament.uk/income-inequality-by-ethnic-group/#:~:text=Significant%20income%20inequality%20exists%20between,from%20a%20Black%20ethnic%20group.

Fraser, A., Macdonald-Wallis, C., Tilling, K., Boyd, A., Golding, J., Davey Smith, G., Henderson, J., Macleod, J., Molloy, L., Ness, A., Ring, S., Nelson, S. M., & Lawlor, D. A. (2013). Cohort profile: The Avon Longitudinal Study of Parents and Children: ALSPAC mothers cohort. *International Journal of Epidemiology*, *42*(1), 97–110. https://doi.org/10.1093/ije/dys066

Friso-van Den Bos, I., & van De Weijer-Bergsma, E. (2020). Classroom versus individual working memory assessment: Predicting academic achievement and the role of attention and response inhibition. *Memory*, *28*(1), 70–82. https://doi.org/10.1080/09658211.2019.1682170

Fry, A. F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological Science*, *7*(4), 237–241. https://doi.org/10.1111/j.1467-9280.1996.tb00366.x

Fry, A. F., & Hale, S. (2000). Relationships among processing speed, working memory, and fluid intelligence in children. *Biological Psychology*, *54*(1–3), 1–34. https://doi.org/10.1016/S0301-0511(00)00051-X

Fuchs, F., Monet, B., Ducruet, T., Chaillet, N., & Audibert, F. (2018). Effect of maternal age on the risk of preterm birth: A large cohort study. *PLoS ONE*, *13*(1), e0191002. https://doi.org/10.1371/journal.pone.0191002

Fuchs, F., & Senat, M.-V. (2016). Multiple gestations and preterm birth. *Seminars in Fetal and Neonatal Medicine*, *21*(2), 113–120. https://doi.org/10.1016/j.siny.2015.12.010

Fuhs, M. W., & Day, J. D. (2011). Verbal ability and executive functioning development in preschoolers at head start. *Developmental Psychology*, *47*(2), 404–416. https://doi.org/10.1037/a0021065

Galal, M., Symonds, I., Murray, H., Petraglia, F., & Smith, R. (2012). Post term pregnancy. *Facts, Views & Vision in ObGyn*, *4*(3), 175–187.

Gallen, C. L., Schaerlaeken, S., Younger, J. W., Project iLEAD Consortium, Younger, J. W., O'Laughlin, K. D., Anguera, J. A., Bunge, S. A., Ferrer, E. E., Hoeft, F., McCandliss, B. D., Mishra, J., Rosenberg-Lee, M., Gazzaley, A., Uncapher, M. R., Anguera, J. A., & Gazzaley, A. (2023). Contribution of sustained attention abilities to real-world academic skills in children. *Scientific Reports,* 13(1), 2673. https://doi.org/10.1038/s41598-023-29427-w

Ganuthula, V. R. R., & Sinha, S. (2019). The looking glass for intelligence quotient tests: The interplay of motivation, cognitive functioning, and affect. *Frontiers in Psychology*, *10*, 2857. https://doi.org/10.3389/fpsyg.2019.02857

Gathercole, S. E., & Alloway, T. P. (2006). Practitioner review: Short-term and working memory impairments in neurodevelopmental disorders: diagnosis and remedial support. *Journal of Child Psychology and Psychiatry*, *47*(1), 4–15. https://doi.org/10.1111/j.1469-7610.2005.01446.x

Gathercole, S. E., Brown, L., & Pickering, S. J. (2003). Working memory assessments at school entry as longitudinal predictors of National Curriculum attainment levels. *Educational and Child Psychology*, *20*(3), 109–122. https://doi.org/10.53841/bpsecp.2003.20.3.109

Gathercole, S. E., Hitch, G. J., Service, E., & Martin, A. J. (1997). Phonological short-term memory and new word learning in children. *Developmental Psychology*, *33*(6), 966–979. https://doi.org/10.1037/0012-1649.33.6.966

Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at 7 years of age. *British Journal of Educational Psychology*, *70*(2), 177–194. https://doi.org/10.1348/000709900158047

Gathercole, S. E., Pickering, S. J., Knight, C., & Stegmann, Z. (2004). Working memory skills and educational attainment: Evidence from national curriculum assessments at 7 and 14 years of age. *Applied Cognitive Psychology*, *18*(1), 1–16. https://doi.org/10.1002/acp.934

Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology*, *47*(6), 1539–1552. https://doi.org/10.1037/a0025510

Ghanamah, R., Eghbaria-Ghanamah, H., Karni, A., & Adi-Japha, E. (2020). Too little, too much: A limited range of practice ‘doses’ is best for retaining grapho-motor skill in children. *Learning and Instruction*, *69*, 101351. https://doi.org/10.1016/j.learninstruc.2020.101351

Giles, O. T., Shire, K. A., Hill, L. J. B., Mushtaq, F., Waterman, A., Holt, R. J., Culmer, P. R., Williams, J. H. G., Wilkie, R. M., & Mon-Williams, M. (2018). Hitting the target: Mathematical attainment in children is related to interceptive-timing ability. *Psychological Science*, *29*(8), 1334–1345. https://doi.org/10.1177/0956797618772502

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2015). G. A., Isquith P. K., Guy S. C., Kenworthy L. (2015). Behavior Rating Inventory of Executive Function®, Second Edition (BRIEF®2). Lutz, FL: PAR Inc.

Gnigler, M., Neubauer, V., Griesmaier, E., Zotter, S., Kager, K., & Kiechl-Kohlendorfer, U. (2015). Very preterm children are at increased risk of reduced processing speed at 5 years of age, predicted by typical complications of prematurity and prenatal smoking. *Acta Paediatrica*, *104*(3), e124–e129. https://doi.org/10.1111/apa.12859

Goldenberg, R. L., Culhane, J. F., Iams, J. D., & Romero, R. (2008). Epidemiology and causes of preterm birth. *The Lancet*, *371*(9606), 75–84. https://doi.org/10.1016/S0140-6736(08)60074-4

Gomes, B. A., Plaska, C. R., Ortega, J., & Ellmore, T. M. (2023). A simultaneous EEG-fMRI study of thalamic load-dependent working memory delay period activity. *Frontiers in Behavioral Neuroscience*, *17*, 1132061. https://doi.org/10.3389/fnbeh.2023.1132061

Gopagondanahalli, K. R., Li, J., Fahey, M. C., Hunt, R. W., Jenkin, G., Miller, S. L., & Malhotra, A. (2016). Preterm hypoxic–ischemic encephalopathy. *Frontiers in Pediatrics*, *4*. https://doi.org/10.3389/fped.2016.00114

Graham, S., Harris, K. R., & Hebert, M. (2011). It is more than just the message: Presentation effects in scoring writing. *Focus on Exceptional Children*, *44*(4). https://doi.org/10.17161/foec.v44i4.6687

Grammer, J. K., Coffman, J. L., Ornstein, P. A., & Morrison, F. J. (2013). Change over time: Conducting longitudinal studies of children's cognitive development. *Journal of Cognition and Development*, *14*(4), 515–528. https://doi.org/10.1080/15248372.2013.833925

Gray, P. H., Edwards, D. M., Hughes, I. P., & Pritchard, M. (2018). Social-emotional development in very preterm infants during early infancy. *Early Human Development*, *121*, 44–48. https://doi.org/10.1016/j.earlhumdev.2018.05.002

Grissmer, D., Grimm, K. J., Aiyer, S. M., Murrah, W. M., & Steele, J. S. (2010). Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology*, *46*(5), 1008–1017. https://doi.org/10.1037/a0020104

Gritsenko, V., Yakovenko, S., & Kalaska, J. F. (2009). Integration of predictive feedforward and sensory feedback signals for online control of visually guided movement. *Journal of Neurophysiology*, *102*(2), 914–930. https://doi.org/10.1152/jn.91324.2008

Grönqvist, H., Strand Brodd, K., & von Hofsten, C. (2011). Reaching strategies of very preterm infants at 8 months corrected age. *Experimental Brain Research*, *209*(2), 225–233. https://doi.org/10.1007/s00221-011-2538-x

Grus, C. L. (2001). The development of cognitive and academic abilities: Growth curves from an early childhood educational experiment. *Journal of Developmental & Behavioral Pediatrics*, *22*(4).

Guarini, A., Bonifacci, P., Tobia, V., Alessandroni, R., Faldella, G., & Sansavini, A. (2019). The profile of very preterm children on academic achievement. A cross-population comparison with children with specific learning disorders. *Research in Developmental Disabilities*, *87*, 54–63. https://doi.org/10.1016/j.ridd.2019.02.001

Gurka, M. J., LoCasale-Crouch, J., & Blackman, J. A. (2010). Long-term cognition, achievement, socioemotional, and behavioral development of healthy late-preterm infants. *Archives of Pediatrics & Adolescent Medicine*, *164*(6). https://doi.org/10.1001/archpediatrics.2010.83

Habibi, P., & Chattopadhyay, D. (2021). The impact of handedness on user performance in touchless input. *International Journal of Human-Computer Studies*, *149*, 102600. https://doi.org/10.1016/j.ijhcs.2021.102600

Hackshaw, A. (2008). Small studies: Strengths and limitations. *European Respiratory Journal*, *32*(5), 1141–1143. https://doi.org/10.1183/09031936.00136408

Haddad, J. M., Claxton, L. J., Melzer, D. K., Hamill, J., & van Emmerik, R. E. A. (2013). Developmental changes in postural stability during the performance of a precision manual task. *Journal of Motor Learning and Development*, *1*(1), 12–19. https://doi.org/10.1123/jmld.1.1.12

Hadders-Algra, M. (2013). Typical and atypical development of reaching and postural control in infancy. *Developmental Medicine & Child Neurology*, *55*(s4), 5–8. https://doi.org/10.1111/dmcn.12298

Hale, S. (1990). A global developmental trend in cognitive processing speed. *Child Development*, *61*(3), 653–663. https://psycnet.apa.org/doi/10.2307/1130951

Halek, J., Muckova, A., Svoboda, Z., Janura, M., Marikova, J., Horakova, K., Kantor, L., & Nemcova, N. (2015). Kinematic analysis of preterm newborns' spontaneous movements for postural activity assessment. *Biomedical Papers*, *159*(4), 657–660. https://doi.org/10.5507/bp.2014.053

Hasler, H. M., & Akshoomoff, N. (2019). Mathematics ability and related skills in preschoolers born very preterm. *Child Neuropsychology*, *25*(2), 162–178. https://doi.org/10.1080/09297049.2017.1412413

Hayes, J., & Flower, L. (1980). Identifying the organization of writing processes. In L. W. Gregg & E. R. Steinberg (Eds.), *Cognitive Processes in Writing: An Interdisciplinary Approach* (pp. 3–30). Lawrence Erlbaum.

Haynes, R. L., Borenstein, N. S., Desilva, T. M., Folkerth, R. D., Liu, L. G., Volpe, J. J., & Kinney, H. C. (2005). Axonal development in the cerebral white matter of the human fetus and infant. *Journal of Comparative Neurology*, *484*(2), 156–167. https://doi.org/10.1002/cne.20453

Haynes, R. L., Sleeper, L. A., Volpe, J. J., & Kinney, H. C. (2013). Neuropathologic studies of the encephalopathy of prematurity in the late preterm infant. *Clinics in Perinatology*, *40*(4), 707–722. https://doi.org/10.1016/j.clp.2013.07.003

Heckman, J. J. (2008). Schools, skills, and synapses. *Economic Inquiry*, *46*(3), 289–324. https://doi.org/10.1111/j.1465-7295.2008.00163.x

Hedderson, M. (2003). Gestational diabetes mellitus and lesser degrees of pregnancy hyperglycemia: Association with increased risk of spontaneous preterm birth. *Obstetrics & Gynecology*, *102*(4), 850–856. https://doi.org/10.1016/S0029-7844(03)00661-6

Hedges, A., Corman, H., Noonan, K., & Reichman, N. E. (2021). Gestational age at term and educational outcomes at age nine. *Pediatrics*, *148*(2), e2020021287. https://doi.org/10.1542/peds.2020-021287

Hellgren, K. M., Tornqvist, K., Jakobsson, P. G., Lundgren, P., Carlsson, B., Källén, K., Serenius, F., Hellström, A., & Holmström, G. (2016). Ophthalmologic outcome of extremely preterm infants at 6.5 years of age: Extremely preterm infants in Sweden Study (EXPRESS). *JAMA Ophthalmology*, *134*(5), 555–562. https://doi.org/10.1001/jamaophthalmol.2016.0391

Henderson, S. E., Sugden, D. A., & Barnett, A. (2007). *Movement assessment battery for children: Second edition*. Pearsons Clinical https://www.pearsonclinical.co.uk/store/ukassessments/en/Store/Professional-Assessments/Motor-Sensory/Movement-Assessment-Battery-for-Children-%7C-Second-Edition/p/P100009221.html?srsltid=AfmBOoq_0J0_fdO5RxOcjREBhDdGjbyH6t0LHxqa-RB4iqDVJIKnH-gU.

Hendler, I., Goldenberg, R. L., Mercer, B. M., Iams, J. D., Meis, P. J., Moawad, A. H., MacPherson, C. A., Caritis, S. N., Miodovnik, M., Menard, K. M., Thurnau, G. R., & Sorokin, Y. (2005). The preterm prediction study: Association between maternal body mass index and spontaneous and indicated preterm birth. *American Journal of Obstetrics and Gynecology*, *192*(3), 882–886. https://doi.org/10.1016/j.ajog.2004.09.021

Herculano-Houzel, S. (2009). The human brain in numbers: A linearly scaled-up primate brain. *Frontiers in Human Neuroscience*, *3*. https://doi.org/10.3389/neuro.09.031.2009

Herrera, L., Al-Lal, M., & Mohamed, L. (2020). Academic achievement, self-concept, personality and emotional intelligence in primary education. Analysis by gender and cultural group. *Frontiers in Psychology*, *10*, 3075. https://doi.org/10.3389/fpsyg.2019.03075

Hicks, P., & Bolen, L. M. (1996). Review of the Woodcock-Johnson Psycho-Educational Battery-Revised. *Journal of School Psychology*, *34*(1), 93–102. https://doi.org/10.1016/0022-4405(95)00027-5

Hill, L. J. B., Shires, K., Allen, R., Crossley, K. L., Wood, M., Mason, D., & Waterman, A. (2021). Large-scale assessment of 7-11 year olds' cognitive and sensorimotor function within the Born in Bradford longitidual birth cohort. Welcome Open Research. https://wellcomeopenresearch.org/articles/6-53

Hobbs, G., & Vignoles, A. (2010). Is children's free school meal 'eligibility' a good proxy for family income? *British Educational Research Journal*, *36*(4), 673–690. https://doi.org/10.1080/01411920903083111

Hodel, A. S., Brumbaugh, J. E., Hunt, R. H., Van Den Heuvel, S. E., Wiltgen, A. M., & Thomas, K. M. (2019). Individual differences in ERP measures of executive function in early childhood: Relation to low-risk preterm birth and parent-reported behavior. *Child Neuropsychology*, *25*(7), 914–942. https://doi.org/10.1080/09297049.2018.1540690

Hodel, A. S., Brumbaugh, J. E., Morris, A. R., & Thomas, K. M. (2016). Hot executive function following moderate-to-late preterm birth: Altered delay discounting at 4 years of age. *Developmental Science*, *19*(2), 221–234. https://doi.org/10.1111/desc.12307

Hoffman, S., & Hatch, M. C. (1996). Stress, social support and pregnancy outcome: A reassessment based on recent research. *Paediatric and Perinatal Epidemiology*, *10*(4), 380–405. https://doi.org/10.1111/j.1365-3016.1996.tb00063.x

Holmes, J., & Adams, J. W. (2006). Working memory and children’s mathematical skills: Implications for mathematical development and mathematics curricula. *Educational Psychology*, *26*(3), 339–366. https://doi.org/10.1080/01443410500341056

Holmes, J., Hilton, K. A., Place, M., Alloway, T. P., Elliott, J. G., & Gathercole, S. E. (2014). Children with low working memory and children with ADHD: Same or different? *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00976

Houdt, C. A., Oosterlaan, J., Wassenaer-Leemhuis, A. G., Kaam, A. H., & Aarnoudse-Moens, C. S. H. (2019). Executive function deficits in children born preterm or at low birthweight: A meta-analysis. *Developmental Medicine & Child Neurology*, *61*(9), 1015–1024. https://doi.org/10.1111/dmcn.14213

Hu, Y., & Qian, Y. (2023). Gender, education expansion and intergenerational educational mobility around the world. *Nature Human Behaviour*, *7*(4), 583–595. https://doi.org/10.1038/s41562-023-01545-5

Hua, J., Barnett, A. L., Lin, Y., Guan, H., Sun, Y., Williams, G. J., Fu, Y., Zhou, Y., & Du, W. (2022). Association of gestational age at birth with subsequent neurodevelopment in early childhood: A national retrospective cohort study in China. *Frontiers in Pediatrics*, *10*, 860192. https://doi.org/10.3389/fped.2022.860192

Hubber, P. J., Gilmore, C., & Cragg, L. (2019). Mathematics students demonstrate superior visuo-spatial working memory to humanities students under conditions of low central executive processing load. *Journal of Numerical Cognition*, *5*(2), 189–219. https://doi.org/10.5964/jnc.v5i2.175

Huddy, C. L. J. (2001). Educational and behavioural problems in babies of 32-35 weeks gestation. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *85*(1), 23F – 28. https://doi.org/10.1136/fn.85.1.F23

Hughes, E. G., & Appel, B. (2016). The cell biology of CNS myelination. *Current Opinion in Neurobiology*, *39*, 93–100. https://doi.org/10.1016/j.conb.2016.04.013

Huijbregts, S. C. J., Warren, A. J., De Sonneville, L. M. J., & Swaab-Barneveld, H. (2008). Hot and cool forms of inhibitory control and externalizing behavior in children of mothers who smoked during pregnancy: An exploratory study. *Journal of Abnormal Child Psychology*, *36*(3), 323–333. https://doi.org/10.1007/s10802-007-9180-x

Hulme, C., Thomson, N., Muir, C., & Lawrence, A. (1984). Speech rate and the development of short-term memory span. *Journal of Experimental Child Psychology*, *38*(2), 241–253. https://doi.org/10.1016/0022-0965(84)90124-3

Hüppi, P. S., Warfield, S., Kikinis, R., Barnes, P. D., Zientara, G. P., Jolesz, F. A., Tsuji, M. K., & Volpe, J. J. (1998). Quantitative magnetic resonance imaging of brain development in premature and mature newborns. *Annals of Neurology*, *43*(2), 224–235. https://doi.org/10.1002/ana.410430213

Hurtado Suazo, J. A., García Reymundo, M., Calvo Aguilar, M. J., Ginovart Galiana, G., Jiménez Moya, A., Trincado Aguinagalde, M. J., & Demestre Guasch, X. (2014). Recomendaciones para el manejo perinatal y seguimiento del recién nacido prematuro tardío. *Anales de Pediatría*, *81*(5), 327.e1-327.e7. https://doi.org/10.1016/j.anpedi.2014.06.006

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *The Journal of Comparative Neurology*, *387*(2), 167–178. https://doi.org/10.1002/(SICI)1096-9861(19971020)387:2<167::AID-CNE1>3.0.CO;2-Z

Ibbotson, P., & Roque-Gutierrez, E. (2023). The development of working memory: Sex differences in accuracy and reaction times. *Journal of Cognition and Development*, *24*(4), 581–597. https://doi.org/10.1080/15248372.2023.2178437

Ibrahimi, D., Mendiola Santibañez, J. D., & Rodríguez-Reséndiz, J. (2023). Visual performance and perceptual–motor skills of late preterm children and healthy controls using the TVPS-3rd and VMI-6th editions. *Technologies*, *11*(2), 53. https://doi.org/10.3390/technologies11020053

Imbo, I., & Vandierendonck, A. (2007). The role of phonological and executive working memory resources in simple arithmetic strategies. *European Journal of Cognitive Psychology*, *19*(6), 910–933. https://doi.org/10.1080/09541440601051571

Inder, T. E., Warfield, S. K., Wang, H., Hüppi, P. S., & Volpe, J. J. (2005). Abnormal cerebral structure is present at term in premature infants. *Pediatrics*, *115*(2), 286–294. https://doi.org/10.1542/peds.2004-0326

Institute of Medicine. (2007). *Preterm birth: Causes, consequences, and prevention* (p. 11622). National Academies Press. https://doi.org/10.17226/11622

Ion, R., & Bernal, A. L. (2015). Smoking and preterm birth. *Reproductive Sciences*, *22*(8), 918–926. https://doi.org/10.1177/1933719114556486

Ishihara, M., & Imanaka, K. (2007). Motor preparation of manual aiming at a visual target manipulated in size, luminance contrast, and location. *Perception*, *36*(9), 1375–1390. https://doi.org/10.1068/p5776

Iuculano, T., Moro, R., & Butterworth, B. (2011). Updating working memory and arithmetical attainment in school. *Learning and Individual Differences*, *21*(6), 655–661. https://doi.org/10.1016/j.lindif.2010.12.002

Jackson, D. L., Gillaspy, J. A., & Purc-Stephenson, R. (2009). Reporting practices in confirmatory factor analysis: An overview and some recommendations. *Psychological Methods*, *14*(1), 6–23. https://doi.org/10.1037/a0014694

Jackson, M. I., Kiernan, K., & McLanahan, S. (2017). Maternal Education, Changing Family Circumstances, and Children’s Skill Development in the United States and UK. *The ANNALS of the American Academy of Political and Social Science*, *674*(1), 59–84. https://doi.org/10.1177/0002716217729471

Jackson, R. A., Gibson, K. A., Wu, Y. W., & Croughan, M. S. (2004). Perinatal outcomes in singletons following in vitro fertilization: A meta-Analysis. *Obstetrics & Gynecology*, *103*(3), 551–563. https://doi.org/10.1097/01.AOG.0000114989.84822.51

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Review of Educational Research*, *85*(4), 512–552. https://doi.org/10.3102/0034654314561338

Jaekel, J., Heuser, K. M., Zapf, A., Roll, C., Nuñez, F. B., Bartmann, P., Wolke, D., Felderhoff-Mueser, U., & Huening, B. (2021). Preterm children's long-term academic performance after adaptive computerized training: An efficacy and process analysis of a randomized controlled trial. *Pediatric Research*, *89*(6), 1492–1499. https://doi.org/10.1038/s41390-020-01114-w

Jager, K. J., Zoccali, C., MacLeod, A., & Dekker, F. W. (2008). Confounding: What it is and how to deal with it. *Kidney International*, *73*(3), 256–260. https://doi.org/10.1038/sj.ki.5002650

James, S.-N., Rommel, A.-S., Rijsdijk, F., Michelini, G., McLoughlin, G., Brandeis, D., Banaschewski, T., Asherson, P., & Kuntsi, J. (2020). Is association of preterm birth with cognitive-neurophysiological impairments and ADHD symptoms consistent with a causal inference or due to familial confounds? *Psychological Medicine*, *50*(8), 1278–1284. https://doi.org/10.1017/S0033291719001211

Jalovaara, M., Andersson, L., & Miettinen, A. (2022). Parity disparity: Educational differences in Nordic fertility across parities and number of reproductive partners. *Population Studies*, *76*(1), 119–136. https://doi.org/10.1080/00324728.2021.1887506

Jansen, L., Peeters-Scholte, C., Bruine, S. W., ven den Berg-Huysmans, A., van Klink, J., van Steenis, A., Rijken, M., Vermeiren, R., & Steggerda, S. (2020). Classroom-evaluated school performance at nine years of age after very preterm birth. *Early Human Development*, *140*, 104834. https://doi.org/10.1016/j.earlhumdev.2019.104834

Jansen, L., Peeters-Scholte, C. M. P. C. D., Berg-Huysmans, A. A. van den, Klink, J. M. M. van, Rijken, M., Egmond-van Dam, J. C. van, Vermeiren, R. R. J. M., & Steggerda, S. J. (2021). Longitudinal follow-up of children born preterm: Neurodevelopment from 2 to 10 years of age. *Frontiers in Pediatrics*, *9*, 674221. https://doi.org/10.3389/fped.2021.674221

Jarrold, C., Mackett, N., & Hall, D. (2014). Individual differences in processing speed mediate a relationship between working memory and children's classroom behaviour. *Learning and Individual Differences*, *30*, 92–97. https://doi.org/10.1016/j.lindif.2013.10.016

Jaworski, M., Janvier, A., Bourque, C. J., Mai-Vo, T.-A., Pearce, R., Synnes, A. R., & Luu, T. M. (2022). Parental perspective on important health outcomes of extremely preterm infants. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, 107(5), 495–500. https://doi.org/10.1136/archdischild-2021-322711

Jeneson, A., & Squire, L. R. (2012). Working memory, long-term memory, and medial temporal lobe function. *Learning & Memory*, *19*(1), 15–25. https://doi.org/10.1101/lm.024018.111

Jeng, S.-F., Chen, L.-C., & Yau, K.-I. T. (2002). Kinematic analysis of kicking movements in preterm infants with very low birth weight and full-term infants. *Physical Therapy*, *82*(2), 148–159. https://doi.org/10.1093/ptj/82.2.148

Jensen, A. R. (1993). Why is reaction time correlated with psychometric *g? Current Directions in Psychological Science*, *2*(2), 53–56. https://doi.org/10.1111/1467-8721.ep10770697

Ji, Z., & Guo, K. (2023). The association between working memory and mathematical problem solving: A three-level meta-analysis. *Frontiers in Psychology*, *14*, 1091126. https://doi.org/10.3389/fpsyg.2023.1091126

Jimerson, S., Egeland, B., & Teo, A. (1999). A longitudinal study of achievement trajectories: Factors associated with change. *Journal of Educational Psychology*, *91*(1), 116–126. https://doi.org/10.1037/0022-0663.91.1.116

Jin, J. H., Yoon, S. W., Song, J., Kim, S. W., & Chung, H. J. (2020). Long-term cognitive, executive, and behavioral outcomes of moderate and late preterm at school age. *Clinical and Experimental Pediatrics*, *63(6)*, 219–225. https://doi.org/10.3345/kjp.2019.00647

Johansson, A.-M., Domellöf, E., & Rönnqvist, L. (2014). Long-term influences of a preterm birth on movement organization and side specialization in children at 4-8 years of age: Movement Performance in Children Born Preterm. *Developmental Psychobiology*, n/a-n/a. https://doi.org/10.1002/dev.21206

Johnson, D., Policelli, J., Li, M., Dharamsi, A., Hu, Q., Sheridan, M. A., McLaughlin, K. A., & Wade, M. (2021). Associations of early-life threat and deprivation with executive functioning in childhood and adolescence: A systematic review and meta-analysis. *JAMA Pediatrics*, *175*(11), e212511. https://doi.org/10.1001/jamapediatrics.2021.2511

Johnson, S., Bamber, D., Bountziouka, V., Clayton, S., Cragg, L., Gilmore, C., Griffiths, R., Marlow, N., Simms, V., & Wharrad, H. J. (2019). Improving developmental and educational support for children born preterm: Evaluation of an e-learning resource for education professionals. *BMJ Open*, *9*(6), e029720. https://doi.org/10.1136/bmjopen-2019-029720

Johnson, S., Gilmore, C., Gallimore, I., Jaekel, J., & Wolke, D. (2015). The long-term consequences of preterm birth: What do teachers know? *Developmental Medicine & Child Neurology*, *57*(6), 571–577. https://doi.org/10.1111/dmcn.12683

Johnson, S., Hennessy, E., Smith, R., Trikic, R., Wolke, D., & Marlow, N. (2009). Academic attainment and special educational needs in extremely preterm children at 11 years of age: The EPICure study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *94*(4), F283–F289. https://doi.org/10.1136/adc.2008.152793

Johnson, S., & Marlow, N. (2011). Preterm birth and childhood psychiatric disorders. *Pediatric Research*, *69*(5 Part 2), 11R-18R. https://doi.org/10.1203/PDR.0b013e318212faa0

Johnson, S., & Marlow, N. (2017). Early and long-term outcome of infants born extremely preterm. *Archives of Disease in Childhood*, *102*(1), 97. https://doi.org/10.1136/archdischild-2015-309581

Johnson, S., Waheed, G., Manktelow, B. N., Field, D. J., Marlow, N., Draper, E. S., & Boyle, E. M. (2018). Differentiating the preterm phenotype: Distinct profiles of cognitive and behavioral development following late and moderately preterm birth. *The Journal of Pediatrics*, *193*, 85-92.e1. https://doi.org/10.1016/j.jpeds.2017.10.002

Johnson, S., & Wolke, D. (2013). Behavioural outcomes and psychopathology during adolescence. *Early Human Development*, *89*(4), 199–207. https://doi.org/10.1016/j.earlhumdev.2013.01.014

Johnson, S., Wolke, D., Hennessy, E., & Marlow, N. (2011). Educational outcomes in extremely preterm children: Neuropsychological correlates and predictors of attainment. *Developmental Neuropsychology*, *36*(1), 74–95. https://doi.org/10.1080/87565641.2011.540541

Jolliffe, I. T., & Cadima, J. (2016). Principal component analysis: A review and recent developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *374*(2065), 20150202. https://doi.org/10.1098/rsta.2015.0202

Jones, R. M., Clark, E. M., Broad, K., & Smit, E. (2018). Outcome following preterm intraventricular haemorrhage – what to tell the parents. *Paediatrics and Child Health*, *28*(9), 431–435. https://doi.org/10.1016/j.paed.2018.07.005

Jonides, J., Schumacher, E. H., Smith, E. E., Koeppe, R. A., Awh, E., Reuter-Lorenz, P. A., Marshuetz, C., & Willis, C. R. (1998). The role of parietal cortex in verbal working memory. *The Journal of Neuroscience*, *18*(13), 5026–5034. https://doi.org/10.1523/JNEUROSCI.18-13-05026.1998

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review*, *99*(1), 122–149. https://doi.org/10.1037/0033-295X.99.1.122

Kail, R. (1991). Developmental change in speed of processing during childhood and adolescence. *Psychological Bulletin*, *109*(3), 490–501. https://doi.org/10.1037/0033-2909.109.3.490

Kail, R. (1992). Processing speed, speech rate, and memory. *Developmental Psychology*, *28*(5), 899–904. https://doi.org/10.1037/0012-1649.28.5.899

Kail, R., & Hall, L. K. (1994). Processing speed, naming speed, and reading. *Developmental Psychology*, *30*(6), 949–954. https://doi.org/10.1037/0012-1649.30.6.949

Kail, R., & Salthouse, T. A. (1994). Processing speed as a mental capacity. *Acta Psychologica*, *86*(2–3), 199–225. https://doi.org/10.1016/0001-6918(94)90003-5

Kallen, K. (2001). The impact of maternal smoking during pregnancy on delivery outcome. *The European Journal of Public Health*, *11*(3), 329–333. https://doi.org/10.1093/eurpub/11.3.329

Kamath, B. D., Todd, J. K., Glazner, J. E., Lezotte, D., & Lynch, A. M. (2009). Neonatal outcomes after elective cesarean delivery. *Obstetrics & Gynecology*, *113*(6), 1231–1238. https://doi.org/10.1097/AOG.0b013e3181a66d57

Kamath-Rayne, B. D., Rozance, P. J., Goldenberg, R. L., & Jobe, A. H. (2016). Antenatal corticosteroids beyond 34 weeks gestation: What do we do now? *American Journal of Obstetrics and Gynecology*, *215*(4), 423–430. https://doi.org/10.1016/j.ajog.2016.06.023

Kandel, D. B., Griesler, P. C., & Schaffran, C. (2009). Educational attainment and smoking among women: Risk factors and consequences for offspring. *Drug and Alcohol Dependence*, *104*, S24–S33. https://doi.org/10.1016/j.drugalcdep.2008.12.005

Kanopka, K., Claro, S., Loeb, S., West, M., & Fricke, H. (2024). Are changes in reported social-emotional skills just noise? The predictive power of longitudinal differences in self-reports. *AERA Open*, *10*, 23328584241233277. https://doi.org/10.1177/23328584241233277

Karmiloff-Smith, A. (1998). Development itself is the key to understanding developmental disorders. *Trends in Cognitive Sciences*, *2*(10), 389–398. https://doi.org/10.1016/S1364-6613(98)01230-3

Karnati, S., Kollikonda, S., & Abu-Shaweesh, J. (2020). Late preterm infants – Changing trends and continuing challenges. *International Journal of Pediatrics and Adolescent Medicine*, *7*(1), 38–46. https://doi.org/10.1016/j.ijpam.2020.02.006

Karr, J. E., Areshenkoff, C. N., Rast, P., Hofer, S. M., Iverson, G. L., & Garcia-Barrera, M. A. (2018). The unity and diversity of executive functions: A systematic review and re-analysis of latent variable studies. *Psychological Bulletin*, *144*(11), 1147–1185. https://doi.org/10.1037/bul0000160

Kaufmann, A. S., & Kaufmann, N. L. (1998). *K-TEA : Kaufman test of Educational Achievement: Brief form.* American Guidance Service.

Kaul, Y. F., Rosander, K., Grönqvist, H., Strand Brodd, K., Hellström-Westas, L., & von Hofsten, C. (2019). Reaching skills of infants born very preterm predict neurodevelopment at 2.5 years. *Infant Behavior and Development*, *57*, 101333. https://doi.org/10.1016/j.infbeh.2019.101333

Ke, L., Barnett, A. L., Wang, Y., Duan, W., Hua, J., & Du, W. (2021). Discrepancies between parent and teacher reports of motor competence in 5–10-year-old children with and without suspected Developmental Coordination Disorder. *Children*, *8*(11), 1028. https://doi.org/10.3390/children8111028

Kelly, C. E., Cheong, J. L. Y., Gabra Fam, L., Leemans, A., Seal, M. L., Doyle, L. W., Anderson, P. J., Spittle, A. J., & Thompson, D. K. (2016). Moderate and late preterm infants exhibit widespread brain white matter microstructure alterations at term-equivalent age relative to term-born controls. *Brain Imaging and Behavior*, *10*(1), 41–49. https://doi.org/10.1007/s11682-015-9361-0

Kelly, C. E., Thompson, D. K., Chen, J., Josev, E. K., Pascoe, L., Spencer-Smith, M. M., Adamson, C., Nosarti, C., Gathercole, S., Roberts, G., Lee, K. J., Doyle, L. W., Seal, M. L., & Anderson, P. J. (2020). Working memory training and brain structure and function in extremely preterm or extremely low birth weight children. *Human Brain Mapping*, *41*(3), 684–696. https://doi.org/10.1002/hbm.24832

Kent, S., Wanzek, J., Petscher, Y., Al Otaiba, S., & Kim, Y.-S. (2014). Writing fluency and quality in kindergarten and first grade: The role of attention, reading, transcription, and oral language. Reading and Writing, 27(7), 1163–1188. https://doi.org/10.1007/s11145-013-9480-1

Kerstjens, J. M., de Winter, A. F., Bocca-Tjeertes, I. F., ten Vergert, E. M. J., Reijneveld, S. A., & Bos, A. F. (2011). Developmental Delay in Moderately Preterm-Born Children at School Entry. *The Journal of Pediatrics*, *159*(1), 92–98. https://doi.org/10.1016/j.jpeds.2010.12.041

Kesmodel, U., Olsen, S. F., & Secher, N. J. (2000). Does alcohol increase the risk of preterm delivery? *Epidemiology*, *11*(5) , 512–518. https://doi.org/10.1097/00001648-200009000-00005

Khan, K., Petrou, S., Dritsaki, M., Johnson, S., Manktelow, B., Draper, E., Smith, L., Seaton, S., Marlow, N., Dorling, J., Field, D., & Boyle, E. (2015). Economic costs associated with moderate and late preterm birth: A prospective population-based study. *BJOG: An International Journal of Obstetrics & Gynaecology*, *122*(11), 1495–1505. https://doi.org/10.1111/1471-0528.13515

Kinney, H. C. (2006). The near-term (late preterm) human brain and risk for periventricular leukomalacia: A review. *Optimizing Care and Outcomes for Late Preterm (Near-Term) Infants: Part 2*, *30*(2), 81–88. https://doi.org/10.1053/j.semperi.2006.02.006

Klumper, J., Ravelli, A. C., Roos, C., & Oudijk, M. A. (2020). Low socio-economic status is associated with a higher rate of spontaneous preterm birth. *American Journal of Obstetrics and Gynecology*, *222*(1), S96. https://doi.org/10.1016/j.ajog.2019.11.141

Knudson, D. V., & Lindsey, C. (2014). Type I and Type II errors in correlations of various sample sizes. *Comprehensive Psychology*, *3*, 03.CP.3.1. https://doi.org/10.2466/03.CP.3.1

Köck, K., Köck, F., Klein, K., Bancher-Todesca, D., & Helmer, H. (2010). Diabetes mellitus and the risk of preterm birth with regard to the risk of spontaneous preterm birth. *The Journal of Maternal-Fetal & Neonatal Medicine*, *23*(9), 1004–1008. https://doi.org/10.3109/14767050903551392

Koenigs, M., Barbey, A. K., Postle, B. R., & Grafman, J. (2009). Superior parietal cortex is critical for the manipulation of information in working memory. *The Journal of Neuroscience*, *29*(47), 14980–14986. https://doi.org/10.1523/JNEUROSCI.3706-09.2009

Kofler, M. J., Singh, L. J., Soto, E. F., Chan, E. S. M., Miller, C. E., Harmon, S. L., & Spiegel, J. A. (2020). Working memory and short-term memory deficits in ADHD: A bifactor modeling approach. *Neuropsychology*, *34*(6), 686–698. https://doi.org/10.1037/neu0000641

Kostović, I., & Judaš, M. (2010). The development of the subplate and thalamocortical connections in the human foetal brain. *Acta Paediatrica*, *99*(8), 1119–1127. https://doi.org/10.1111/j.1651-2227.2010.01811.x

Koullali, B., van Zijl, M. D., Kazemier, B. M., Oudijk, M. A., Mol, B. W. J., Pajkrt, E., & Ravelli, A. C. J. (2020). The association between parity and spontaneous preterm birth: A population based study. *BMC Pregnancy and Childbirth*, *20*(1), 233. https://doi.org/10.1186/s12884-020-02940-w

Kuhn, S., Gritti, L., Crooks, D., & Dombrowski, Y. (2019). Oligodendrocytes in development, myelin generation and beyond. *Cells*, *8*(11), 1424. https://doi.org/10.3390/cells8111424

Kuhtz-Buschbeck, J. P., Stolze, H., Jöhnk, K., Boczek-Funcke, A., & Illert, M. (1998). Development of prehension movements in children: A kinematic study.

Experimental Brain Research, *122*(4), 424–432. https://doi.org/10.1007/s002210050530

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?! *Intelligence*, *14*(4), 389–433. https://doi.org/10.1016/S0160-2896(05)80012-1

Kyrklund-Blomberg, N. B., Granath, F., & Cnattingius, S. (2005). Maternal smoking and causes of very preterm birth. *Acta Obstetricia et Gynecologica Scandinavica*, *84*(6), 572–577. https://doi.org/10.1111/j.0001-6349.2005.00848.x

Lawder, R., Whyte, B., Wood, R., Fischbacher, C., & Tappin, D. M. (2019). Impact of maternal smoking on early childhood health: A retrospective cohort linked dataset analysis of 697 003 children born in Scotland 1997–2009. *BMJ Open*, *9*(3), e023213. https://doi.org/10.1136/bmjopen-2018-023213

Lee, B., Kim, J. S., & Chung, C. K. (2022). Parietal and medial temporal lobe interactions in working memory goal-directed behavior. *Cortex*, *150*, 126–136. https://doi.org/10.1016/j.cortex.2022.02.005

Lee, C. S. C., Pei, J., Andrew, G., A Kerns, K., & Rasmussen, C. (2017). Effects of working memory training on children born preterm. *Applied Neuropsychology: Child*, *6*(4), 281–296. https://doi.org/10.1080/21622965.2016.1161513

Lee, K., Bull, R., & Ho, R. M. H. (2013). Developmental changes in executive functioning. *Child Development*, *84*(6), 1933–1953. https://doi.org/10.1111/cdev.12096

Lehrl, S., Evangelou, M., & Sammons, P. (2020). The home learning environment and its role in shaping children’s educational development. *School Effectiveness and School Improvement*, *31*(1), 1–6. https://doi.org/10.1080/09243453.2020.1693487

Lehto, J. E., Juujärvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology*, *21*(1), 59–80. https://doi.org/10.1348/026151003321164627

Lépine, R. L., Parrouillet, P., & Camos, V. (2005). What makes working memory spans so predictive of high-level cognition? *Psychonomic Bulletin & Review*, *12*(1), 165–170. https://doi.org/10.3758/BF03196363

Lewis, J., & West, A. (2017). Early childhood education and care in England under austerity: Continuity or change in political ideas, policy goals, availability, affordability and quality in a childcare market? *Journal of Social Policy*, *46*(2), 331–348. https://doi.org/10.1017/S0047279416000647

Li, X., Zhang, W., Lin, J., Liu, H., Yang, Z., Teng, Y., Duan, S., Li, Y., Xie, Y., Lin, X., Xie, L., Peng, Q., Huang, J., Chen, J., Duan, W., Luo, J., & Zhang, J. (2018). Preterm birth, low birthweight, and small for gestational age among women with preeclampsia: Does maternal age matter? *Pregnancy Hypertension*, *13*, 260–266. https://doi.org/10.1016/j.preghy.2018.07.004

Libuy, N., Gilbert, R., Mc Grath-Lone, L., Blackburn, R., Etoori, D., & Harron, K. (2023). Gestational age at birth, chronic conditions and school outcomes: A population-based data linkage study of children born in England. *International Journal of Epidemiology*, *52*(1), 132–143. https://doi.org/10.1093/ije/dyac105

Linder, N., Hiersch, L., Fridman, E., Klinger, G., Lubin, D., Kouadio, F., & Nir Melamed. (2017). Post-term pregnancy is an independent risk factor for neonatal morbidity even in low-risk singleton pregnancies. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *102*(4), F286. https://doi.org/10.1136/archdischild-2015-308553

Lindström, K., Lindblad, F., & Hjern, A. (2011). Preterm Birth and attention-deficit/hyperactivity disorder in schoolchildren. *Pediatrics*, *127*(5), 858–865. https://doi.org/10.1542/peds.2010-1279

Linsell, L., Johnson, S., Wolke, D., O'Reilly, H., Morris, J. K., Kurinczuk, J. J., & Marlow, N. (2018). Cognitive trajectories from infancy to early adulthood following birth before 26 weeks of gestation: A prospective, population-based cohort study. *Archives of Disease in Childhood*, *103*(4), 363–370. https://doi.org/10.1136/archdischild-2017-313414

Lipkind, H. S., Slopen, M. E., Pfeiffer, M. R., & McVeigh, K. H. (2012). School-age outcomes of late preterm infants in New York City. *American Journal of Obstetrics and Gynecology*, *206*(3), 222.e1-222.e6. https://doi.org/10.1016/j.ajog.2012.01.007

Liu, B., Xu, G., Sun, Y., Qiu, X., Ryckman, K. K., Yu, Y., Snetselaar, L. G., & Bao, W. (2020). Maternal cigarette smoking before and during pregnancy and the risk of preterm birth: A dose–response analysis of 25 million mother–infant pairs.

PLOS Medicine, *17*(8), e1003158. https://doi.org/10.1371/journal.pmed.1003158

Liu, L., Wang, L., Yang, W., Ni, W., Jin, L., Liu, J., & Ren, A. (2019). Gestational hypertension and pre-eclampsia and risk of spontaneous premature rupture of membranes: A population-based cohort study. *International Journal of Gynecology & Obstetrics*, *147*(2), 195–201. https://doi.org/10.1002/ijgo.12943

Liu, M.-X., Li, H.-F., Wu, M.-Q., Geng, S.-S., Ke, L., Lou, B.-W., Du, W., & Hua, J. (2023). Associations of preterm and early-term birth with suspected developmental coordination disorder: A national retrospective cohort study in children aged 3–10 years. *World Journal of Pediatrics*, *19*(3), 261–272. https://doi.org/10.1007/s12519-022-00648-9

Liutsko, L., Muiños, R., Tous Ral, J. M., & Contreras, M. J. (2020). Fine motor precision tasks: Sex differences in performance with and without visual guidance across different age groups. *Behavioral Sciences*, *10*(1), 36. https://doi.org/10.3390/bs10010036

Lock, N. E., DeBoer, M. D., Scharf, R. J., & Miller, S. E. (2024). Academic performance in moderately and late preterm children in the United States: Are they catching up? *Journal of Perinatology*. https://doi.org/10.1038/s41372-024-01938-y

Loe, I. M., Feldman, H. M., & Huffman, L. C. (2014). Executive function mediates effects of gestational age on functional outcomes and behavior in preschoolers. *Journal of Developmental & Behavioral Pediatrics*, *35*(5), 323–333. https://doi.org/10.1097/DBP.0000000000000063

Loe, I. M., Heller, N. A., & Chatav, M. (2019). Behavior problems and executive function impairments in preterm compared to full term preschoolers. *Early Human Development*, *130*, 87–95. https://doi.org/10.1016/j.earlhumdev.2019.01.014

Loftin, R. W., Habli, M., Snyder, C. C., Cormier, C. M., Lewis, D. F., & Defranco, E. A. (2010). Late preterm birth. *Reviews in Obstetrics & Gynecology*, *3*(1), 10–19.

Logan, S. W., Ross, S. M., Chee, K., Stodden, D. F., & Robinson, L. E. (2018). Fundamental motor skills: A systematic review of terminology. *Journal of Sports Sciences*, *36*(7), 781–796. https://doi.org/10.1080/02640414.2017.1340660

Logie, R. H. (2011). The functional organization and capacity limits of working memory. *Current Directions in Psychological Science*, *20*(4), 240–245. https://doi.org/10.1177/0963721411415340

López Hernández, A. M., Fernández, M. D. L., & Padilla Muñoz, E. M. (2022). Executive functions, child development and social functioning in premature preschoolers. A multi-method approach. *Cognitive Development*, *62*, 101173. https://doi.org/10.1016/j.cogdev.2022.101173

Louis, D., Oberoi, S., Ricci, M. F., Pylypjuk, C., Alvaro, R., Seshia, M., de Cabo, C., Moddemann, D., Lix, L. M., Garland, A., & Ruth, C. A. (2022). School readiness among children born preterm in Manitoba, Canada. *JAMA Pediatrics*, *176*(10), 1010. https://doi.org/10.1001/jamapediatrics.2022.2758

Luke, D. A. (2020). *Multilevel modeling* (Second edition). SAGE. https://doi.org/10.4135/9781412985147

Luke, N., & O'Higgins, A. (2018). Is the care system to blame for the poor educational outcomes of children looked after? Evidence from a systematic review and national database analysis. *Children Australia*, *43*(2), 135–151. https://doi.org/10.1017/cha.2018.22

Luo, Z., Jose, P. E., Huntsinger, C. S., & Pigott, T. D. (2007). Fine motor skills and mathematics achievement in East Asian American and European American kindergartners and first graders. *British Journal of Developmental Psychology*, *25*(4), 595–614. https://doi.org/10.1348/026151007X185329

Luoma, L., Herrgård, E., & Martikainen, A. (1998). Neuropsychological analysis of the visuomotor problems in children born preterm at 32 weeks of gestation: A 5-year prospective follow-up. *Developmental Medicine & Child Neurology*, *40*(1), 21–30. https://doi.org/10.1111/j.1469-8749.1998.tb15352.x

Mack, C., & Westreich, D. (2018). Managing missing data in patient registries: Addendum to registries for evaluating patient outcomes: A user's guide. In *Agency for Healthcare Research and Quality (US)* (Third Edition). https://www.ncbi.nlm.nih.gov/books/NBK493614/

MacKay, D. F., Smith, G. C. S., Dobbie, R., & Pell, J. P. (2010). Gestational age at delivery and special educational need: Retrospective cohort study of 407,503 school children. *PLoS Medicine*, *7*(6), e1000289. https://doi.org/10.1371/journal.pmed.1000289

Majerus, S., & Cowan, N. (2016). The nature of verbal short-term impairment in dyslexia: The importance of serial order. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01522

Malpique, A. A., Pino-Pasternak, D., & Roberto, M. S. (2020). Writing and reading performance in Year 1 Australian classrooms: Associations with handwriting automaticity and writing instruction. *Reading and Writing*, *33*(3), 783–805. https://doi.org/10.1007/s11145-019-09994-z

Marks, G. N. (2017). Is SES really that important for educational outcomes in Australia? A review and some recent evidence. *The Australian Educational Researcher*, *44*(2), 191–211. https://doi.org/10.1007/s13384-016-0219-2

Marlow, N., Hennessy, E. M., Bracewell, M. A., Wolke, D., & for the EPICure Study Group. (2007). Motor and executive function at 6 years of age after extremely preterm birth. *Pediatrics*, *120*(4), 793–804. https://doi.org/10.1542/peds.2007-0440

Martin, J. A., & Osterman, M. J. K. (2018). Describing the increase in preterm births in the United States, 2014-2016. *NCHS Data Brief*, *312*, 1–8.

Martindale, N. (2022). Austerity, outsourcing and the state school workforce: Trends from 20,000 English state schools. *British Journal of Sociology of Education*, *43*(3), 451–474. https://doi.org/10.1080/01425692.2021.2018650

Martínez-Nadal, S., & Bosch, L. (2020). Cognitive and learning outcomes in late preterm infants at school age: A systematic review. *International Journal of Environmental Research and Public Health*, *18*(1), 74. https://doi.org/10.3390/ijerph18010074

Marvin-Dowle, K., Kilner, K., & Burley, V. J. (2018). Impact of adolescent age on maternal and neonatal outcomes in the Born in Bradford cohort. *BMJ Open*, *8*(3), e016258. https://doi.org/10.1136/bmjopen-2017-016258

Matthews, L. G., Walsh, B. H., Knutsen, C., Neil, J. J., Smyser, C. D., Rogers, C. E., & Inder, T. E. (2018). Brain growth in the NICU: Critical periods of tissue-specific expansion. *Pediatric Research*, *83*(5), 976–981. https://doi.org/10.1038/pr.2018.4

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2003). The role of working memory in motor learning and performance. *Consciousness and Cognition*, *12*(3), 376–402. https://doi.org/10.1016/S1053-8100(03)00005-9

Mayes, S. D., & Calhoun, S. L. (2007). Learning, attention, writing, and processing speed in typical children and children with ADHD, autism, anxiety, depression, and oppositional-defiant disorder. *Child Neuropsychology*, *13*(6), 469–493. https://doi.org/10.1080/09297040601112773

Mayes, S. D., Calhoun, S. L., Bixler, E. O., & Zimmerman, D. N. (2009). IQ and neuropsychological predictors of academic achievement. *Learning and Individual Differences*, *19*(2), 238–241. https://doi.org/10.1016/j.lindif.2008.09.001

Mboya, I. B., Mahande, M. J., Obure, J., & Mwambi, H. G. (2021). Predictors of singleton preterm birth using multinomial regression models accounting for missing data: A birth registry-based cohort study in northern Tanzania. *PLOS ONE*, *16*(4), e0249411. https://doi.org/10.1371/journal.pone.0249411

McAuley, T., & White, D. A. (2011). A latent variables examination of processing speed, response inhibition, and working memory during typical development. *Journal of Experimental Child Psychology*, *108*(3), 453–468. https://doi.org/10.1016/j.jecp.2010.08.009

McClelland, M. M., & Cameron, C. E. (2019). Developing together: The role of executive function and motor skills in children’s early academic lives. *Early Childhood Research Quarterly*, *46*, 142–151. https://doi.org/10.1016/j.ecresq.2018.03.014

McCutchen, D. (1996). A capacity theory of writing: Working memory in composition. *Educational Psychology Review*, *8*(3), 299–325. https://doi.org/10.1007/BF01464076

McGrew, K. S., & Pehl, J. (1988). Prediction of future achievement by the Woodcock-Johnson Psycho-Educational Battery and the WISC-R. *Journal of School Psychology*, *26*(3), 275–281. https://doi.org/10.1016/0022-4405(88)90006-4

McHale, P., Fahy, K., Pennington, A., Schlüter, D. K., Barr, B., & Taylor-Robinson, D. (2025). How do socioeconomic inequalities and preterm birth interact to modify health and education outcomes? A narrative systematic review. *BMJ Open*, *15*(1), e084147. https://doi.org/10.1136/bmjopen-2024-084147

McHale, P., Maudsley, G., Pennington, A., Schlüter, D. K., Barr, B., Paranjothy, S., & Taylor-Robinson, D. (2022). Mediators of socioeconomic inequalities in preterm birth: A systematic review. *BMC Public Health*, *22*(1), 1134. https://doi.org/10.1186/s12889-022-13438-9

McIntire, D. D., & Levono, K. J. (2008). Neonatal mortality and morbidity in late preterm births. *AAP Grand Rounds*, *19*(6), 61–62. https://doi.org/10.1542/gr.19-6-61

McPhillips, M., & Jordan-Black, J. (2007). The effect of social disadvantage on motor development in young children: A comparative study. *Journal of Child Psychology and Psychiatry*, *48*(12), 1214–1222. https://doi.org/10.1111/j.1469-7610.2007.01814.x

Medwell, J., Strand, S., & Wray, D. (2009). The links between handwriting and composing for Y6 children. *Cambridge Journal of Education*, *39*(3), 329–344. https://doi.org/10.1080/03057640903103728

Mekic, N., Selimovic, A., Cosickic, A., Mehmedovic, M., Hadzic, D., Zulic, E., Mustafic, S., & Serak, A. (2023). Predictors of adverse short-term outcomes in late preterm infants. *BMC Pediatrics*, *23*(1), 298. https://doi.org/10.1186/s12887-023-04112-z

Messer, D., Bernardi, M., Botting, N., Hill, E. L., Nash, G., Leonard, H. C., & Henry, L. A. (2018). An exploration of the factor structure of executive functioning in children. *Frontiers in Psychology*, *9*, 1179. https://doi.org/10.3389/fpsyg.2018.01179

Miall, R. C., Weir, D. J., & Stein, J. F. (1993). Intermittency in human manual tracking tasks. *Journal of Motor Behavior*, *25*(1), 53–63. https://doi.org/10.1080/00222895.1993.9941639

Miall, R. C., & Wolpert, D. M. (1996). Forward Models for Physiological Motor Control. *Neural Networks*, *9*(8), 1265–1279. https://doi.org/10.1016/S0893-6080(96)00035-4

Miller, L. T., & Vernon, P. A. (1996). Intelligence, reaction time, and working memory in 4- to 6-year-old children. *Intelligence*, *22*(2), 155–190. https://doi.org/10.1016/S0160-2896(96)90014-8

Miranda-Herrero, M. C., Vázquez-López, M., Barredo-Valderrama, E., de Castro de Castro, P., Chacón-Pascual, A., & Pascual-Pascual, S. I. (2021). Visuospatial functions in preterm schoolchildren without cognitive delay: Using Pascual's Graphomotor test as a screening method. *Early Human Development*, *161*, 105454. https://doi.org/10.1016/j.earlhumdev.2021.105454

Mirowsky, J., & Ross, C. E. (2017). *Education, social status, and health* (1st ed.). Routledge. https://doi.org/10.4324/9781351328081

Missiuna, C., Pollock, N., Campbell, W., DeCola, C., Hecimovich, C., Sahagian Whalen, S., Siemon, J., Song, K., Gaines, R., Bennett, S., McCauley, D., Stewart, D., Cairney, J., Dix, L., & Camden, C. (2017). Using an innovative model of service delivery to identify children who are struggling in school. *British Journal of Occupational Therapy*, *80*(3), 145–154. https://doi.org/10.1177/0308022616679852

Mitha, A., Chen, R., Razaz, N., Johansson, S., Stephansson, O., Altman, M., & Bolk, J. (2024). Neurological development in children born moderately or late preterm: National cohort study. *BMJ*, e075630. https://doi.org/10.1136/bmj-2023-075630

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Montagna, A., & Nosarti, C. (2016). Socio-emotional development following very preterm birth: Pathways to psychopathology. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.00080

Mooney, K. E., Pickett, K. E., Shire, K., Allen, R. J., & Waterman, A. H. (2022). Socioeconomic disadvantage and ethnicity are associated with large differences in children's working memory ability: Analysis of a prospective birth cohort study following 13,500 children. *BMC Psychology*, *10*(1), 67. https://doi.org/10.1186/s40359-022-00773-0

Moore, T., Hennessy, E. M., Myles, J., Johnson, S. J., Draper, E. S., Costeloe, K. L., & Marlow, N. (2012). Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: The EPICure studies. *BMJ*, *345*(dec04 3), e7961–e7961. https://doi.org/10.1136/bmj.e7961

Morag, I., Bart, O., Raz, R., Shayevitz, S., Simchen, M. J., Strauss, T., Zangen, S., Kuint, J., & Gabis, L. (2013). Developmental characteristics of late preterm infants at six and twelve months: A prospective study. *Infant Behavior and Development*, *36*(3), 451–456. https://doi.org/10.1016/j.infbeh.2013.03.010

Morell, P., & Quarles, R. H. (1999). Biology of myelin. In G. J. Siegel (Ed.), *Basic neurochemistry: Molecular, cellular and medical aspects* (6. ed). Lippincott Williams & Wilkins.

Morey, C. C. (2018). The case against specialized visual-spatial short-term memory. *Psychological Bulletin*, *144*(8), 849–883. https://doi.org/10.1037/bul0000155

Morin, F., Chabanas, M., Courtecuisse, H., & Payan, Y. (2017). Biomechanical modeling of brain soft tissues for medical applications. In *Biomechanics of Living Organs* (pp. 127–146). Elsevier. https://doi.org/10.1016/B978-0-12-804009-6.00006-7

Morse, S. B., Zheng, H., Tang, Y., & Roth, J. (2009). Early school-age outcomes of late preterm infants. *Pediatrics*, *123*(4), e622–e629. https://doi.org/10.1542/peds.2008-1405

Moster, D., Lie, R. T., & Markestad, T. (2008). Long-term medical and social consequences of preterm birth. *New England Journal of Medicine*, *359*(3), 262–273. https://doi.org/10.1056/NEJMoa0706475

Mrzljak, L., Uylings, H. B. M., Kostovic, I., & van Eden, C. G. (1988). Prenatal development of neurons in the human prefrontal cortex: I. A qualitative Golgi study. *Journal of Comparative Neurology*, *271*(3), 355–386. https://doi.org/10.1002/cne.902710306

Muhr, J., Arbor, T. C., & Ackerman, K. M. (2024). Embryology, gastrulation. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK554394/

Mulder, H., Pitchford, N. J., Hagger, M. S., & Marlow, N. (2009). Development of executive function and attention in preterm children: A systematic review. *Developmental Neuropsychology*, *34*(4), 393–421. https://doi.org/10.1080/87565640902964524

Mulder, H., Pitchford, N. J., & Marlow, N. (2010). Processing speed and working memory underlie academic attainment in very preterm children. *Archives of*

Disease in Childhood - Fetal and Neonatal Edition, *95*(4), F267–F272. https://doi.org/10.1136/adc.2009.167965

Mulder, H., Pitchford, N. J., & Marlow, N. (2011). Processing speed mediates executive function difficulties in very preterm children in middle childhood. *Journal of the International Neuropsychological Society*, *17*(3), 445–454. https://doi.org/10.1017/S1355617711000373

Munakata, S., Okada, T., Okahashi, A., Yoshikawa, K., Usukura, Y., Makimoto, M., Hosono, S., Takahashi, S., Mugishima, H., & Okuhata, Y. (2013). Gray matter volumetric MRI differences late-preterm and term infants. *Brain and Development*, *35*(1), 10–16. https://doi.org/10.1016/j.braindev.2011.12.011

Murphy, M. A., Willén, C., & Sunnerhagen, K. S. (2011). Kinematic variables quantifying upper-reaching and drinking from a glass. *Neurorehabilitation and Neural Repair*, *25*(1), 71–80. https://doi.org/10.1177/1545968310370748

Murray, S. R., Stock, S. J., Cowan, S., Cooper, E. S., & Norman, J. E. (2018). Spontaneous preterm birth prevention in multiple pregnancy. *The Obstetrician & Gynaecologist*, *20*(1), 57–63. https://doi.org/10.1111/tog.12460

Naber, M., & Murphy, P. (2020). Pupillometric investigation into the speed-accuracy trade-off in a visuo-motor aiming task. *Psychophysiology*, *57*(3). https://doi.org/10.1111/psyp.13499

Nagengast, B., & Marsh, H. W. (2012). Big fish in little ponds aspire more: Mediation and cross-cultural generalizability of school-average ability effects on self-concept and career aspirations in science. *Journal of Educational Psychology*, *104*(4), 1033–1053. https://doi.org/10.1037/a0027697

National Institute for Health and Care Excellence. (2017). *Developmental follow-up of children and young people born preterm.* National Institute for Health and Care Excellence (NICE). https://www.nice.org.uk/guidance/ng72/resources/developmental-followup-of-children-and-young-people-born-preterm-pdf-1837630868677

Nepomnyaschy, L., Hegyi, T., Ostfeld, B. M., & Reichman, N. E. (2012). Developmental outcomes of late-preterm infants at 2 and 4 years. *Maternal and Child Health Journal*, *16*(8), 1612–1624. https://doi.org/10.1007/s10995-011-0853-2

Nieuwenhuis, J., & Chiang, Y.-L. (2021). Oh, the education (you think) you'll have! Relative deprivation and students' academic expectations, aspirations, and attainment. *British Journal of Sociology of Education*, *42*(7), 1037–1054. https://doi.org/10.1080/01425692.2021.1959300

Noble, S., McLellan, D., Plunkett, E., Gutacker, N., Silk, M., & Wright, G. (2019). *The English Indices of Deprivation 2019 Research report*. Ministry of Housing, Communities and Local Government. https://assets.publishing.service.gov.uk/media/5d8b364ced915d03709e3cf2/IoD2019_Research_Report.pdf

Nobre, A. D. P., Rodrigues, J. D. C., Sbicigo, J. B., Piccolo, L. D. R., Zortea, M., Junior, S. D., & De Salles, J. F. (2013). Tasks for assessment of the episodic buffer: A systematic review. *Psychology & Neuroscience*, *6*(3), 331–343. https://doi.org/10.3922/j.psns.2013.3.10

Norris, T., Johnson, W., Petherick, E., Cameron, N., Oddie, S., Johnson, S., Wright, J., Draper, E., & Baker, P. N. (2018). Investigating the relationship between fetal growth and academic attainment: Secondary analysis of the Born in Bradford (BiB) cohort. *International Journal of Epidemiology*, *47*(5), 1475–1484. https://doi.org/10.1093/ije/dyy157

Odd, D., Emond, A., & Whitelaw, A. (2012). Long-term cognitive outcomes of infants born moderately and late preterm: Cognitive outcomes of late preterm infants. *Developmental Medicine & Child Neurology*, *54*(8), 704–709. https://doi.org/10.1111/j.1469-8749.2012.04315.x

Odd, D., Evans, D., & Emond, A. (2016). Preterm Birth, Age at School Entry and Long Term Educational Achievement. *PLOS ONE*, *11*(5), Article 5. https://doi.org/10.1371/journal.pone.0155157

Odd, D., Evans, D., & Emond, A. M. (2019). Prediction of school outcome after preterm birth: A cohort study. *Archives of Disease in Childhood*, *104*(4), 348–353. https://doi.org/10.1136/archdischild-2018-315441

Odd, D., Lingam, R., Emond, A., & Whitelaw, A. (2013). Movement outcomes of infants born moderate and late preterm. *Acta Paediatrica*, *102*(9), 876–882. https://doi.org/10.1111/apa.12320

OECD. (2002). *Understanding the brain: Towards a new learning science*. OECD. https://doi.org/10.1787/9789264174986-en

Office for National Statistics. (2022). *Birth characteristics in England and Wales: 2020*. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthcharacteristicsinenglandandwales

Office for National Statistics. (2023a). *Annual population survey (APS) QMI*. Office for National Statistics. https://www.nomisweb.co.uk/reports/lmp/la/1946157124/report.aspx?town=bradford

Office for National Statistics. (2023b). *How life has changed in Derby: Census*. Crown Copyright. https://www.ons.gov.uk/visualisations/censusareachanges/E06000015/

Office for National Statistics. (2024). Births in England and Wales: summary tables. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/datasets/birthsummarytables

Ofsted. (2014). *Are you ready? Good practice in school readiness*. Crown Copyright. https://assets.publishing.service.gov.uk/media/5a817e64ed915d74e6232919/Are_you_ready_Good_practice_in_school_readiness.pdf

Ogden, T., Olseth, A., Sørlie, M.-A., & Hukkelberg, S. (2023). Teacher's assessment of gender differences in school performance, social skills, and externalizing behavior from fourth through seventh grade. *Journal of Education*, *203*(1), 211–221. https://doi.org/10.1177/00220574211025071

Olive, T. (2012). Writing and working memory. In E. L. Grigorenko, E. Mambrino, & D. D. Preiss (Eds.), *Writing* (1st ed.). Psychology Press. https://doi.org/10.4324/9780203808481

Omizzolo, C., Scratch, S. E., Stargatt, R., Kidokoro, H., Thompson, D. K., Lee, K. J., Cheong, J., Neil, J., Inder, T. E., Doyle, L. W., & Anderson, P. J. (2014). Neonatal brain abnormalities and memory and learning outcomes at 7 years in children born very preterm. *Memory (Hove, England)*, *22*(6), 605–615. https://doi.org/10.1080/09658211.2013.809765

Oosterbeek, H., Ter Meulen, S., & van Der Klaauw, B. (2021). Long-term effects of school-starting-age rules. *Economics of Education Review*, *84*, 102144. https://doi.org/10.1016/j.econedurev.2021.102144

Ortinau, C., & Neil, J. (2015). The neuroanatomy of prematurity: Normal brain development and the impact of preterm birth. *Clinical Anatomy*, *28*(2), 168–183. https://doi.org/10.1002/ca.22430

Østbø, I. U., & Zachrisson, H. D. (2022). Student motivation and parental attitude as mediators for SES effects on mathematics achievement: Evidence from Norway in TIMSS 2015. *Scandinavian Journal of Educational Research*, *66*(5), 808–823. https://doi.org/10.1080/00313831.2021.1939138

Ou, X., Glasier, C. M., Ramakrishnaiah, R. H., Kanfi, A., Rowell, A. C., Pivik, R. T., Andres, A., Cleves, M. A., & Badger, T. M. (2017). Gestational age at birth and brain white matter development in term-born infants and children. *American Journal of Neuroradiology*, *38*(12), 2373–2379. https://doi.org/10.3174/ajnr.A5408

Oudgenoeg-Paz, O., Mulder, H., Jongmans, M. J., van der Ham, I. J. M., & Van der Stigchel, S. (2017). The link between motor and cognitive development in children born preterm and/or with low birth weight: A review of current evidence. *Neuroscience & Biobehavioral Reviews*, *80*, 382–393. https://doi.org/10.1016/j.neubiorev.2017.06.009

Panter, J. E., & Bracken, B. A. (2009). Validity of the Bracken School Readiness Assessment for predicting first grade readiness. *Psychology in the Schools*, *46*(5), 397–409. https://doi.org/10.1002/pits.20385

Pascal, A., Govaert, P., Oostra, A., Naulaers, G., Ortibus, E., & Van den Broeck, C. (2018). Neurodevelopmental outcome in very preterm and very-low-birthweight infants born over the past decade: A meta-analytic review. *Developmental Medicine & Child Neurology*, *60*(4), 342–355. https://doi.org/10.1111/dmcn.13675

Peacock, P. J., Henderson, J., Odd, D., & Emond, A. (2012). Early school attainment in late-preterm infants. *Archives of Disease in Childhood*, *97*(2), 118–120. https://doi.org/10.1136/adc.2011.300925

Peelen, M. J. C. S., Kazemier, B. M., Ravelli, A. C. J., de Groot, C. J. M., van der Post, J. A. M., Mol, B. W. J., Hajenius, P. J., & Kok, M. (2016). Impact of fetal gender on the risk of preterm birth, a national cohort study. *Acta Obstetricia et Gynecologica Scandinavica*, *95*(9), 1034–1041. https://doi.org/10.1111/aogs.12929

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., Dardick, W., & Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological Bulletin*, *144*(1), 48–76. https://doi.org/10.1037/bul0000124

Pérez-Pereira, M., Fernández, M. P., Gómez-Taibo, M. L., Martínez-López, Z., & Arce, C. (2020). A follow-up study of cognitive development in low risk preterm children. *International Journal of Environmental Research and Public Health*, *17*(7), 2380. https://doi.org/10.3390/ijerph17072380

Perry, L. B., & McConney, A. (2010). Does the SES of the school matter? An examination of socioeconomic status and student achievement Using PISA 2003. *Teachers College Record: The Voice of Scholarship in Education*, *112*(4), 1137–1162. https://doi.org/10.1177/016146811011200401

Pettinger, K. J., Copper, C., Boyle, E., Blower, S., Hewitt, C., & Fraser, L. (2023). Risk of developmental disorders in children born at 32 to 38 weeks' gestation: A meta-analysis. *Pediatrics*, e2023061878. https://doi.org/10.1542/peds.2023-061878

Pettinger, K. J., Kelly, B., Sheldon, T. A., Mon-Williams, M., Wright, J., & Hill, L. J. B. (2020). Starting school: Educational development as a function of age of entry and prematurity. *Archives of Disease in Childhood*, *105*(2), 160. https://doi.org/10.1136/archdischild-2019-317124

Pfefferbaum, A., Chanraud, S., Pitel, A.-L., Muller-Oehring, E., Shankaranarayanan, A., Alsop, D. C., Rohlfing, T., & Sullivan, E. V. (2011). Cerebral blood flow in posterior cortical nodes of the default mode network decreases with task engagement but remains higher than in most brain region. *Cerebral Cortex*, *21*(1), 233–244. https://doi.org/10.1093/cercor/bhq090

Pinquart, M., & Ebeling, M. (2020). Parental educational expectations and academic achievement in children and adolescents—A meta-analysis. *Educational*

Psychology Review, *32*(2), 463–480. https://doi.org/10.1007/s10648-019-09506-z

Pitcher, J. B., Schneider, L. A., Burns, N. R., Drysdale, J. L., Higgins, R. D., Ridding, M. C., Nettelbeck, T. J., Haslam, R. R., & Robinson, J. S. (2012). Reduced corticomotor excitability and motor skills development in children born preterm: Preterm birth and corticomotor function. *The Journal of Physiology*, *590*(22), 5827–5844. https://doi.org/10.1113/jphysiol.2012.239269

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*(4), 371–379. https://doi.org/10.1111/ppe.12058

Pourhoseingholi, M. A., Baghestani, A. R., & Vahedi, M. (2012). How to control confounding effects by statistical analysis. *Gastroenterology and Hepatology from Bed to Bench*, *5*(2), 79–83.

Premji, S. S., Currie, G., Reilly, S., Dosani, A., Oliver, L. M., Lodha, A. K., & Young, M. (2017). A qualitative study: Mothers of late preterm infants relate their experiences of community-based care. PLOS ONE, 12(3), e0174419. https://doi.org/10.1371/journal.pone.0174419

Preston, N., Weightman, A., Culmer, P., Levesley, M., Bhakta, B., & Mon-Williams, M. (2014). The Cerebral Palsy Kinematic Assessment Tool (CPKAT): Feasibility testing of a new portable tool for the objective evaluation of upper limb kinematics in children with cerebral palsy in the non-laboratory setting. *Disability and Rehabilitation: Assistive Technology*, 1–6. https://doi.org/10.3109/17483107.2014.951974

Prickett, K. C., & Augustine, J. M. (2016). Maternal Education and Investments in Children's Health. *Journal of Marriage and Family*, *78*(1), 7–25. https://doi.org/10.1111/jomf.12253

Pritchard, V. E., Clark, C. A. C., Liberty, K., Champion, P. R., Wilson, K., & Woodward, L. J. (2009). Early school-based learning difficulties in children born very preterm. *Early Human Development*, *85*(4), 215–224. https://doi.org/10.1016/j.earlhumdev.2008.10.004

Privitera, A. J., Zhou, Y., & Xie, X. (2023). Inhibitory control as a significant predictor of academic performance in Chinese high schoolers. *Child Neuropsychology*, *29*(3), 457–473. https://doi.org/10.1080/09297049.2022.2098941

Purdy, I. B., Wiley, D. J., Smith, L. M., Howes, C., Gawlinski, A., Robbins, W., & Badr, L. K. (2008). Cumulative perinatal steroids: Child development of preterm infants. *Journal of Pediatric Nursing*, *23*(3), 201–214. https://doi.org/10.1016/j.pedn.2007.09.006

Purves, D., Augustine, G., & Fitzpatrick, D. (Eds.). (2001). Neuroglial cells. In *Neuroscience.* (2nd Edition). Sinauer Associates. https://www.ncbi.nlm.nih.gov/books/NBK10869/

Quigley, M. A., Poulsen, G., Boyle, E., Wolke, D., Field, D., Alfirevic, Z., & Kurinczuk, J. J. (2012). Early term and late preterm birth are associated with poorer school performance at age 5 years: A cohort study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *97*(3), F167. https://doi.org/10.1136/archdischild-2011-300888

Rabie, N. Z., Bird, T. M., Magann, E. F., Hall, R. W., & McKelvey, S. S. (2015). ADHD and developmental speech/language disorders in late preterm, early term and term infants. *Journal of Perinatology*, *35*(8), 660–664. https://doi.org/10.1038/jp.2015.28

Rachwani, J., Santamaria, V., Saavedra, S. L., & Woollacott, M. H. (2015). The development of trunk control and its relation to reaching in infancy: A longitudinal study. *Frontiers in Human Neuroscience*, *9*. https://doi.org/10.3389/fnhum.2015.00094

Raghubar, K. P., Barnes, M. A., & Hecht, S. A. (2010). Working memory and mathematics: A review of developmental, individual difference, and cognitive approaches. *Learning and Individual Differences*, *20*(2), 110–122. https://doi.org/10.1016/j.lindif.2009.10.005

Raju, T. N. K. (2006). Epidemiology of late preterm (near-term) births. *Clinics in Perinatology*, *33*(4), 751–763. https://doi.org/10.1016/j.clp.2006.09.009

Raju, T. N. K. (2017). The “late preterm” birth—Ten years later. *Pediatrics*, *139*(3), e20163331. https://doi.org/10.1542/peds.2016-3331

Ratzon, N. Z., Efraim, D., & Bart, O. (2007). A short-term graphomotor program for improving writing readiness skills of first-grade students. *The American Journal of Occupational Therapy*, *61*(4), 399–405. https://doi.org/10.5014/ajot.61.4.399

Reardon, S. F., Kalogrides, D., Shores, K. A., & Greenberg, E. H. (2013). *Patterns and trends in racial academic achievement gaps among States, 1999-2011.* Standford CEPA. https://cepa.stanford.edu/content/patterns-and-trends-racial-academic-achievement-gaps-among-states-1999-2011

Rea-Sandin, G., Korous, K. M., & Causadias, J. M. (2021). A systematic review and meta-analysis of racial/ethnic differences and similarities in executive function performance in the United States. *Neuropsychology*, *35*(2), 141–156. https://doi.org/10.1037/neu0000715

Reijneveld, S. A., Hornman, J., Boelema, S. R., & de Winter, A. F. (2021). Stability of executive functioning of moderately-late preterm and full-term born children at ages 11 and 19: The TRAILS cohort study. *International Journal of Environmental Research and Public Health*, *18*(8), 4161. https://doi.org/10.3390/ijerph18084161

Requejo, J., Merialdi, M., Althabe, F., Keller, M., Katz, J., & Menon, R. (2013). Born too soon: Care during pregnancy and childbirth to reduce preterm deliveries and improve health outcomes of the preterm baby. *Reproductive Health*, *10*(S1), S4. https://doi.org/10.1186/1742-4755-10-S1-S4

Reynold De Seresin, M., Roy, A., Theveniaut, C., Le Goff, J., Chopin, C., Rouger, V., Roze, J.-C., Flamant, C., & Muller, J.-B. (2023). Assessing of executive functions in daily life in preterm children aged 3–4 years old from the “Behavior Rating Inventory of Executive Function—Preschool version” questionnaire. *Frontiers in Pediatrics*, *11*, 999100. https://doi.org/10.3389/fped.2023.999100

Ribner, A. D., Willoughby, M. T., & Blair, C. B. (2017). Executive function buffers the association between early math and later academic skills. *Frontiers in Psychology*, *8*, 869. https://doi.org/10.3389/fpsyg.2017.00869

Rice, D., & Barone, S. (2000). Critical periods of vulnerability for the developing nervous system: Evidence from humans and animal models. *Environmental Health Perspectives*, *108*(suppl 3), 511–533. https://doi.org/10.1289/ehp.00108s3511

Richards, J. L., Drews-Botsch, C., Sales, J. M., Flanders, W. D., & Kramer, M. R. (2016). Describing the shape of the relationship between gestational age at birth and cognitive development in a nationally representative U.S. birth cohort. *Paediatric and Perinatal Epidemiology*, *30*(6), 571–582. https://doi.org/10.1111/ppe.12319

Richards, J. L., Kramer, M. S., Deb-Rinker, P., Rouleau, J., Mortensen, L., Gissler, M., Morken, N.-H., Skjærven, R., Cnattingius, S., Johansson, S., Delnord, M., Dolan, S. M., Morisaki, N., Tough, S., Zeitlin, J., & Kramer, M. R. (2016). Temporal trends in late preterm and early term birth rates in 6 high-income countries in North America and Europe and association with clinician-initiated obstetric interventions. *JAMA*, *316*(4), 410. https://doi.org/10.1001/jama.2016.9635

Rimfeld, K., Malanchini, M., Hannigan, L. J., Dale, P. S., Allen, R., Hart, S. A., & Plomin, R. (2019). Teacher assessments during compulsory education are as reliable, stable and heritable as standardized test scores. *Journal of Child Psychology and Psychiatry*, *60*(12), 1278–1288. https://doi.org/10.1111/jcpp.13070

Rindermann, H., Michou, C. D., & Thompson, J. (2011). Children's writing ability: Effects of parent's education, mental speed and intelligence. *Learning and Individual Differences*, *21*(5), 562–568. https://doi.org/10.1016/j.lindif.2011.07.010

Ritchie, S. J., & Bates, T. C. (2013). Enduring links from childhood mathematics and reading achievement to adult socioeconomic status. *Psychological Science*, *24*(7), 1301–1308. https://doi.org/10.1177/0956797612466268

Roberts, G., Lim, J., Doyle, L. W., & Anderson, P. J. (2011). High rates of school readiness difficulties at 5 years of age in very preterm infants compared with term controls. *Journal of Developmental & Behavioral Pediatrics*, *32*(2), 117–124. https://doi.org/10.1097/DBP.0b013e318206d5c9

Robson, C. (2009). Real world research: A resource for social scientists and practitioner-researchers (2. ed.,). Blackwell.

Rodríguez Fernández, C., Mata Zubillaga, D., Rodríguez Fernández, L. M., Regueras Santos, L., Reguera García, M. M., de Paz Fernández, J. A., & Lapeña López de Armentia, S. (2016). Evaluation of coordination and balance in preterm children. *Anales de Pediatría (English Edition)*, *85*(2), 86–94. https://doi.org/10.1016/j.anpede.2015.10.023

Rogers, C. E., Barch, D. M., Sylvester, C. M., Pagliaccio, D., Harms, M. P., Botteron, K. N., & Luby, J. L. (2014). Altered gray matter volume and school age anxiety in children born late preterm. *The Journal of Pediatrics*, *165*(5), 928–935. https://doi.org/10.1016/j.jpeds.2014.06.063

Rohde, T. E., & Thompson, L. A. (2007). Predicting academic achievement with cognitive ability. *Intelligence*, *35*(1), 83–92. https://doi.org/10.1016/j.intell.2006.05.004

Romero-Guzman, G. J., & Lopez-Munoz, F. (2017). [Prevalence and risk factors for periventricular leukomalacia in preterm infants. A systematic review]. *Revista De Neurologia*, *65*(2), 57–62.

Rönnqvist, L., & Domellöf, E. (2006). Quantitative assessment of right and left reaching movements in infants: A longitudinal study from 6 to 36 months. *Developmental Psychobiology*, *48*(6), 444–459. https://doi.org/10.1002/dev.20160

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2011). Modeling a cascade of effects: The role of speed and executive functioning in preterm/full-term differences in academic achievement: Executive function in preterm adolescents. *Developmental Science*, *14*(5), 1161–1175. https://doi.org/10.1111/j.1467-7687.2011.01068.x

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. https://doi.org/10.1093/biomet/70.1.41

Rosenblum, S., & Josman, N. (2003). The relationship between postural control and fine manual dexterity. *Physical & Occupational Therapy in Pediatrics*, *23*(4), 47–60. https://doi.org/10.1080/J006v23n04_04

Ross, C. E., & Wu, C. (1995). The links between education and health. *American Sociological Review*, *60*(5), 719. https://doi.org/10.2307/2096319

Roze, E., Reijneveld, S. A., Stewart, R. E., & Bos, A. F. (2021). Multi-domain cognitive impairments at school age in very preterm-born children compared to term-born peers. *BMC Pediatrics*, *21*(1), 169. https://doi.org/10.1186/s12887-021-02641-z

Ruiz, M., Goldblatt, P., Morrison, J., Kukla, L., Švancara, J., Riitta-Järvelin, M., Taanila, A., Saurel-Cubizolles, M.-J., Lioret, S., Bakoula, C., Veltsista, A., Porta, D., Forastiere, F., van Eijsden, M., Vrijkotte, T. G. M., Eggesbø, M., White, R. A., Barros, H., Correia, S., … Pikhart, H. (2015). Mother's education and the risk of preterm and small for gestational age birth: A DRIVERS meta-analysis of 12 European cohorts. *Journal of Epidemiology and Community Health*, *69*(9), 826–833. https://doi.org/10.1136/jech-2014-205387

Russell, D. M., & Sternad, D. (2001). Sinusoidal visuomotor tracking: Intermittent servo-control or coupled oscillations? *Journal of Motor Behavior*, *33*(4), 329–349. https://doi.org/10.1080/00222890109601918

Rust, J., Golombok, S., Kosinski, M., & Golombok, S. (2009). *Modern psychometrics: The science of psychological assessment* (3rd Ed). Routledge/Taylor & Francis Group. https://doi.org/10.4324/9781315637686

Rutter, M. (1994). Beyond longitudinal data: Causes, consequences, changes, and continuity. *Journal of Consulting and Clinical Psychology*, *62*(5), 928–940. https://doi.org/10.1037/0022-006X.62.5.928

Sagnol, C., Debillon, T., & Debû, B. (2007). Assessment of motor control using kinematics analysis in preschool children born very preterm. *Developmental Psychobiology*, *49*(4), 421–432. https://doi.org/10.1002/dev.20211

Salehinejad, M. A., Ghanavati, E., Rashid, M. H. A., & Nitsche, M. A. (2021). Hot and cold executive functions in the brain: A prefrontal-cingular network. *Brain and Neuroscience Advances*, *5*, 239821282110077. https://doi.org/10.1177/23982128211007769

Sambol, S., Suleyman, E., Scarfo, J., & Ball, M. (2023). A true reflection of executive functioning or a representation of task-specific variance? Re-evaluating the unity/diversity framework. *Acta Psychologica*, *236*, 103934. https://doi.org/10.1016/j.actpsy.2023.103934

Sandoval, C. C., Gaspardo, C. M., & Linhares, M. B. M. (2022). The impact of preterm birth on the executive functioning of preschool children: A systematic review. *Applied Neuropsychology: Child*, *11*(4), 873–890. https://doi.org/10.1080/21622965.2021.1915145

Santangelo, T., & Graham, S. (2016). A comprehensive meta-analysis of handwriting instruction. *Educational Psychology Review*, *28*(2), 225–265. https://doi.org/10.1007/s10648-015-9335-1

Sarici, S. Ü., Serdar, M. A., Korkmaz, A., Erdem, G., Oran, O., Tekinalp, G., Yurdakök, M., & Yigit, S. (2004). Incidence, course, and prediction of hyperbilirubinemia in near-term and term newborns. *Pediatrics*, *113*(4), 775–780. https://doi.org/10.1542/peds.113.4.775

Sarlegna, F. R., & Mutha, P. K. (2015). The influence of visual target information on the online control of movements. *Vision Research*, *110*, 144–154. https://doi.org/10.1016/j.visres.2014.07.001

Sato, J., Mossad, S. I., Wong, S. M., Hunt, B. A. E., Dunkley, B. T., Urbain, C., & Taylor, M. J. (2019). Spectral slowing is associated with working memory performance in children born very preterm. *Scientific Reports*, *9*(1), 15757. https://doi.org/10.1038/s41598-019-52219-0

Sato, N. T. D. S., & Tudella, E. (2018). Influence of sitting positions and level of trunk control during reaching movements in late preterm and full-term Infants. *Frontiers in Pediatrics*, *6*, 185. https://doi.org/10.3389/fped.2018.00185

Schachar, R., Logan, G. D., Robaey, P., Chen, S., Ickowicz, A., & Barr, C. (2007). Restraint and cancellation: Multiple inhibition deficits in Attention Deficit Hyperactivity Disorder. *Journal of Abnormal Child Psychology*, *35*(2), 229–238. https://doi.org/10.1007/s10802-006-9075-2

Scher, M. S., Johnson, M. W., Ludington, S. M., & Loparo, K. (2011). Physiologic brain dysmaturity in late preterm infants. *Pediatric Research*, *70*(5), 524–528. https://doi.org/10.1203/PDR.0b013e31822f24af

Schneider, H., Ryan, M., & Mahone, E. M. (2020). Parent versus teacher ratings on the BRIEF-preschool version in children with and without ADHD. *Child Neuropsychology*, *26*(1), 113–128. https://doi.org/10.1080/09297049.2019.1617262

Schnider, B., Disselhoff, V., Held, U., Latal, B., Hagmann, C. F., & Wehrle, F. M. (2020). Executive function deficits mediate the association between very preterm birth and behavioral problems at school-age. *Early Human Development*, *146*, 105076. https://doi.org/10.1016/j.earlhumdev.2020.105076

Searle, A. K., Smithers, L. G., Chittleborough, C. R., Gregory, T. A., & Lynch, J. W. (2017). Gestational age and school achievement: A population study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *102*(5), F409–F416. https://doi.org/10.1136/archdischild-2016-310950

Sejer, E. P. F., Bruun, F. J., Slavensky, J. A., Mortensen, E. L., & Schiøler Kesmodel, U. (2019). Impact of gestational age on child intelligence, attention and executive function at age 5: A cohort study. *BMJ Open*, *9*(9), e028982. https://doi.org/10.1136/bmjopen-2019-028982

Setänen, S., Lehtonen, L., Parkkola, R., Matomäki, J., & Haataja, L. (2016). The motor profile of preterm infants at 11 y of age. *Pediatric Research*, *80*(3), 389–394. https://doi.org/10.1038/pr.2016.90

Setia, M. (2016). Methodology series module 3: Cross-sectional studies. *Indian Journal of Dermatology*, *61*(3), 261. https://doi.org/10.4103/0019-5154.182410

Shah, M. M. (2014). Dendrites. In *Encyclopedia of the Neurological Sciences* (p. 970). Elsevier. https://doi.org/10.1016/B978-0-12-385157-4.00056-7

Shah, P. E., Kaciroti, N., Richards, B., & Lumeng, J. C. (2016). Gestational age and kindergarten school readiness in a national sample of preterm infants. *The Journal of Pediatrics*, *178*, 61–67. https://doi.org/10.1016/j.jpeds.2016.06.062

Shapiro-Mendoza, C. K., Tomashek, K. M., Kotelchuck, M., Barfield, W., Nannini, A., Weiss, J., & Declercq, E. (2008). Effect of late-preterm birth and maternal medical conditions on newborn morbidity risk. *Pediatrics*, *121*(2), e223–e232. https://doi.org/10.1542/peds.2006-3629

Sheehan, J. C., Kerns, K. A., & Müller, U. (2017). The effect of task complexity on planning in preterm-born children. *The Clinical Neuropsychologist*, *31*(2), 438–458. https://doi.org/10.1080/13854046.2016.1244248

Shi, Y., & Qu, S. (2022). Analysis of the effect of cognitive ability on academic achievement: Moderating role of self-monitoring. *Frontiers in Psychology*, *13*, 996504. https://doi.org/10.3389/fpsyg.2022.996504

Shing, Y. L., Lindenberger, U., Diamond, A., Li, S.-C., & Davidson, M. C. (2010). Memory maintenance and inhibitory control differentiate from early childhood to adolescence. *Developmental Neuropsychology*, *35*(6), 679–697. https://doi.org/10.1080/87565641.2010.508546

Shire, K. A. (2016). *Motor coordination in children: Determinants, screening and intervention*. White Rose Network. https://etheses.whiterose.ac.uk/13405/

Shire, K. A., Andrews, E., Barber, S., Bruce, A., Corkett, J., Hill, L. J. B., Kelly, B., McEachan, R. R. C., Mon-Williams, M., Tracey, L., Waterman, A. H., & Wright, J. (2020). Starting school: A large-scale start of school assessment within the 'Born in Bradford' longitudinal cohort. *Wellcome Open Research*, *5*, 47. https://doi.org/10.12688/wellcomeopenres.15610.1

Shire, K. A., Hill, L. J. B., Snapp-Childs, W., Bingham, G. P., Kountouriotis, G. K., Barber, S., & Mon-Williams, M. (2016). Robot guided 'pen skill' training in children with motor difficulties. *PLoS ONE*, *11*(3), e0151354. https://doi.org/10.1371/journal.pone.0151354

Shumway-Cook, A., & Woollacott, M. H. (1985). The growth of stability: Postural control from a developmental perspective. *Journal of Motor Behavior*, *17*(2), 131–147. https://doi.org/10.1080/00222895.1985.10735341

Silventoinen, K., Luukkonen, J., Myrskylä, M., & Martikainen, P. (2023). Birth size, school performance and family social position: A study of 650,000 children. *Pediatric Research*, *94*(6), 2105–2114. https://doi.org/10.1038/s41390-023-02757-1

Skarda, I., Cookson, R., & Gilbert, R. (2025). Does household income predict health and educational outcomes in childhood better than neighbourhood deprivation? *Journal of Public Health*, *47*(1), 62–73. https://doi.org/10.1093/pubmed/fdae283

Smith, G. C. S. (2003). Interpregnancy interval and risk of preterm birth and neonatal death: Retrospective cohort study. *BMJ*, *327*(7410), 313–0. https://doi.org/10.1136/bmj.327.7410.313

Snelgrove, J. W., & Murphy, K. E. (2015). Preterm birth and social inequality: Assessing the effects of material and psychosocial disadvantage in a UK birth cohort. *Acta Obstetricia et Gynecologica Scandinavica*, *94*(7), Article 7. https://doi.org/10.1111/aogs.12648

Song, I. G. (2023). Neurodevelopmental outcomes of preterm infants. *Clinical and Experimental Pediatrics*, *66*(7), 281–287. https://doi.org/10.3345/cep.2022.00822

Souissi, S., Chamari, K., & Bellaj, T. (2022). Assessment of executive functions in school-aged children: A narrative review. *Frontiers in Psychology*, *13*, 991699. https://doi.org/10.3389/fpsyg.2022.991699

Spencer, J. P. (2020). The Development of Working Memory. *Current Directions in Psychological Science*, *29*(6), 545–553. https://doi.org/10.1177/0963721420959835

Spengler, M., Brunner, M., Damian, R. I., Lüdtke, O., Martin, R., & Roberts, B. W. (2015). Student characteristics and behaviors at age 12 predict occupational success 40 years later over and above childhood IQ and parental socioeconomic status. *Developmental Psychology*, *51*(9), 1329–1340. https://doi.org/10.1037/dev0000025

Spittle, A. J., Cheong, J., Doyle, L. W., Roberts, G., Lee, K. J., Lim, J., Hunt, R. W., Inder, T. E., & Anderson, P. J. (2011). Neonatal white matter abnormality predicts childhood motor impairment in very preterm children: White Matter Abnormalities and Motor Impairment. *Developmental Medicine & Child Neurology*, *53*(11), 1000–1006. https://doi.org/10.1111/j.1469-8749.2011.04095.x

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *Quarterly Journal of Experimental Psychology*, *59*(4), 745–759. https://doi.org/10.1080/17470210500162854

Stacey, T., Prady, S., Haith-Cooper, M., Downe, S., Simpson, N., & Pickett, K. (2016). Ethno-specific risk factors for adverse pregnancy outcomes: Findings from the Born in Bradford cohort study. *Maternal and Child Health Journal*, *20*(7), 1394–1404. https://doi.org/10.1007/s10995-016-1936-x

Stålnacke, S. R., Tessma, M., Böhm, B., & Herlenius, E. (2019). Cognitive development trajectories in preterm children with very low birth weight longitudinally followed until 11 years of age. *Frontiers in Physiology*, *10*, 307. https://doi.org/10.3389/fphys.2019.00307

Standards and Testing Agency. (2014a). *National curriculum assessments: Check administrators' guide phonics screening check*. Crown Copyright. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/att achment_data/file/317685/2014_KeyStage1_CheckAdministratorsGuide__CAG_Web.pdf

Standards and Testing Agency. (2014b). *Teacher assessment: Key stage 1 tasks and tests*. https://www.gov.uk/guidance/teacher-assessment-key-stage-1-tasks-and-tests

Starr, A., Haider, Z. F., & von Stumm, S. (2024). Do school grades matter for growing up? Testing the predictive validity of school performance for outcomes in emerging adulthood. *Developmental Psychology*, *60*(4), 665–679. https://doi.org/10.1037/dev0001548

StataCorp. (2021). Stata statistical software: Release 17. StataCorp LLC.

Steele, F. (2008). Multilevel models for longitudinal data. *Journal of the Royal Statistical Society Series A: Statistics in Society*, *171*(1), 5–19. https://doi.org/10.1111/j.1467-985X.2007.00509.x

Steenbergen, M. R., & Jones, B. S. (2002). Modeling multilevel data structures. *American Journal of Political Science*, *46*(1), 218. https://doi.org/10.2307/3088424

Steiner, P. M., Cook, T. D., Shadish, W. R., & Clark, M. H. (2010). The importance of covariate selection in controlling for selection bias in observational studies. *Psychological Methods*, *15*(3), 250–267. https://doi.org/10.1037/a0018719

Stewart, E. B. (2008). School structural characteristics, student effort, peer associations, and parental involvement: The influence of school- and individual-level factors on academic achievement. *Education and Urban Society*, *40*(2), 179–204. https://doi.org/10.1177/0013124507304167

Steyer, R., Gabler, S., von Davier, A. A., Nachtigall, C., & Buhl, T. (2000). Causal regression models: I. Individual and average causal effects. *Methods of Psychological Research*, *5*(2), 39–71.

Stiles, J., & Jernigan, T. L. (2010). The basics of brain development. *Neuropsychology Review*, *20*(4), 327–348. https://doi.org/10.1007/s11065-010-9148-4

Stock, S. J., & Bauld, L. (2020). Maternal smoking and preterm birth: An unresolved health challenge. *PLOS Medicine*, *17*(9), e1003386. https://doi.org/10.1371/journal.pmed.1003386

Stone, G., Andrade, J., Martin, K., & Styles, B. (2020). Helping handwriting shine: Evaluation report. *Education Endowment Foundation*. https://d2tic4wvo1iusb.cloudfront.net/production/documents/projects/Helping_Handwriting_Shine_Report_-_final.pdf?v=1715939000

Strand, S. (2014). School effects and ethnic, gender and socio-economic gaps in educational achievement at age 11. *Oxford Review of Education*, *40*(2), 223–245. https://doi.org/10.1080/03054985.2014.891980

Strand, S. (2021). Ethnic, socio-economic and sex inequalities in educational achievement at age 16: An analysis of the Second Longitudinal Study of Young People in England (LSYPE2). Report for the Commission on Race and Ethnic Disparities (CRED), Department for Education, University of Oxford. https://www.gov.uk/government/publications/the-report-of-the-commission-on-race-and-ethnic-disparities-supporting-research/ethnic-socio-economic-and-sex-inequalities-in-educational-achievement-at-age-16-by-professor-steve-strand

Strandberg-Larsen, K., Poulsen, G., Bech, B. H., Chatzi, L., Cordier, S., Dale, M. T. G., Fernandez, M., Henriksen, T. B., Jaddoe, V. W., Kogevinas, M., Kruithof, C. J., Lindhard, M. S., Magnus, P., Nohr, E. A., Richiardi, L., Rodriguez-Bernal, C. L., Rouget, F., Rusconi, F., Vrijheid, M., & Andersen, A.-M. N. (2017). Association of light-to-moderate alcohol drinking in pregnancy with preterm birth and birth weight: Elucidating bias by pooling data from nine European cohorts. *European Journal of Epidemiology*, *32*(9), 751–764. https://doi.org/10.1007/s10654-017-0323-2

Suggate, S., Pufke, E., & Stoeger, H. (2016). The effect of fine and grapho-motor skill demands on preschoolers' decoding skill. *Journal of Experimental Child Psychology*, *141*, 34–48. https://doi.org/10.1016/j.jecp.2015.07.012

Suggate, S., Pufke, E., & Stoeger, H. (2019). Children's fine motor skills in kindergarten predict reading in grade 1. *Early Childhood Research Quarterly*, *47*, 248–258. https://doi.org/10.1016/j.ecresq.2018.12.015

Suikkanen, J., Miettola, S., Heinonen, K., Vääräsmäki, M., Tikanmäki, M., Sipola, M., Matinolli, H.-M., Järvelin, M.-R., Räikkönen, K., Hovi, P., & Kajantie, E. (2021). Reaction times, learning, and executive functioning in adults born preterm. *Pediatric Research*, *89*(1), 198–204. https://doi.org/10.1038/s41390-020-0851-4

Sullivan, G. M., & Feinn, R. (2012). Using effect size-or why the P value is not enough. *Journal of Graduate Medical Education*, *4*(3), 279–282. https://doi.org/10.4300/JGME-D-12-00156.1

Süß, H.-M., Oberauer, K., Wittmann, W. W., Wilhelm, O., & Schulze, R. (2002). Working-memory capacity explains reasoning ability—And a little bit more. Intelligence. *Intelligence*, *30*(3), 261–288. https://doi.org/10.1016/S0160-2896(01)00100-3

Swanson, H. L. (1994). Short-term memory and working memory: Do both contribute to our understanding of academic achievement in children and adults with learning disabilities? *Journal of Learning Disabilities*, *27*(1), 34–50. https://doi.org/10.1177/002221949402700107

Talge, N. M., Holzman, C., Van Egeren, L. A., Symonds, L. L., Scheid, J. M., Senagore, P. K., & Sikorskii, A. (2012). Late-preterm birth by delivery circumstance and its association with parent-reported attention problems in childhood. *Journal of Developmental and Behavioral Pediatrics : JDBP*, *33*(5), 405–415. PubMed. https://doi.org/10.1097/DBP.0b013e3182564704

Tamis-LeMonda, C. S., Luo, R., McFadden, K. E., Bandel, E. T., & Vallotton, C. (2019). Early home learning environment predicts children's 5th grade academic skills. *Applied Developmental Science*, *23*(2), 153–169. https://doi.org/10.1080/10888691.2017.1345634

Tayebi, T., Zahrani, S. T., & Mohammadpour, R. (2013). Relationship between adequacy of prenatal care utilization index and pregnancy outcomes. *Iranian Journal of Nursing and Midwifery Research*, *18*(5), 360–366.

Taylor, C. M., Emond, A. M., Lingam, R., & Golding, J. (2018). The ALSPAC Coordination Test (subtests of the Movement ABC): Methodology and data on associations with prenatal exposures to lead, cadmium and mercury. *Data in Brief*, *19*, 189–197. https://doi.org/10.1016/j.dib.2018.04.130

Taylor, H. G., Espy, K. A., & Anderson, P. J. (2009). Mathematics deficiencies in children with very low birth weight or very preterm birth. *Developmental Disabilities Research Reviews*, *15*(1), 52–59. https://doi.org/10.1002/ddrr.51

Taylor-Robinson, D., Agarwal, U., Diggle, P. J., Platt, M. J., Yoxall, B., & Alfirevic, Z. (2011). Quantifying the impact of deprivation on preterm births: A retrospective cohort study. *PLoS ONE*, *6*(8), e23163. https://doi.org/10.1371/journal.pone.0023163

Textor, J., Van Der Zander, B., Gilthorpe, M. S., Liśkiewicz, M., & Ellison, G. T. H. (2017). Robust causal inference using directed acyclic graphs: The R package 'dagitty'. *International Journal of Epidemiology*, dyw341. https://doi.org/10.1093/ije/dyw341

The Health Foundation. (2023). *Map of child poverty*. https://www.health.org.uk/evidence-hub/money-and-resources/poverty/map-of-child-poverty#:~:text=In%20the%20seven%20local%20authorities,%25%20in%20Kingston%20upon%20Hull).

The Smallest Things. (2017). *Prem Aware Award: Supporting schools to help children born prematurely*. The Smallest Things Premature Baby Charity. https://www.thesmallestthings.org/prem-aware-award

Thomson, K., Moffat, M., Arisa, O., Jesurasa, A., Richmond, C., Odeniyi, A., Bambra, C., Rankin, J., Brown, H., Bishop, J., Wing, S., McNaughton, A., & Heslehurst, N. (2021). Socioeconomic inequalities and adverse pregnancy outcomes in the UK and Republic of Ireland: A systematic review and meta-analysis. *BMJ Open*, *11*(3), e042753. https://doi.org/10.1136/bmjopen-2020-042753

Thomson, S. (2018). Achievement at school and socioeconomic background—An educational perspective. *NPJ Science of Learning*, *3*(1), 5, s41539-018-0022–0. https://doi.org/10.1038/s41539-018-0022-0

Thoren, E. M., Metze, B., Bührer, C., & Garten, L. (2013). Online support for parents of preterm infants: A qualitative and content analysis of Facebook 'preemie' groups. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, 98(6), F534–F538. https://doi.org/10.1136/archdischild-2012-303572

Tingleff, T., Räisänen, S., Vikanes, Å., Sandvik, L., Sugulle, M., Murzakanova, G., & Laine, K. (2023). Different pathways for preterm birth between singleton and twin pregnancies: A population-based registry study of 481 176 nulliparous women. *BJOG: An International Journal of Obstetrics & Gynaecology*, *130*(4), 387–395. https://doi.org/10.1111/1471-0528.17344

Tipton, E., Hallberg, K., Hedges, L. V., & Chan, W. (2017). Implications of small samples for generalization: Adjustments and rules of thumb. *Evaluation Review*, *41*(5), 472–505. https://doi.org/10.1177/0193841X16655665

Tomashek, K. M., Shapiro-Mendoza, C. K., Weiss, J., Kotelchuck, M., Barfield, W., Evans, S., Naninni, A., & Declercq, E. (2006). Early discharge among late preterm and term newborns and risk of neonatal morbidity. *Seminars in Perinatology*, *30*(2), 61–68. https://doi.org/10.1053/j.semperi.2006.02.003

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner Review: Do performance-based measures and ratings of executive function assess the same construct?: Performance-based and rating measures of EF. *Journal of Child Psychology and Psychiatry*, *54*(2), 131–143. https://doi.org/10.1111/jcpp.12001

Townley Flores, C., Gerstein, A., Phibbs, C. S., & Sanders, L. M. (2021). Short-term and long-term educational outcomes of infants born moderately and late preterm. *The Journal of Pediatrics*, *232*, 31-37.e2. https://doi.org/10.1016/j.jpeds.2020.12.070

Trickett, J., Bernardi, M., Fahy, A., Lancaster, R., Larsen, J., Ni, Y., Suonpera, E., Wolke, D., Marlow, N., & Johnson, S. (2022). Neuropsychological abilities underpinning academic attainment in children born extremely preterm. *Child Neuropsychology*, *28*(6), 746–767. https://doi.org/10.1080/09297049.2021.2014433

Trickett, J., Johnson, S., & Wolke, D. (2020). Behaviour and educational outcomes following extreme preterm birth: Current controversies and future directions. In E. M. Boyle & J. Cusack (Eds.), *Emerging topics and controversies in neonatology*. Springer International Publishing. https://doi.org/10.1007/978-3-030-28829-7

Tso, W. W., Ho, F. K. W., Coghill, D., Lee, T. M., Wang, Y., Lee, S., Wong, M. S., Yam, J. C. S., Wong, I. C. K., & Ip, P. (2023). Preterm postnatal complications and risk of attention-deficit/hyperactivity disorder. *Developmental Medicine & Child Neurology*, *65*(3), 358–366. https://doi.org/10.1111/dmcn.15401

Tuñón-Domínguez, I., Cuesta-Gómez, A., Molina-Rueda, F., Juárez-Vela, R., Ruiz De Viñaspre-Hernández, R., Santolalla-Arnedo, I., Sánchez-González, J. L., & Carratalá-Tejada, M. (2022). The influence between gestational age and postural control, a systematic review. *Frontiers in Pediatrics*, *10*, 883218. https://doi.org/10.3389/fped.2022.883218

Twilhaar, E. S., de Kieviet, J. F., Aarnoudse-Moens, C. S., van Elburg, R. M., & Oosterlaan, J. (2018). Academic performance of children born preterm: A meta-analysis and meta-regression. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, *103*(4), F322. https://doi.org/10.1136/archdischild-2017-312916

Twilhaar, E. S., de Kieviet, J. F., van Elburg, R. M., & Oosterlaan, J. (2018). Academic trajectories of very preterm born children at school age. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, fetalneonatal-2018-315028. https://doi.org/10.1136/archdischild-2018-315028

Twisk, J., de Boer, M., de Vente, W., & Heymans, M. (2013). Multiple imputation of missing values was not necessary before performing a longitudinal mixed-model analysis. *Journal of Clinical Epidemiology*, *66*(9), 1022–1028. https://doi.org/10.1016/j.jclinepi.2013.03.017

UNISON. (2018). *Lessons in Austerity: A UNISON survey of school support staff*. https://www.unison.org.uk/content/uploads/2018/08/Lessons-In-Austerity-report.docx#:~:text=Reducing%20support%20staff%20is%20also,losing%20out%20on%20vital%20help.

University of Nottingham. (2024). *Preterm birth information for education professionals*. PRISM; Premature Infants' Skills in Mathematics. https://www.nottingham.ac.uk/helm/dev/prism/

van Beek, P. E., van der Horst, I. E., Wetzer, J., van Baar, A. L., Vugs, B., & Andriessen, P. (2021). Developmental trajectories in very preterm born children up to 8 years: A longitudinal cohort study. *Frontiers in Pediatrics*, *9*, 672214–672214. PubMed. https://doi.org/10.3389/fped.2021.672214

Van Braeckel, K., Butcher, P. R., Geuze, R. H., Van Duijn, M. A. J., Bos, A. F., & Bouma, A. (2008). Less efficient elementary visuomotor processes in 7- to 10-year-old preterm-born children without cerebral palsy: An indication of impaired dorsal stream processes. *Neuropsychology*, *22*(6), 755–764. https://doi.org/10.1037/a0013212

Van Braeckel, K., Butcher, P. R., Geuze, R. H., van Dujin, M. A. J., Bos, A. F., & Bouma, A. (2010). Difference rather than delay in development of elementary visuomotor processes in children born preterm without cerebral palsy: A quasi-longitudinal study. *Neuropsychology*, *24*(1), 90–100. https://doi.org/10.1037/a0016804

van der Kleij, S. W., Burgess, A. P., Ricketts, J., & Shapiro, L. R. (2023). Tracking vocabulary and reading growth in children from lower and higher socioeconomic backgrounds during the transition from primary to secondary education. *Child Development*, *94*(1). https://doi.org/10.1111/cdev.13862

van der Ven, S. H. G., Kroesbergen, E. H., Boom, J., & Leseman, P. P. M. (2013). The structure of executive functions in children: A closer examination of inhibition, shifting, and updating: *Structure of executive functions*. *British Journal of Developmental Psychology*, *31*(1), 70–87. https://doi.org/10.1111/j.2044-835X.2012.02079.x

van Houdt, C. A., Aarnoudse-Moens, C. S. H., van Wassenaer-Leemhuis, A. G., Laarman, A. R. C., Koopman-Esseboom, C., van Kaam, A. H., & Oosterlaan, J. (2019). Effects of executive function training on attentional, behavioral and emotional functioning and self-perceived competence in very preterm children: A randomized controlled trial. *Frontiers in Psychology*, *10*, 2100. https://doi.org/10.3389/fpsyg.2019.02100

van Steensel, R. (2006). Relations between socio-cultural factors, the home literacy environment and children’s literacy development in the first years of primary education. *Journal of Research in Reading*, *29*(4), 367–382. https://doi.org/10.1111/j.1467-9817.2006.00301.x

van Veen, S., van Wassenaer-Leemhuis, A. G., van Kaam, A. H., Oosterlaan, J., & Aarnoudse-Moens, C. S. H. (2019). Visual perceptive skills account for very preterm children’s mathematical difficulties in preschool. *Early Human Development*, *129*, 11–15. https://doi.org/10.1016/j.earlhumdev.2018.12.018

Vignoles, A. (2021). Longitudinal research. In R. Coe, M. Waring, L. V. Hedges, & L. D. Ashley (Eds.), *Research methods and methodologies in education* (3rd edition, pp. 153–161). SAGE.

Vintzileos, A. M., Ananth, C. V., Smulian, J. C., Scorza, W. E., & Knuppel, R. A. (2002). The impact of prenatal care in the United States on preterm births in the presence and absence of antenatal high-risk conditions. *American Journal of Obstetrics and Gynecology*, *187*(5), 1254–1257. https://doi.org/10.1067/mob.2002.127140

Visser, J. (2003). Developmental coordination disorder: A review of research on subtypes and comorbidities. *Human Movement Science*, 22(4–5), 479–493. https://doi.org/10.1016/j.humov.2003.09.005

Vohr, B. (2014). Speech and language outcomes of very preterm infants. *Seminars in Fetal and Neonatal Medicine*, *19*(2), 78–83. https://doi.org/10.1016/j.siny.2013.10.007

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

Volpe, J. J. (2019). Dysmaturation of premature brain: Importance, cellular mechanisms, and potential interventions. *Pediatric Neurology*, *95*, 42–66. https://doi.org/10.1016/j.pediatrneurol.2019.02.016

Volpe, J. J. (2022). Commentary—The late preterm infant: Vulnerable cerebral cortex and large burden of disability. *Journal of Neonatal-Perinatal Medicine*, *15*(1), 1–5. https://doi.org/10.3233/NPM-210803

von Stumm, S., Cave, S. N., & Wakeling, P. (2022). Persistent association between family socioeconomic status and primary school performance in Britain over 95 years. *Npj Science of Learning*, *7*(1), 4. https://doi.org/10.1038/s41539-022-00120-3

Voss, W., Neubauer, A., Wachtendorf, M., Verhey, J. F., & Kattner, E. (2007). Neurodevelopmental outcome in extremely low birth weight infants: What is the minimum age for reliable developmental prognosis? *Acta Paediatrica*, *96*(3), 342–347. https://doi.org/10.1111/j.1651-2227.2006.00130.x

Walsh, J. M., Doyle, L. W., Anderson, P. J., Lee, K. J., & Cheong, J. L. Y. (2014). Moderate and late preterm birth: Effect on brain size and maturation at term-equivalent age. *Radiology*, *273*(1), 232–240. https://doi.org/10.1148/radiol.14132410

Wang, M. L., Dorer, D. J., Fleming, M. P., & Catlin, E. A. (2004). Clinical outcomes of near-term infants. *Pediatrics*, *114(2)*, 372–376. https://doi.org/10.1542/peds.114.2.372

Waterman, A. H., Atkinson, A. L., Aslam, S. S., Holmes, J., Jaroslawska, A., & Allen, R. J. (2017). Do actions speak louder than words? Examining children's ability to follow instructions. *Memory & Cognition*, *45*(6), 877–890. https://doi.org/10.3758/s13421-017-0702-7

Waterman, A. H., Havelka, J., Culmer, P. R., Hill, L. J. B., & Mon-Williams, M. (2015). The ontogeny of visual–motor memory and its importance in handwriting and reading: A developing construct. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1798), 20140896. https://doi.org/10.1098/rspb.2014.0896

Wehby, G. L., Prater, K., McCarthy, A. M., Castilla, E. E., & Murray, J. C. (2011). The impact of maternal smoking during pregnancy on early child neurodevelopment. *Journal of Human Capital*, *5*(2), 207–254. https://doi.org/10.1086/660885

Wehrle, F. M., Stöckli, A., Disselhoff, V., Schnider, B., Grunt, S., Mouthon, A.-L., Latal, B., Hagmann, C. F., & Everts, R. (2021). Effects of correcting for prematurity on executive function scores of children born very preterm at school age. *The Journal of Pediatrics*, *238*, 145-152.e2. https://doi.org/10.1016/j.jpeds.2021.06.070

Weightman, A. L., Morgan, H. E., Shepherd, M. A., Kitcher, H., Roberts, C., & Dunstan, F. D. (2012). Social inequality and infant health in the UK: Systematic review and meta-analyses. *BMJ Open*, *2*(3), e000964. https://doi.org/10.1136/bmjopen-2012-000964

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology*, *44*(2), 575–587. https://doi.org/10.1037/0012-1649.44.2.575

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A. C., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology*, *108*(3), 436–452. https://doi.org/10.1016/j.jecp.2010.08.008

Wildenberg, W. P. M. V. D., & Christoffels, I. K. (2010). STOP TALKING! Inhibition of speech is affected by word frequency and dysfunctional impulsivity. *Frontiers in Psychology*, *1*. https://doi.org/10.3389/fpsyg.2010.00145

Wilkinson, G. S., & Robertson, G. J. (2006). *Wide Range Achievement Test 4* [Databaserecord]. APA PsycTests. https://doi.org/10.1037/t27160-000

Williams, T. C., Bach, C. C., Matthiesen, N. B., Henriksen, T. B., & Gagliardi, L. (2018). Directed acyclic graphs: A tool for causal studies in paediatrics. *Pediatric Research*, *84*(4), 487–493. https://doi.org/10.1038/s41390-018-0071-3

Willoughby, M. T., Blair, C. B., Wirth, R. J., Greenberg, M., & The Family Life Project Investigators. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment*, *22*(2), 306–317. https://doi.org/10.1037/a0018708

Wilson, C. A., Santorelli, G., Howard, L. M., Ismail, K., Reynolds, R. M., & Simonoff, E. (2023). Child educational progress in Born in Bradford pregnancies affected by gestational diabetes and also exposed to maternal common mental disorders. *Scientific Reports*, *13*(1), 17991. https://doi.org/10.1038/s41598-023-44619-0

Withanawasam, N., & Tara, S. (2019). The shortened cervix in pregnancy: Investigation and current management recommendations for primary caregivers. *Australian Journal of General Practice*, *48*(3), 121–123. https://doi.org/10.31128/AJGP-09-18-4708

Wolke, D., Johnson, S., & Mendonca, M. (2019). The life course consequences of very preterm birth. *Annual Review of Developmental Psychology*, 41. https://doi.org/10.1146/annurev-devpsych-121318-084804

Wolke, D., Samara, M., Bracewell, M., & Marlow, N. (2008). Specific language difficulties and school achievement in children born at 25 weeks of gestation or less. *The Journal of Pediatrics*, *152*(2), 256-262.e1. https://doi.org/10.1016/j.jpeds.2007.06.043

Wood, M. (2021). Exploring sociodemographic influences upon sensorimotor control across childhood using kinematic assessment. https://etheses.whiterose.ac.uk/30608/

Wood, M., Waterman, A., Mon-Williams, M., & Hill, L. (2024). Key kinematic measures of sensorimotor control identified via data reduction techniques in a population study (Born in Bradford). *Wellcome Open Research*, *9*, 381. https://doi.org/10.12688/wellcomeopenres.22486.1

Woodcock RW, and Johnson, M.B. (1989). *Woodcock-Johnson Tests of Achievement.* [Computer software]. DLM Teaching Resources.

Woythaler, M., McCormick, M. C., Mao, W.-Y., & Smith, V. C. (2015). Late preterm infants and neurodevelopmental outcomes at kindergarten. *Pediatrics*, *136*(3), 424–431. https://doi.org/10.1542/peds.2014-4043

Wright, B., Konstantopoulou, K., Sohal, K., Kelly, B., Morgan, G., Cathy Hulin, Sara Mansoor, & Mark Mon-Williams. (2021). Systematic approach to school-based assessments for autism spectrum disorders to reduce inequalities: A feasibility study in 10 primary schools. *BMJ Open*, *11*(1), e041960. https://doi.org/10.1136/bmjopen-2020-041960

Wright, B., Mon-Williams, M., Kelly, B., Williams, S., Sims, D., Mushtaq, F., Sohal, K., Blackwell, J. E., & Wright, J. (2019). Investigating the association between early years foundation stage profile scores and subsequent diagnosis of an autism spectrum disorder: A retrospective study of linked healthcare and education data. *BMJ Paediatrics Open*, *3*(1), e000483. https://doi.org/10.1136/bmjpo-2019-000483

Wright, J., Small, N., Raynor, P., Tuffnell, D., Bhopal, R., Cameron, N., Fairley, L., Lawlor, D. A., Parslow, R., Petherick, E. S., Pickett, K. E., Waiblinger, D., West, J., & on behalf of the Born in Bradford Scientific Collaborators Group. (2013). Cohort profile: The Born in Bradford multi-ethnic family cohort study. *International Journal of Epidemiology*, *42*(4), 978–991. https://doi.org/10.1093/ije/dys112

Wu, K. K., Chan, S. K., Leung, P. W. L., Liu, W.-S., Leung, F. L. T., & Ng, R. (2011). Components and developmental differences of executive functioning for school-aged children. *Developmental Neuropsychology*, *36*(3), 319–337. https://doi.org/10.1080/87565641.2010.549979

York, T. T., Gibson, C., & Rankin, S. (2015). *Defining and measuring academic success*. *Practical Assessment, Research, and Evaluation* 20(1): 5. https://doi.org/10.7275/hz5x-tx03

You, J., Shamsi, B. H., Hao, M., Cao, C.-H., & Yang, W.-Y. (2019). A study on the neurodevelopment outcomes of late preterm infants. *BMC Neurology*, *19*(1), 108. https://doi.org/10.1186/s12883-019-1336-0

You, J., Yang, H., Hao, M., & Zheng, J. (2019). Late preterm infants' social competence, motor development, and cognition. *Frontiers in Psychiatry*, *10*, 69. https://doi.org/10.3389/fpsyt.2019.00069

Zagar, R. J., Kovach, J. W., Lakhani, A., Stone, T., Singh, I., Portela, M., & Berroa, B. (2018). Can the WRAT-4 math computation subtest predict final grade in college-level science. *Review of European Studies*, *10*(4), 144. https://doi.org/10.5539/res.v10n4p144

Zhang, Q., Dong, X., Jin, W., & Fan, J. (2024). Early brain cognitive development in late preterm infants: An event-related potential and resting EEG study. *Italian Journal of Pediatrics*, *50*(1), 26. https://doi.org/10.1186/s13052-023-01567-9

Zimmermann, D. L., Schned, H., Unterasinger, L., Kirchner, L., Fuiko, R., Olischar, M., Klebermass-Schrehof, K., Berger, A., Weninger, M., & Giordano, V. (2023). Impact of retinopathy of prematurity on visual motor integration. *Neonatology*, *120*(3), 317–324. https://doi.org/10.1159/000529594

Appendix A : Ethics Confirmation

Hi Clare,

Please accept this email as confirmation that your ethics application [Preterm Birth, Education and Educational Interventions - resubmission] has been **approved** by the committee.
The ethics number is PSYC-249 and date of approval is 02/05/2021.

Appendix B : Sample Characteristics of Participants in the Educational Achievement Study

Table B-1

Sociodemographic Characteristics for the EYFSP Assessment in the Educational Achievement Study

Characteristic	VMPT (*n* = 97)		LPT (*n* = 305)		Early Term (*n* = 1703)		Full Term (*n* = 5755)	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Male	45	47	172	56	888	52	2871	50
Female	52	53	133	44	815	48	2884	50
Ethnicity								
White British	48	50	120	39	568	33	2331	40
Pakistani	40	41	132	43	899	53	2691	47
Other Ethnicity	9	9	53	18	236	14	733	13
Smoked								
Smoked	23	24	69	23	250	15	979	17
Did not smoke	74	76	236	77	1453	85	4776	83
Maternal Highest Level of Education								
Higher Education	24	25	82	27	392	23	1359	24
A Levels	18	18	46	15	249	15	876	15
5 GCSEs	25	26	82	27	551	32	1849	32
< 5 GCSEs	22	23	72	24	400	24	1253	22
Other/Unknown	8	8	23	7	111	6	418	7

Table B-1 continued

Characteristic	VMPT (*n* = 97)		LPT (*n* = 305)		Early Term (*n* = 1703)		Full Term (*n* = 5755)	
	n	%	*n*	%	*n*	%	*n*	%
Cohabitation								
Single	21	22	61	20	234	14	973	17
Partnered	76	78	244	80	1469	86	4776	83
Means Tested Benefit								
Received	33	34	130	43	798	47	2428	42
Not Received	64	66	175	57	905	53	3327	58
IMD[1]								
Category 1[1]	63	65	162	53	858	50	2856	50
Categories 2 to 10[1]	34	35	143	47	845	50	2899	50
Mother's Age								
≤ 20 years	11	11	25	8	122	7	610	11
21 to 34 years	74	76	238	78	1298	76	4462	77
Over 34 years	12	1	42	14	283	17	683	12
Parity								
First Born	55	57	128	42	552	32	2281	11
1 to 3 previous births	42	43	160	52	1035	61	3189	77
≥ 4 previous births	0	0	17	6	116	7	285	12

Note. *n* = 7860. [1] IMD = Index of Multiple deprivation (Department for Communities and Local Government, 2010), of which categories 1 is the most deprived areas and category 10 the least deprived

Table B-2

Sociodemographic Characteristics for the Phonics Assessment in the Educational Achievement Study

Characteristic	VMPT (*n* = 106)		LPT (*n* = 306)		Early Term (*n* = 1724)		Full Term (*n* = 5895)	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Male	50	46	176	58	907	53	2954	50
Female	56	54	130	42	817	47	2951	50
Ethnicity								
White British	47	44	125	41	578	33	2386	40
Pakistani	47	44	124	40	909	53	2763	47
Other Ethnicity	12	12	57	19	237	14	746	13
Smoked								
Smoked	24	24	73	24	259	15	979	17
Did Not Smoke	82	76	233	76	1465	85	4917	83
Maternal Highest Level of Education								
Higher Education	24	23	82	27	396	23	1364	23
A Levels	17	16	42	14	241	14	868	15
5 GCSEs	30	28	80	26	561	32	1916	32
< 5 GCSEs	22	21	78	25	407	24	1301	22
Other/Unknown	13	12	24	8	119	7	446	78

Table B-2 continued

Characteristic	VMPT (*n* = 106)		LPT (*n* = 306)		Early Term (*n* = 1724)		Full Term (*n* = 5895)	
	n	%	*n*	%	*n*	%	*n*	%
Cohabitation								
Single	22	21	64	21	226	14	999	17
Partnered	84	79	242	79	1498	86	4896	83
Means Tested Benefit								
Received	39	37	133	44	800	46	2841	42
Not Received	67	63	173	56	924	54	3054	58
IMD[1]								
Category 1[1]	72	68	166	54	865	50	2945	50
Categories 2 to 10[1]	34	32	140	46	859	50	2950	50
Mother's Age								
< 20 years	10	10	28	9	124	7	633	11
21 to 34 years	83	78	239	78	1317	77	4556	77
Over 34 years	13	12	39	13	283	16	706	12
Parity								
First Born	57	54	134	43	564	33	2344	40
1 to 3 Previous births	49	46	158	52	1042	60	3253	55
≥ 4 Previous births	0	0	14	5	118	7	298	5

Note. *n* = 8031.[1] IMD=Index of Multiple Deprivation (Department for Communities and Local Government, 2010), of which categories 1 is the most deprived areas and category 10 the least deprived.

Table B-3

Sociodemographic Characteristics of Participants for the KS1 Assessment in Educational Achievement Study

Characteristic	VMPT (*n* = 63)		LPT (*n* = 204)		Early Term (*n* = 1237)		Full Term (*n* = 4056)	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Female	35	56	91	45	594	48	202	50
Male	28	44	113	55	643	52	2034	50
Ethnicity								
White British	34	54	81	40	410	33	1641	40
Pakistani	23	37	87	43	658	53	1893	47
Other Ethnicity	6	9	336	17	169	14	522	13
Smoked								
Smoked	17	27	43	21	199	16	726	18
Did not smoke	46	73	161	79	1038	84	3330	82
Maternal Highest Level of Education								
Higher Education	15	24	53	25	287	23	844	21
A Levels	14	22	28	26	397	32	1296	32
5 GCSEs	16	25	53	14	193	16	664	16
< 5 GCSEs	13	21	51	26	287	23	972	24
Other/Unknown	5	8	19	9	73	6	280	76

Table B-3 continued

Characteristic	VMPT (*n* = 63)		LPT (*n* = 204)		Early Term (*n* = 1237)		Full Term (*n* = 4056)	
	n	%	*n*	%	*n*	%	*n*	%
Cohabitation								
Single	16	25	44	22	167	14	704	17
Partnered	47	75	160	78	1070	86	3352	83
Means Tested Benefit								
Received	24	38	91	45	581	47	1779	44
Not Received	39	62	113	55	656	53	2277	56
IMD								
Category 1[1]	44	70	104	51	647	52	2032	50
Categories 2 to 10[1]	19	30	100	49	590	48	2024	50
Mother's Age								
≤ 20 years	5	8	17	8	80	7	415	10
21 to 34 years	50	79	162	80	946	76	3170	78
Over 34 years	8	13	25	12	211	17	471	12
Parity								
First Born	33	52	81	40	397	32	1604	40
1 to 3 Previous births	30	48	114	56	757	61	2252	55
≥ 4 Previous births	0	0	9	4	83	7	200	5

Note. n = 5560. [1] Index of Multiple Deprivation (Department for Communities and Local Government, 2010), of which categories 1 is the most deprived areas and category 10 the least deprived.

Table B-4

Sociodemographic Characteristics of Participants for the KS2 Data Assessment

Characteristic	VMPT (*n* = 43)		LPT (*n* = 101)		Early Term (*n* = 468)		Full Term (*n* = 1774)	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Female	20	46	41	41	215	46	877	49
Male	23	54	60	59	253	54	897	51
Ethnicity								
White British	14	33	42	42	150	32	697	39
Pakistani	23	53	39	38	256	55	874	49
Other Ethnicity	6	14	20	20	62	13	203	12
Smoked								
Smoked	7	16	28	28	55	12	248	14
Did not smoke	36	84	73	72	413	88	1526	86
Maternal Highest Level of Education								
Higher Education	10	23	23	24	97	21	378	21
A Levels	4	9	14	14	47	10	201	11
5 GCSEs	14	33	31	31	159	34	592	34
< 5 GCSEs	8	19	26	26	121	26	442	25
Other/ Unknown	7	16	6	5	44	9	161	9

Table B-4 continued

Characteristic	VMPT (*n* = 63)		LPT (*n* = 204)		Early Term (*n* = 1237)		Full Term (*n* = 4056)	
	n	%	*n*	%	*n*	%	*n*	%
Cohabitation								
Single	5	12	18	18	64	14	280	16
Partnered	38	88	171	172	404	86	1494	84
Means Tested Benefit								
Received	15	35	46	46	222	47	699	39
Not Received	28	65	55	54	246	53	1045	61
IMD								
Category 1[1]	28	65	59	58	226	48	894	50
Categories 2 to 10[1]	15	35	42	42	242	52	880	50
Mother's Age								
≤ 20 years	5	12	42	42	150	32	697	39
21 to 34 years	33	53	39	38	26	55	874	49
Over 34 years	5	14	20	20	62	13	203	12
Parity								
First Born	25	58	36	46	152	32	703	40
1 to 3 previous births	18	42	48	47	283	61	976	55
≥ 4 previous births	0	0	7	7	33	7	95	5

Note. n = 2399. [1] Index of Multiple Deprivation (Department for Communities and Local Government, 2010), of which categories 1 is the most deprived areas and category 10 the least deprived.

Appendix C : Covariates with Missing Data Analysis for Educational Achievement Study

Table C-1

Covariates with Missing Data Analysis in the Educational Achievement Study

Covariate	BiB Sample %	After excl.[1] %	EYFS Sample %	Phonics Sample %	KS1 Sample %	KS2 Sample %
Smoked During Pregnancy						
No	84	84	83	83	82	86
Yes	16	16	17	17	18	14
Cohabitation						
Partnered	84	84	84	84	83	85
Single	16	16	16	16	17	15
Ethnicity						
White British	40	38	39	39	39	38
Pakistani	45	48	48	48	48	50
Other	15	14	13	13	13	12
IMD						
Categories 2-10	50	49	50	50	49	49
Category 1	50	51	50	50	51	51
Maternal Highest Level of Education						
Higher Education	25	24	24	23	23	21
A Level	15	15	15	15	16	11
5 GCSEs	32	32	32	32	32	34
Less than 5 GCSEs	21	22	22	23	22	25
Other	7	7	7	7	7	9
Parity						
First Born	40	38	39	39	38	39
1 3 previous births	54	56	56	56	57	55
≥ 4 previous births	6	6	5	5	5	6
Means Tested Benefit						
No	59	57	57	57	56	59
Yes	41	43	43	43	44	41

Note. [1] After Exclusions. Exclusion criteria: observations were excluded if they did not have covariate data, outcome or gestational data; the gestation was ≥42 weeks, the child was a looked-after" child or the "looked after" data was missing; or the birth was a multiple birth.

Appendix D : Simple Regression Tables for Educational Achievement Study

Table D-1

Simple Logistic Regression Table for Overall Educational Achievement: Predicted by Gestational Group

Variable	EYFSP Overall Academic Attainment[a]			
	OR	SE	95% CI LL, UL	p
Intercept	0.57	0.07	0.54, 0.60	**< .001**
Early Term[1]	1.09	0.22	-0.98, 1.22	.130
LPT[1]	1.67	0.43	1.33, 2.10	**< .001**
VMPT[1]	1.71	0.11	1.15, 2.56	**.009**
Variable	KS1 Overall Academic Attainment[b]			
	OR	SE	95% CI LL, UL	p
Intercept	0.50	0.02	0.54, 0.60	**< .001**
Early Term[1]	1.00	0.07	0.87, 1.15	.992
LPT[1]	1.47	0.21	1.10, 1.95	**.009**
VMPT[1]	0.94	0.26	0.55, 1.60	.807
Variable	KS2 Overall Academic Attainment[c]			
	OR	SE	95% CI LL, UL	p
Intercept	0.53	0.03	0.48, 0.58	**< .001**
Early Term[1]	1.20	0.13	0.97, 1.48	.089
LPT[1]	1.53	0.32	1.02, 2.29	**.039**
VMPT[1]	2.19	0.68	1.19, 4.02	**.011**

Note. Comparator Group: [1]Full Term. [a]n = 7680, pseudo R^2 = 0.00, p < .001, [b]n = 5560, pseudo R^2 = 0.00, p = .075; [c]n = 2386, pseudo R^2 = 0.00, p = .007. Abbreviations: KS1 = Key Stage One; OR = Odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table D-2

Simple Logistic Regression Table for Reading: Predicted by Gestational Group

Variable	EFYSP Reading[a]			
	OR	SE	95% CI LL, UL	p
Intercept	0.41	0.01	0.39, 0.44	**< .001**
Early Term[1]	1.13	0.07	1.01, 1.27	**.036**
LPT[1]	1.48	0.18	1.17, 1.88	**.001**
VMPT[1]	1.56	0.33	1.03, 2.35	**.035**
Variable	Phonics[b]			
	OR	SE	95% CI LL, UL	p
Intercept	0.24	0.01	0.23, 0.26	**< .001**
Early Term[1]	1.05	0.07	0.92, 1.20	.502
LPT[1]	1.73	0.22	1.35, 2.23	**< .001**
VMPT[1]	1.85	0.39	1.22, 2.81	**.002**
*V*ariable	Reading at KS1[c]			
	OR	SE	95% CI LL, UL	p
Intercept	0.31	0.01	0.29, 0.33	**< .001**
Early Term[1]	1.02	0.08	0.88, 1.19	.764
LPT[1]	1.29	0.21	0.94, 1.76	.114
VMPT[1]	1.01	0.30	0.56, 1.82	.968
*V*ariable	Reading at KS2[d]			
	OR	SE	95% CI LL, UL	p
Intercept	0.36	0.02	0.33, 0.40	**< .001**
Early Term[1]	1.17	0.13	0.93, 1.46	.181
LPT[1]	1.53	0.33	1.00, 2.33	**.048**
VMPT[1]	1.48	0.48	0.78, 2.79	.229

Note. Comparator Group: [1]Full Term. [a] $n = 7680$, pseudo $R^2 = 0.00$, $p < .001$; [b]$n = 8031$, pseudo $R^2 = 0.00$, $p < .001$; [c]$n = 5560$, pseudo $R^2 = 0.00$, $p = .489$; [d]$n = 7680$, pseudo $R^2 = 0.00$, $p = .108$. Abbreviations: KS1 = Key Stage One; OR = Odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table D-3

Logistic Regression Table for Writing: Predicted by Gestational Group

Variable	Writing at EFYSP[a]			
	OR	SE	95% CI LL, UL	p
Intercept	0.51	0.01	0.48, 0.54	**< .001**
Early Term[1]	1.09	0.06	0.97, 1.22	.154
LPT[1]	1.75	0.21	1.39, 2.21	**< .001**
VMPT[1]	1.63	0.34	1.09, 2.44	**.018**
Variable	**Writing at KS1[b]**			
	OR	SE	95% CI LL, UL	p
Intercept	0.39	0.01	0.37, 0.42	**< .001**
Early Term[1]	1.02	0.07	0.88, 1.17	.808
LPT[1]	1.39	0.21	1.03, 1.87	**.029**
VMPT[1]	1.02	0.29	0.59, 1.77	.945
Variable	**Writing at KS2[c]**			
	OR	SE	95% CI LL, UL	p
Intercept	0.24	0.01	0.21, 0.26	**< .001**
Early Term[1]	1.31	0.16	1.02, 1.67	**.033**
LPT[1]	1.71	0.39	1.09, 2.68	**.019**
VMPT[1]	2.05	0.68	1.07, 3.92	**.030**
Variable	**EGPS at KS2[d]**			
	OR	SE	95% CI LL, UL	p
Intercept	0.22	0.01	0.20, 0.25	**< .001**
Early Term[1]	1.20	0.15	0.93, 1.54	.161
LPT[1]	2.40	0.52	1.57, 3.68	**< .001**
VMPT[1]	1.96	0.66	1.01, 3.80	**.046**

Note. Comparator Group: [1]Full Term. [a] $n = 7680$, pseudo $R^2 = 0.00$, $p < .001$; [b] $n = 5560$, pseudo $R^2 = 0.00$, $p = .201$; [c] $n = 2386$, pseudo $R^2 = 0.00$, $p = .007$; [d] $n = 2386$, pseudo $R^2 = .008$, $p < .001$. Abbreviations: KS1 = Key Stage One; OR = Odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table D-4

Logistic Regression Table for Mathematics: Predicted by Gestational Group

Variable	Mathematics at EFYSP[a]			
	OR	SE	95% CI LL, UL	p
Intercept	0.43	0.01	0.41, 0.46	**< .001**
Early Term[1]	1.12	0.07	1.00, 1.26	.051
LPT[1]	1.65	0.20	1.31, 2.09	**< .001**
VMPT[1]	2.00	0.41	1.34, 3.00	**.001**
*V*ariable	Number at EYFSP[b]			
	OR	SE	95% CI LL, UL	p
Intercept	0.40	0.01	0.38, 0.42	**< .001**
Early Term[1]	1.14	0.07	1.01, 1.28	**.029**
LPT[1]	1.68	0.20	1.32, 2.12	**< .001**
VMPT[1]	2.00	0.41	1.34, 3.00	**< .001**
Variable	Shape, Space and Measure at EYFSP[c]			
	OR	SE	95% CI LL, UL	p
Intercept	0.35	0.01	0.33, 0.37	**< .001**
Early Term[1]	1.12	0.07	0.99, 1.26	.073
LPT[1]	1.54	0.19	1.21, 1.96	**.001**
VMPT[1]	1.94	0.41	1.29, 2.93	**.002**

Note. Comparator Group: [1]Full Term. [a]*n* = 7680, Pseudo R^2 = 0.00, p < .001; [b]*n* = 7680, Pseudo R^2 = .003, p < .001; [c]*n* = 7680, Pseudo R^2 = .002, p < .001. Abbreviations: KS1 = Key Stage One; OR = Odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table D-5

Logistic Regression Table for Mathematics at KS1 and KS2: Predicted by Gestational Group

Variable	Mathematics at KS1[a]			
	OR	SE	95% CI LL, UL	p
Intercept	0.30	0.01	0.28, 0.32	**< .001**
Early Term[1]	1.05	0.08	0.90, 1.21	.556
LPT[1]	1.58	0.24	1.17, 2.14	**.003**
VMPT[1]	0.95	0.29	0.52, 1.72	.855
Variable	**Mathematics at KS2[b]**			
	OR	SE	95% CI LL, UL	p
Intercept	0.24	0.01	0.21, 0.27	**< .001**
Early Term[1]	1.18	0.15	0.92, 1.52	.188
LPT[1]	2.22	0.48	1.45, 3.40	**< .001**
VMPT[1]	2.24	0.73	1.19, 4.25	**.013**

Note. Comparator Group: [1]Full Term. [a]n = 5560, pseudo R^2 = 0.00, p = .036; [b]n = 2386, Pseudo R^2 = 0.01, p < .001. Abbreviations: KS1 = Key Stage One; OR = Odds ratio; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm

Appendix E : Sample Characteristics of Participants in the Educational Scores Study

Table E-1

Sociodemographic Characteristics of Participants

Characteristic	VMPT (*n* = 26)		LPT (*n* = 76)		Early Term (*n* = 364)		Full Term (*n* = 1410)	
	n	%	*n*	%	*n*	%	*n*	%
Sex								
Male	11	52	44	58	192	53	683	48
Female	15	46	32	42	172	47	727	52
Ethnicity								
White British	11	42	30	40	114	32	528	37
Pakistani	13	50	29	38	198	54	687	49
Other Ethnicity	2	8	17	22	52	14	195	14
Smoked								
Smoked	6	23	22	29	40	11	207	15
Did not smoke	20	77	54	71	324	89	1203	85
Cohabitation								
Single	4	15	14	18	51	14	216	15
Partnered	22	85	62	82	313	86	1194	85
Maternal Highest Level of Education								
Higher Education	6	23	19	25	76	21	307	22
A Levels	2	8	14	18	39	11	166	12
5 GCSEs	9	35	24	32	128	35	459	33
< 5 GCSEs	7	27	16	21	94	26	359	25
Other/Unknown	2	8	3	4	27	7	119	8

Table E-1 continued

Characteristic	VMPT (*n* = 26)		LPT (*n* = 76)		Early Term (*n* = 364)		Full Term (*n* = 1410)	
	n	%	*n*	%	*n*	%	*n*	%
Means Tested Benefit								
Received	7	27	35	46	181	50	552	39
Not Received	19	73	41	54	183	50	858	61
IMD[1]								
Category 1[1]	10	38	35	46	184	51	707	50
Category 2 to 10[1]	16	62	41	54	180	49	703	50
Mother's Age								
< 20 years	5	8	14	18	32	9	170	12
21 to 34 years	19	73	53	70	275	75	1065	76
Over 34 years	2	19	9	12	57	16	175	12
Parity								
First Born	17	66	31	41	110	30	547	39
1 to 3 previous births	9	34	38	50	226	62	791	56
≥ 4 previous births	0	0	7	9	28	8	72	5

Note. *n* = 1876. 1 Index of Multiple Deprivation (Department for Communities and Local Government, 2010), of which categories 1 is the most deprived areas and category 10 the least deprived.

Appendix F : Points Score Equivalence for Educational Scores

Table F-1

Department for Education Scoring for KS1

KS1 National curriculum teacher assessment level	Point score equivalent
Level 4	27
Level 3	21
Level 2A	17
Level 2B or undifferentiated Level 2	15
Level 2C	13
Level 1	9
Working Towards Level 1	3
Missing/disapplied/absent	Disregard

Note. KS1 Points Test and Examination Point Score: Reproduced from Department for Education (2019b).

Table F-2

Department for Education Scoring for Writing at KS2

Teacher Assessed Writing Ranking	Score
Working Towards Expected Standard	91
Working at Expected Standard	103
Working at Greater Depth	113

Note. Scoring taken from Department for Education (2019b).

Table F-3

Department for Education Scoring for Children not Sitting KS2 Test

Teacher Assessed Ranking	Score
Standard 6 (working at the KS1 Expected Standard)	79
Standard 5 (working towards the KS1 Expected Standard)	76
Standard 4	73
Standard 3	70
Standard 2	67
Standard 1	64
Children working below the pre-key stage but not on P scales	62
P scale P4	61
P1i to P3ii	59
P scale P4	61
P1i to P3ii	59

Note. Children working well below the Key Stage Standard at KS2 who were unable to sit actual tests had teacher assessed outcomes within pre-Key Stage assessment, pursuant to the KS2 curriculum (Department for Education, 2019b). The Department for education provide a score equivalent to these, as shown.

Appendix G : Z-Scored Mean Education Scores by Gestational Group

Table G-1

Z-Scored Mean Educational Scores by Gestational Group

Time	Full Term (*n* = 1410)			Early Term (*n* =364)			LPT (*n* = 76)			VMPT (*n* = 26)		
	M	S.E	95% CI LL, UL	*M*	S.E.	95% CI LL, UL	*M*	S.E.	95% CI LL, UL	*M*	S.E.	95% CI LL, UL
T1	0.04	.03	-0.01, 0.09	- 0.07	.05	-0.17, 0.03	- 0.19	.13	-0.44, 0.06	-0.62	.19	-1.01, -0.24
T2	0.06	.03	0.01, 0.11	- 0.13	.06	-0.25, -0.02	- 0.18	.14	-0.46, 0.10	-0.62	.16	-0.94, -0.30
T3	0.03	.03	-0.02, 0.08	- 0.05	.06	-0.16, 0.06	- 0.19	.14	-0.47, 0.09	-0.50	.17	-0.85, -0.15

Note: *n* = 1876. *M* = mean, *SE* = standard error, *95% CI* = 95% Confidence Interval, *LL* = Lower Limit, *UL* = Upper Limit.

LPT = Late Preterm; VMPT = Very and moderately preterm. Higher score equates to better performance.

Appendix H : Multi-Level Modelling Regression Tables for Educational Scores Study

Table H-1

Multi-level Model T1-T2 and T1-T3: Unadjusted

Variables	T1 to T2 and T1 to T3: Unadjusted			
	B	95% CI LL, UL	S.E	p
Fixed Effects				
Intercept	0.04	-0.01, 0.09	0.03	.134
Change T1 - T2	0.02	-0.03, 0.06	0.02	.476
Change T1 - T3	-0.01	-0.05, 0.03	0.02	.728
Early Term[1]	-0.11	-0.22, 0.01	0.06	.062
LPT[1]	-0.23	-0.46, -0.00	0.12	**.049**
VMPT[1]	-0.66	-1.05, -0.28	0.20	**.001**
Early Term/time interaction T1 - T2[1]	-0.08	-0.17, 0.02	0.05	.101
Early Term/time interaction T1 - T3[1]	0.03	-0.07, 0.12	0.05	.559
LPT/time interaction T1 - T2[1]	0.00	-0.19, 0.19	0.10	.987
LPT/time interaction T1 - T3[1]	0.01	-0.18, 0.19	0.10	.951
VMPT/time interaction T1 - T2[1]	-0.01	-0.32, 0.30	0.16	.947
VMPT/time interaction T1 - T3[1]	0.13	-0.18, 0.45	0.16	.401
Random Effects				
intercept variance	0.66	0.61, 0.71	0.03	
residual variance	0.33	0.31, 0.34	0.01	
Deviance	13366			

Note. *n* = 1876. Comparator: [1] Full Term Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

.

Table H-2

Multilevel Model T1-T2 and T1-T3: Adjusted for SES Covariates

Variables	T1 to T2 & T1 to T3: Adjusted for SES Covariates			
	B	95% CI LL, UL	S.E	p
Fixed Effects				
Intercept	0.60	-0.47, 073	0.07	**< .001**
Change from T1 - T2	0.02	-0.03, 0.06	0.02	.476
Change from T1 - T3	-0.01	-0.05, 0.03	0.02	.728
Early Term[1]	-0.10	-0.21, 0.02	0.06	.093
LPT[1]	-0.25	-0.47, -0.03	0.11	**.029**
VMPT[1]	-0.67	-1.04, -0.30	0.19	**< .001**
Early Term/time interaction T1 - T2[1]	-0.08	-0.17, 0.02	0.05	.101
Early Term/time interaction T1 - T3[1]	0.03	-0.07, 0.12	0.05	.559
LPT/time interaction T1 - T2[1]	0.00	-0.19, 0.19	0.10	.989
LPT/time interaction T1 - T3[1]	0.01	-0.18, 0.19	0.10	.951
VMPT/time interaction T1 - T2[1]	-0.01	-0.32, 0.30	0.16	.947
VMPT/time interaction T1 - T3[1]	0.13	-0.18, 0.45	0.16	**.401**
Maternal Education: A Levels[2]	-0.35	-0.49, -0.21	0.07	**< .001**
Maternal Education: 5 GCSEs[2]	-0.39	-0.50, -0.28	0.06	**< .001**
Maternal Education: < 5 GCSEs[2]	-0.61	-0.73, -0.50	0.06	**< .001**
Maternal Education: other[2]	-0.19	-0.35, -0.04	0.08	**.017**
Receipt of means tested benefit[3]	-0.15	-0.23, -0.07	0.04	**< .001**
Mother Aged 21 to 34 years[4]	-0.18	-0.29, -0.06	0.06	**.003**
Mother Aged ≤ 20 years[4]	-0.23	-0.39, -0.07	0.08	**.004**
Random Effects				
intercept variance	0.60	0.55, 0.77	0.02	
residual variance	0.33	0.31, 0.34	0.01	
Deviance	13204			

Note. *n* = 1876. Comparator: [1]Full Term; [2]Higher Education; [3]Means tested benefit not received; [4]Age 35 or over at child's birth. IMD, smoking and cohabitation were not significant in the model and therefore were removed. Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table H-3

Multilevel Model T1-T2 and T1-T3: Adjusted for SES & Antenatal Covariates

Variables	B	95% CI LL, UL	S.E	p
Fixed Effects				
Intercept	0.85	-0.69, 1.01	0.08	**< .001**
Change from T1 - T2	0.02	-0.03, 0.06	0.02	.476
Change from T1 - T3	-0.01	-0.05, 0.03	0.02	.728
Early Term[1]	-0.08	-0.19, 0.03	0.06	.137
LPT[1]	-0.24	-0.46, -0.02	0.11	**.031**
VMPT[1]	-0.68	-1.05, -0.31	0.19	**< .001**
Early Term/time interaction T1 - T2[1]	-0.08	-0.17, 0.02	0.05	.101
Early Term/time interaction T1 - T3[1]	0.03	-0.07, 0.12	0.05	.559
LPT/time interaction to T1 - T2[1]	0.00	-0.19, 0.19	0.10	.987
LPT/time interaction to T1 - T3[1]	0.01	-0.18, 0.19	0.10	.951
VMPT/time interaction T1 - T2[1]	-0.01	-0.32, 0.30	0.16	.947
VMPT/time interaction T1 - T3[1]	0.13	-0.18, 0.45	0.16	.401
Maternal Education: A Levels[2]	-0.34	-0.48, -0.21	0.07	**< .001**
Maternal Education: 5 GCSEs[2]	-0.39	-0.50, -0.28	0.06	**< .001**
Maternal Education: < 5 GCSEs[2]	-0.60	-0.72, -0.49	0.06	**< .001**
Maternal Education: other[2]	-0.20	-0.36, -0.04	0.08	**.014**
Receipt of means tested benefit[3]	-0.12	-0.20, -0.04	0.04	**.004**
Mother aged 21 to 34 years[4]	-0.16	-0.27, -0.04	0.06	**.007**
Mother aged ≤ 20 years [4]	-0.19	-0.35, -0.03	0.08	**.021**
Academic Month of birth	-0.02	-0.03, -0.01	0.01	**.002**
Male[5]	-0.21	-0.29, -0.14	0.04	**< .001**
Pakistani ethnicity[6]	-0.10	-0.19, -0.01	0.04	**.023**
Other Ethnicity[6]	0.05	-0.07, 0.17	0.06	.440
Single Parent[7]	-0.14	-0.25, -0.02	0.06	**.022**
Random Effects				
intercept variance	0.58	0.54, 0.63	0.02	
residual variance	0.33	0.31, 0.34	0.01	
Deviance		13153		

Note. *n* = 1876. Comparator: [1]Full Term; [2]Higher Education; [3]Means tested benefit not received; [4]Age 35 or over at child's birth; [5]Female; [6]White British; [7]Lives with partner. IMD and smoking were not significant in the model and therefore were removed. Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table H-4

Multi-level Model T2 to T3: Unadjusted

Variables	B	95% CI LL, UL	S.E	p
Fixed Effects				
Intercept	0.06	0.00, 0.11	0.03	**.037**
Change T2 - T3	-0.02	-0.07, 0.02	0.02	.289
Early Term[1]	-0.19	-0.30, -0.07	0.06	**.001**
LPT[1]	-0.23	-0.46, -0.00	0.12	**.047**
VMPT[1]	-0.67	-1.06, -0.29	0.20	**.001**
Early Term/time interaction T2 - T3	0.11	0.01, 0.20	0.05	**.026**
LPT/Time interaction T2 - T3	0.01	-0.18, 0.19	0.10	.938
VMPT/time interaction T2 - T3	0.15	-0.17, 0.46	0.16	.365
Random Effects				
intercept variance	0.78	0.73, 0.84	0.03	
residual variance	0.21	0.19, 0.22	0.01	
Deviance		13366		

Note. *n* = 1876. Comparator: [1]Full Term. Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table H-5

Multi-Level Model T2 to T3: Adjusted for SES Covariates

Variables	T2 to T3: Adjusted for SES Covariates			
	B	95% CI LL – UL	S.E	p
Fixed Effects				
Intercept	0.61	0.48, 0.75	0.07	**< .001**
Change T2 - T3	-0.02	-0.07, 0.02	0.02	.289
Early Term[1]	-0.17	-0.29, -0.06	0.06	**.002**
LPT[1]	-0.25	-0.47, -0.03	0.11	**.028**
VMPT[1]	-0.68	-1.05, -0.30	0.19	**< .001**
Early Term/time interaction T2 - T3[1]	0.11	0.01, 0.20	0.05	**.026**
LPT/time interaction T2 - T3[1]	0.01	-0.18, 0.19	0.10	.938
VMPT/time interaction T2 - T3[1]	0.15	-0.17, 0.46	0.16	.365
Maternal Education: A Levels[2]	-0.35	-0.49 -0.21	0.07	**< .001**
Maternal Education: 5 GCSEs[2]	-0.39	-0.50, -0.28	0.06	**< .001**
Maternal Education: < 5 GCSEs[2]	-0.61	-0.73, -0.50	0.06	**< .001**
Maternal Education: other[2]	-0.19	-0.35, -0.04	0.08	**.017**
Receipt of means tested benefit[3]	-0.15	-0.23, -0.07	0.04	**< .001**
Mother Aged 21 to 34 years[4]	-0.18	-0.29, -0.06	0.06	**.003**
Mother Aged ≤ 20 years[4]	-0.23	-0.39, -0.07	0.08	**.004**
Random Effects				
intercept variance	0.72	0.67, 0.78	0.02	
residual variance	0.21	0.19, 0.22	0.01	
Deviance		13199		

Note. *n* = 1876. Comparator: [1]Full Term; [2] Higher Education; [3]Means tested benefit not received; [4]Age 35 or over at child's birth. IMD, smoking and cohabitation were not significant in the model and therefore were removed. . Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table H-6

Multi-Level Model T2 to T3: Adjusted for SES and Antenatal Covariates

Variables	T2 to T3: Adjusted for SES & Antenatal Covariates			
	B	95% CI LL, UL	S.E	p
Fixed Effects				
Intercept	0.86	0.70, 1.03	0.08	**< .001**
Change T2 - T3	-0.02	-0.07, 0.02	0.02	.289
Early Term[1]	-0.16	-0.27, -0.05	0.06	**.004**
LPT[1]	-0.25	-0.47, -0.02	0.11	**.030**
VMPT[1]	-0.69	-1.06, -0.32	0.19	**< .001**
Early Term/time interaction T2 - T3[1]	0.11	0.01, 0.20	0.05	**.026**
LPT/time interaction T2 - T3[1]	0.01	-0.18, 0.19	0.10	.938
VMPT/time interaction T2 - T3[1]	0.15	-0.17, 0.46	0.16	.365
Maternal Education: A Levels [2]	-0.35	-0.48, -0.21	0.07	**< .001**
Maternal Education: 5 GCSEs[2]	-0.39	-0.50, -0.28	0.06	**< .001**
Maternal Education: < 5 GCSEs[2]	-0.60	-0.72, -0.49	0.06	**< .001**
Maternal Education: other[2]	-0.20	-0.36, -0.04	0.08	**.014**
Receipt of means tested benefit[3]	-0.12	-0.20, -0.04	0.04	**.004**
Mother aged 21 to 34 years[4]	-0.16	-0.27, -0.04	0.06	**.007**
Mother aged ≤ 20 years [4]	-0.19	-0.35, -0.03	0.08	**.021**
Academic month	-0.02	-0.03, -0.01	0.01	**.002**
Male[5]	-0.21	-0.29, -0.14	0.04	**< .001**
Pakistani Ethnicity[6]	-0.10	-0.19, -0.01	0.05	**.023**
Other Ethnicity[6]	0.05	-0.07, 0.17	0.06	.440
Single Parent[7]	-0.14	-0.25, -0.02	0.06	**.022**
Random Effects				
Intercept variance	0.71	0.66, 0.76	0.03	
Residual variance	0.21	0.19, 0.22	0.01	
Deviance		13153		

Note. *n* = 1876. Comparator: [1] Full Term; [2] Higher Education; [3] Means tested benefit not received; [4]Age 35 or over at child's birth; [5]Female; [6]White British; [7]Lives with partner. IMD and smoking were not significant in the model and therefore removed. .

Abbreviations: T1 = Time 1; T2= Time 2; T3 = Time 3; B = Unstandardized Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Appendix I : Sample Characteristics of Participants in the Executive Function Study

Table I-1

Sociodemographic Characteristics of Participants Before and After Multiple Imputation

Characteristic	VMPT (*n* = 53)		LPT (*n* = 186)		Early Term (*n* = 1119)		Full Term (*n* = 3650)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Sex								
Male	57	57	55	55	55	55	50	50
Female	43	43	45	45	45	45	50	50
Ethnicity								
White British	38	38	30	30	24	24	30	30
Pakistani	49	49	48	48	62	62	56	56
Other	13	13	22	22	14	14	14	14
Smoked								
Smoked	17	20	16	15	11	11	15	15
Did not smoke	83	80	84	85	89	89	85	85
Maternal Highest Level of Education								
Higher	24	24	27	27	23	23	23	23
A Levels	17	17	17	17	13	13	15	15
5 GCSEs	28	27	26	25	32	33	33	33
< 5 GCSEs	19	17	22	23	24	24	23	23
Other/unknown	13	15	08	08	07	07	06	06

Table I-1 continued

Characteristic	VMPT (n = 53)		LPT (n = 186)		Early Term (n = 1119)		Full Term (n = 3650)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Cohabitation								
Single	17	17	15	15	11	11	15	16
Partnered	83	83	85	85	89	89	85	84
Means Tested Benefit								
Received	38	37	46	44	49	49	46	45
Not Received	62	63	54	56	51	51	54	55
IMD[3]								
Category 1	67	68	54	52	54	53	56	55
Categories 2-10	33	32	46	48	46	47	44	45
Mother's Age								
≤ 20 years	2	2	9	9	6	6	10	10
21 to 34 years	87	87	75	75	78	78	78	78
≥ 35 years	11	11	16	16	16	16	12	12
Parity								
First Born	50	51	37	37	28	28	36	36
1 to 3 previous births	48	47	58	58	64	64	58	58
≥ 4 previous births	02	02	05	05	08	08	06	06

Note: [1]PI = Proportions after Imputation. [2]PU = Proportions before Imputation (Unimputed). [3]IMD=Index of Multiple Deprivation. (Department for Communities and Local Government, 2010), of which category 1 is the most deprived areas, and category 10 the least deprived areas.

Appendix J : Regression Analysis for Executive Function Variables without Processing Speed

Table J-1

Regression Analysis for VWM (Without Processing Speed): Predicted by Gestational Group, Age, Sex, Ethnicity, Maternal Education, Mother's Age, Parity and Smoked

Variable	VWM				
	B	SE	95% CI LL, UL	β	p
Intercept	0.30	0.03	0.24,0.35		**< .001**
Early Term[1]	0.00	0.00	-0.01, 0.01	-.01	.588
LPT[1]	-0.01	0.01	-0.03, 0.01	-.01	.553
VMPT[1]	-0.02	0.02	-0.06, 0.02	-.01	.284
Age in months at testing	0.00	0.00	0.00, 0.00	.20	**< .001**
Male[2]	0.00	0.00	0.00, 0.01	.01	.307
Pakistani Ethnicity[3]	0.03	0.01	0.02, 0.04	.12	**< .001**
Other Ethnicity[3]	0.03	0.01	0.02, 0.05	.08	**< .001**
Maternal Education: A Levels[4]	-0.02	0.01	-0.03, 0.00	-.04	**.016**
Maternal Education: 5 GCSEs[4]	-0.03	0.01	-0.04, -0.01	-.08	**< .001**
Maternal Education: < 5 GCSEs[4]	-0.04	0.01	-0.05, -0.02	-.10	**< .001**
Maternal Education: Other[4]	-0.01	0.01	-0.03, 0.01	-.02	.246
Mother's Age: 21 to 34 years[5]	-0.02	0.01	-0.03, -0.01	-.05	**.003**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.05, 0.00	-.06	**.002**
Parity: 1 to 3 previous births[6]	0.01	0.00	0.00, 0.02	.03	**.031**
Parity: ≥4 previous births	0.00	0.01	-0.02, 0.02	.00	.856
Mother smoked in pregnancy[7]	-0.02	0.01	-0.03, 0.00	-.04	**.014**

Note. n = 5008. R^2 = 0.07, *F* (16, 4625.10) = 27.77, *p* < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6] First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: VWM = Verbal working memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm

Table J-2

Regression Analysis for CWM (Without Processing Speed): Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity and Smoked

Variable	CWM				
	B	SE	95% CI LL, UL	β	p
Intercept	-0.01	0.03	-0.08, 0.06		.775
Early Term[1]	0.00	0.01	-0.01, -0.01	.00	.772
LPT[1]	-0.03	0.01	-0.06, 0.00	-.03	**.028**
VMPT[1]	0.00	0.02	-0.05, 0.05	.00	.883
Age in Months at testing	0.01	0.00	0.01, 0.01	.26	**< .001**
Male[2]	-0.03	0.01	-0.04, -0.02	-.08	**< .001**
Pakistani Ethnicity[3]	0.01	0.01	0.00, 0.02	.03	.107
Other Ethnicity[3]	0.02	0.01	0.00, 0.03	.03	.086
Maternal Education: A Levels[4]	-0.03	0.01	-0.04, -0.01	-.05	**.005**
Maternal Education: 5 GCSEs[4]	-0.04	0.01	-0.06, -0.03	-.10	**< .001**
Maternal Education: 5 GCSEs[4]	-0.06	0.01	-0.08, -0.04	-.14	**< .001**
Maternal Education: Other[4]	-0.03	0.01	-0.06, -0.01	-.05	**.006**
Mother's Age: 21 to 34 years[5]	-0.02	0.01	-0.03, 0.00	-.04	**.039**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.05, 0.00	-.04	**.033**
Parity: 1 to 3 previous children[6]	0.01	0.01	0.00, 0.02	.03	**.046**
Parity: ≥ 4 previous children[6]	0.00	0.01	-0.02, 0.03	.01	.701
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.01	-.02	.367

Note. *n* = 5008. R^2 = 0.09, *F* (16, 4758.30) = 20.85, *p* < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: CWM = Complex Working Memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table J-3

Regression Analysis for VSWM (Without Processing Speed): Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, and Smoked

Variable	VSWM				
	B	SE	95% CI LL, UL	β	p
Intercept	-0.05	0.03	-0.01, -0.11		.135
Early Term[1]	-0.01	0.01	-0.02, 0.00	-.025	.062
LPT[1]	-0.02	0.01	-0.04, 0.00	-.22	.100
VMPT[1]	-0.03	0.02	-0.07, 0.02	-.15	.263
Age in Months at testing	0.01	0.00	0.00, 0.01	.26	**< .001**
Male[2]	0.03	0.00	0.02, 0.03	.07	**< .001**
Pakistani Ethnicity[3]	0.01	0.01	0.00, 0.02	.03	.069
Other Ethnicity[3]	0.04	0.01	0.03, 0.06	.09	**< .001**
Maternal Education: A Levels[4]	-0.02	0.01	-0.04, -0.01	-.05	**.006**
Maternal Education: 5 GCSEs[4]	-0.03	0.01	-0.05, -0.02	-.09	**< .001**
Maternal Education: < 5 GCSEs[4]	-0.04	0.01	-0.06, -0.03	-.10	**< .001**
Maternal Education: Other[4]	-0.02	0.01	-0.04, 0.00	-.03	.103
Mother's Age: 21 – 34 years[5]	-0.02	0.01	-0.04, -0.01	-.06	**.001**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.06, -0.01	-.06	**.002**
Parity: 1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.03	**.037**
Parity: ≥ 4 previous births[6]	0.02	0.01	0.00, 0.04	.03	.060
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.00	-.02	.168

Note. n = 5008 R^2 = 0.09, F (16, 4676.50) = 28.57, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: VSWM = Visuo-spatial working memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm

Table J-4

Regression Analysis for Inhibition (Without Processing Speed): Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, and Smoked

Variable	Inhibition				
	B	SE	95% CI	β	p
			LL, UL		
Intercept	-0.64	0.07	-0.78, -0.51		**< .001**
Early Term[1]	-0.01	0.01	-0.04, 0.01	-.01	.358
LMT[1]	0.01	0.03	-0.04, 0.06	.00	.757
VMPT[1]	-0.02	0.05	-0.12, 0.07	-.01	.646
Age in months at testing	0.00	0.00	0.00, 0.01	.10	**< .001**
Male[2]	0.00	0.01	-0.02, 0.02	.00	.761
Pakistani Ethnicity[3]	-0.02	0.01	-0.05, 0.01	-.03	.118
Other Ethnicity[3]	0.00	0.02	-0.03, 0.04	.00	.886
Maternal Education: A Levels[4]	0.02	0.02	-0.02, 0.06	.02	.280
Maternal Education: 5 GCSEs[4]	0.00	0.01	-0.03, 0.03	.00	.841
Maternal Education: < 5 GCSEs[4]	0.00	0.02	-0.03, 0.04	.01	.781
Maternal Education: Other[4]	-0.01	0.02	- 0.06, 0.04	-.01	.604
Mother's Age: 21 – 34 years[5]	-0.02	0.02	- 0.05, 0.01	-.03	.173
Mother's Age: ≤ 20 years[5]	-0.02	0.02	-0.07, 0.04	-.02	.441
Parity: 1 to 3 previous births[6]	0.01	0.01	-0.01, 0.03	.01	.440
Parity: ≥ 4 previous births[6]	0.00	0.02	-0.05, 0.04	.00	.905
Mother smoked in pregnancy[7]	-0.03	0.02	-0.06, 0.01	-.03	128

Note. n = 5008. R^2 =0.03, F (16, 4775.80) = 3.86, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Appendix K : Complete Case Analysis (Adjusted Model) for Executive Function Study

Table K-1

Complete Case Analysis for VWM: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked and Processing Speed

Variable	VWM				
	B	SE	95% CI LL, UL	β	p
Intercept	0.50	0.04	0.43, 0.57		**< .001**
Early Term[1]	0.00	0.01	-0.01, 0.01	.00	.980
LPT[1]	-0.01	0.01	-0.04, 0.01	-.01	.356
VMPT[1]	-0.02	0.02	-0.06, 0.02	-.01	.377
Age in months at testing	0.00	0.00	0.00, 0.01	.16	**< .001**
Male[2]	0.00	0.00	-0.01, 0.01	.01	.718
Pakistani Ethnicity[3]	0.04	0.01	0.03, 0.05	.13	**< .001**
Other Ethnicity[3]	0.03	0.01	0.02, 0.05	.08	**< .001**
Maternal Education: A Levels[4]	-0.02	0.01	-0.03, 0.00	-.05	**.009**
Maternal Education: 5 GCSEs	-0.03	0.01	-0.04, -0.02	-.10	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.04	0.01	-0.05, -0.03	-.12	**< .001**
Maternal Education: Other[4]	-0.02	0.01	-0.04, 0.00	-.03	.075
Mother's Age: 21 – 34 years[5]	-0.02	0.01	-0.03, -0.01	-.05	**.007**
Mother's Age ≤ 20 years[5]	-0.02	0.01	-0.04, 0.00	-.04	.092
Parity: 1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.04	**.038**
Parity: ≥ 4 previous births[6]	0.00	0.01	-0.02, 0.02	.00	.905
Mother smoked in pregnancy[7]	-0.02	0.01	-0.03, -0.01	-.05	**.006**
Processing Speed	-0.02	0.00	-0.03, -0.02	-.18	**< .001**

Note. n = 3967. R^2 = 0.11, F (17, 3967) = 123.70, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: VWM = Verbal Working Memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table K-2

Complete Case Analysis for CWM: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked and Processing Speed

Variable	CWM				
	B	SE	95% CI LL, UL	β	p
Intercept	0.36	0.04	0.27, 0.44		**< .001**
Early Term[1]	0.00	0.01	-0.02, 0.01	-.01	.743
LPT[1]	-0.02	0.01	-0.05, -0.01	-.02	.127
VMPT[1]	0.00	0.03	-0.06, 0.05	.00	.975
Age in months at testing	0.00	0.00	0.00, 0.01	.19	**< .001**
Male[2]	-0.03	0.01	-0.04, -0.02	-.08	**< .001**
Pakistani Ethnicity[3]	0.02	0.01	0.00, 0.03	.05	**.013**
Other Ethnicity[3]	0.02	0.01	0.00, 0.04	.04	**.041**
Maternal Education: A Levels[4]	-0.03	0.01	-0.05, -0.01	-.06	**.001**
Maternal Education: 5 GCSEs[4]	-0.05	0.01	-0.06, -0.03	-.12	**< .001**
Maternal Education: < 5 GCSEs[4]	-0.07	0.01	-0.08, -0.05	-.15	**< .001**
Maternal Education: Other[4]	-0.05	0.01	-0.07, -0.02	-.06	**< .001**
Mother's Age: 21 – 34 years[5]	-0.02	0.01	-0.04, 0.00	-.05	**.014**
Mother's Age: ≤ 20 years[5]	-0.01	0.01	-0.03, 0.01	-.02	.314
Parity: 1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.03	**.046**
Parity: ≥ 4 previous births[6]	0.02	0.01	-0.01, 0.04	.02	.180
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.01	-.02	.250
Processing Speed	-0.04	0.00	-0.05, -0.04	-.25	**< .001**

Note. n = 3967. R^2 = 0.15, F (17, 3949) = 41.77, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: CWM = Complex Working Memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table K-3

Complete Case Analysis for VSWM: predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked and Processing Speed

Variable	VSWM				
	B	SE	95% CI LL, UL	β	p
Intercept	-0.42	0.04	0.35, 0.50		**< .001**
Early Term[1]	-0.01	0.01	-0.02, 0.01	-.01	.390
LPT[1]	-0.02	0.01	-0.05, 0.01	-.02	.167
VMPT[1]	-0.02	0.03	-0.07, 0.03	.01	.518
Age in months at testing	0.00	0.00	0.00, 0.00	.18	**< .001**
Male[2]	0.02	0.00	0.01, 0.03	.07	**< .001**
Pakistani Ethnicity [3]	0.02	0.01	0.01, 0.03	.05	**.003**
Other Ethnicity [3]	0.04	0.01	0.03, 0.06	.09	**< .001**
Maternal Education: A Levels[4]	-0.03	0.01	-0.04, -0.01	-.06	**.001**
Maternal Education: 5 GCSEs[4]	-0.03	0.01	-0.05, -0.02	-.09	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.04	0.01	-0.06, -0.03	-.11	**< .001**
Maternal Education: Other[4]	-0.02	0.01	-0.05, 0.00	-.04	**.026**
Mother's Age: 21 – 34 years[5]	-0.03	0.01	-0.04, -0.01	-.06	**.001**
Mother's Age: ≤ 20 years[5]	-0.03	0.01	-0.05, 0.00	-.05	**.025**
Parity:1 to 3 previous births[6]	0.01	0.01	0.00, 0.02	.04	**.033**
Parity: ≥ 4 previous births[6]	0.03	0.01	0.00, 0.05	.04	**.029**
Mother smoked in pregnancy[7]	-0.01	0.01	-0.03, 0.00	-.03	.101
Processing Speed	-0.04	0.00	-0.05, -0.04	-.27	**< .001**

Note. n = 3967. R2 = 0.16, F (17, 3949) = 1246.08, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: VSWM = Visuospatial working memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table K-4

Complete Case Analysis for Inhibition: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity, Mother Smoked and Processing Speed

Variable	Inhibition				
	B	SE	95% CI LL, UL	β	p
Intercept	-0.25	0.09	-0.43, -0.08		**.005**
Early Term[1]	-0.01	0.01	-0.03, 0.02	-.01	.655
LPT[1]	-0.01	0.03	-0.07, 0.05	.00	.858
VMPT[1]	-0.01	0.06	-0.12, 0.10	.00	.868
Age in months at testing	0.00	0.00	0.00, 0.00	.06	**< .001**
Male[2]	0.00	0.01	-0.03, 0.02	-.01	.733
Pakistani Ethnicity[3]	-0.01	0.01	-0.04, 0.02	-.02	.411
Other Ethnicity[3]	0.00	0.02	-0.04, 0.04	.00	.945
Maternal Education: A Levels[4]	0.03	0.02	-0.01,0.07	.03	.120
Maternal Education: 5 GCSEs[4]	0.01	0.02	-0.02, 0.05	.02	.381
Maternal Education: < 5 GCSEs[4]	0.01	0.02	-0.02, 0.05	.02	.401
Maternal Education: Other[4]	-0.01	0.03	-0.06, 0.04	-.01	.711
Mother's Age: 21 to 34 years[5]	-0.03	0.02	-0.06, 0.01	-.03	.112
Mother's Age: ≤ 20 years[4]	-0.03	0.03	-0.08, 0.03	-.02	.295
Parity:1 to 3 previous births[4]	0.01	0.01	-0.02, 0.03	.01	.680
Parity: ≥ 4 previous births[4]	-0.00	0.03	-0.05, 0.05	.00	.945
Mother smoked in pregnancy[4]	-0.03	0.02	-0.06, 0.01	-.03	.129
Processing Speed	-0.04	0.01	-0.05, -0.03	-.14	**< .001**

Note. n = 3967. R^2 = 0.03, F (17, 3949) = 7.24, p < .001. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]Did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table K-5

Complete Case Analysis for Processing Speed: Predicted by Gestational Group, Age in Months, Sex of Child, Ethnicity, Maternal Education, Mother's Age, Parity and Smoked

Variable	Processing Speed				
	B	SE	95% CI LL, UL	β	p
Intercept	9.09	0.24	8.63, 9.56		**< .001**
Early Term[1]	0.02	0.04	-0.06, 0.11	.01	.589
LPT[1]	0.04	0.09	-0.15, 0.22	.01	.676
VMPT[1]	0.25	0.18	-0.10, 0.59	.02	.162
Age in months at testing	-0.04	0.00	-0.05, -0.04	-.29	**< .001**
Male[2]	-0.07	0.03	-0.14, 0.00	-.03	.052
Pakistani Ethnicity [3]	0.19	0.04	0.11, 0.28	.08	**< .001**
Other Ethnicity[3]	-0.05	0.06	-0.17, -0.06	-.02	.382
Maternal Education: A Levels[4]	0.09	0.06	-0.03, 0.20	.03	.138
Maternal Education: 5 GCSEs[4]	0.11	0.05	0.02, 0.21	.05	**.023**
Maternal Education: < 5 GCSEs[4]	0.15	0.05	0.05, 0.26	.06	**.005**
Maternal Education: Other[4]	0.04	0.08	-0.11, 0.19	.01	.615
Mother's Age: 21 to 34 years[5]	0.00	0.05	-0.11, 0.10	.00	.962
Mother's Age: ≤ 20 years[5]	0.09	0.08	-0.08, 0.25	.02	.293
Parity:1 to 3 previous births[6]	-0.02	0.04	-0.10, 0.06	-.01	.584
Parity: ≥ 4 previous births[6]	0.04	0.08	-0.13, 0.20	.01	670
Mother smoked in pregnancy[7]	0.00	0.06	-0.11, 0.11	.00	.966

Note. n = 3967. R^2 = 0.10, F (16, 3950) = 28.25, p < .001. Comparator: [1]Full Term; [2]female; [3]White British; [4]Higher Education; [5]Aged ≥ 35 years; [6]First Born; [7]did not smoke. The following variables were removed as they were not significant in any model: IMD, means tested benefit. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Appendix L : Complete Case Analysis (Baseline Model) for Executive Function Study

Table L-1

Regression Analysis: Executive Function Complete Case Analysis by Age and Gestational Group

Variable	VWM[a]					
	B	SE	95% CI LL, UL	β	p	R^2
Intercept	0.32	0.26	0.27, 0.37		**< .001**	
Early Term[1]	0.00	0.01	-0.01, 0.12	.01	.656	
LPT[1]	0.00	0.11	-0.26, 0.17	-.01	.712	
VMPT[1]	-0.02	0.20	-0.06, 0.18	-.02	.277	
Age in Months	0.00	0.00	0.00, 0.00	.18	**< .001**	
						0.03*
	CWM[b]					
Variable	B	SE	95% CI LL, UL	β	p	
Intercept	-0.04	0.03	0.10, 0.02		.221	
Early Term[1]	0.00	0.01	-0.13, 0.01	.00	.921	
LPT[1]	-0.03	0.01	-0.06, 0.00	-.03	**.039**	
VMPT[1]	0.00	0.03	-0.05, 0.05	.00	.927	
Age in Months	-0.01	0.00	0.01, 0.01	.25	**< .001**	
						0.06*
	VSWM[c]					
Variable	B	SE	95% CI LL, UL	β	p	
Intercept	0.05	0.00	-0.00, 0.11		.068	
Early Term[1]	-0.01	0.01	-0.02, 0.01	-.01	.333	
LPT[1]	-0.01	0.12	-0.04, 0.11	-.02	.263	
VMPT[1]	-0.24	0.03	-0.07, 0.02	-.01	.294	
Age in Months	0.01	0.00	0.01, 0.01	.25	**< .001**	
						0.06*

Note. n = 5008. *p < .001. Comparator: [1]Full Term. [a]R^2 = 0.03, F (4, 5003) = 43.99, p < .001; [b]R^2 = 0.09, F (4, 5003) = 84.34, p < .001; [c]R^2 = 0.06, F (4, 5003) = 80.13, p < .001. Abbreviations: VWM = Verbal Working Memory; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm; CWM = Complex Working Memory; VSWM = Visuospatial Working Memory.

Table L-1 continued

Variable	Inhibition[d]					
	B	SE	95% CI	β	p	
			LL, UL			
Intercept	-0.67	0.06	-0.78, -0.55		**< .001**	
Early Term[1]	-0.01	0.01	-0.03, 0.13	-.01	.394	
LPT[1]	0.01	0.03	-0.04, 0.06	.01	.685	
VMPT[1]	-0.24	0.05	-0.12, 0.07	-.01	.629	
Age in Months	-0.01	0.00	0.00, 0.01	.10	**< .001**	
						0.11*

Variable	Processing Speed[e]					
	B	SE	95% CI	β	p	
			LL, UL			
Intercept	9.32	0.20	8.94, 9.70		**< .001**	
Early Term[1]	0.03	0.04	-0.04, 0.11	.01	.393	
LPT[1]	0.00	0.08	-0.16, 0.16	.00	.982	
VMPT[1]	0.26	0.15	-0.04, 0.58	.02	.091	
Age in Months	-0.04	0.00	-0.05, -0.04	-.30	**< .001**	
						0.09*

Note. n = 5008. *p < .001. Comparator: [1] Full Term. [d]R^2 = .01, F (4, 5003) = 13.65, p < .001, [e]R^2 = 0.09, F (4, 5003) = 123.70, p < .001. Abbreviations: B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Appendix M : Sample Characteristics of Participants in the Graphomotor Study

Table M-1

Sample Characteristics of Participants at T1 for the Graphomotor Study Before and After Multiple Imputation Comparison of Percentage Proportions

Characteristic	VMPT (*n* = 19)		LPT (*n* = 79)		Early Term (*n* = 561)		Full Term (*n* = 1807)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Sex								
Male	53	53	56	56	53	53	50	50
Female	47	47	44	44	47	47	50	50
Ethnicity								
White British	47	47	34	34	29	29	32	32
Pakistani	46	46	48	48	59	59	55	55
Other	05	05	18	18	12	12	13	13
Smoked								
Smoked	21	21	24	24	12	12	14	14
Did not smoke	79	79	76	76	88	88	86	86
Maternal Highest Level of Education								
Higher Education	16	16	16	16	20	20	21	.21
A Levels	21	21	14	14	12	12	12	.12
5 GCSEs	32	32	30	30	32	32	35	35
< 5 GCSEs	21	21	34	34	27	27	24	24
Other	11	11	05	05	09	09	07	07

Table M1 continued

Characteristic	VMPT (*n* = 19)		LPT (*n* = 79)		Early Term (*n* = 561)		Full Term (*n* = 1807)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Cohabitation								
Single	26	26	15	15	13	13	.13	13
Partnered	74	74	85	85	87	87	87	87
Means Tested Benefit								
Received	37	37	41	41	47	47	41	41
Not received	63	63	59	59	53	53	59	59
IMD[3]								
Category 1	58	58	60	60	51	51	52	51
Categories 2-10	55	42	40	40	49	49	48	49
Mother's Age								
≤ 20 years	16	16	9	9	8	8	11	11
21 to 34 years	84	84	78	78	76	76	78	78
≥ 35 years	0	0	13	13	17	17	11	11
Parity								
First Born	65	65	48	48.	31	31	37	37
1 to 3 previous births	35	35	47	47	59	59	57	57
≥4 previous births	00	00	05	05	10	10	05	05
Handedness								
Right handed	80	80	98	98	89	89	89	89
Left handed	20	20	02	02	11	11	11	11

Note: [1]PI = Proportions after Imputation. [2]PU = Proportions before Imputation (Unimputed), [3]IMD=Index of Multiple Deprivation. (Department for Communities and Local Government, 2010), of which category 1 is the most deprived areas, and category 10 the least deprived areas.

Table M-2

Sample Characteristics of Participants at T2 for the Graphomotor Study: Before and After Multiple Imputation Comparison of Percentage Proportions

Characteristic	VMPT (*n* = 72)		LPT (*n* = 219)		Early Term (*n* = 1330)		Full Term (*n* = 4248)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Sex								
Male	54	54	54	54	54	54	50	50
Female	46	46	46	46	46	46	50	50
Ethnicity								
White British	35	35	29	29	23	23	29	29
Pakistani	51	51	50	50	63	63	57	57
Other Ethnicity	14	14	.21	.21	14	14	14	14
Smoked								
Smoked	19	22	16	17	10	11	14	15
Did not smoke	81	78	84	.83	90	89	86	85
Maternal Highest Level of Education								
Higher Education	26	27	25	26	23	23	23	23
A Levels	16	14	16	16	12	12	14	14
5 GCSEs	28.	27	27	25	33	34	32	32
< 5 GCSEs	19	18	24	25	25	25	24	24
Other	10	11	07	07	.07	07	07	07

Table M-2 continued

Characteristic	VMPT (*n* = 72)		LPT (*n* = 219)		Early Term (*n* = 1330)		Full Term (*n* = 4248)	
	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %	PI[1] %	PU[2] %
Cohabitation								
Single	83	82	85	85	89	89	85	84
Partnered	17	18	15	15	11	11	15	16
Means Tested Benefit								
Received	42	.40	46	47	50	49	46	45
Not Received	58	60	54	53	50	51	54	55
IMD[3]								
Category 1	70	73	54	55	55	54	55	55
Categories 2-10	30	27	46	45	45	46	45	45
Mother's Age								
≤ 20 years	3	3	8	8	6	6	10	10
21 to 34 years	89	89	77	77	78	78	79	79
≥ 35 years	8	8	15	15	16	15	11	11
Parity								
First Born	47	48	37	38	28	28	35	35
1 - 3 previous births	50	49	56	56	63	63	58	58
≥ 4 previous births	03	03	07	07	09	09	06	06
Handedness								
Right handed	82	82	88	88	88	88	90	90
Left handed	18	18	12	12	12	12	10	10

Note: [1]PI = Proportions after Imputation. [2]PU = Proportions before Imputation (Unimputed), [3]IMD=Index of Multiple Deprivation (Department for Communities and Local Government, 2010), of which category 1 is the most deprived areas and category 10 the least deprived areas.

Appendix N : Complete Case Analysis for Graphomotor Study

Table N-1

Complete Case Analysis Regression Table for Tracking at T1: Predicted by Gestational Group, Age in Months, Sex, Maternal Education, Ethnicity and IMD

Variable	Tracking at T1 (age 4 to 5 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.07	0.02	0.03, 0.11		**.002**
Early Term[1]	-0.01	0.04	-0.10, 0.07	-.01	.785
LPT[1]	-0.25	0.10	-0.45, -0.04	-.05	**.019**
VMPT[1]	-0.27	0.21	-0.68, 0.15	-.03	.209
Model 2: Model Adjusted for Covariates					
Intercept	-3.10	0.24	-3.58, -2.63		**< .001**
Early Term[1]	-0.03	0.04	-0.11, 0.05	-.02	.436
LPT[1]	-0.22	0.10	-0.41, -0.02	-.04	**.029**
VMPT[1]	-0.24	0.20	-0.63, 0.16	-.02	.243
Age in Months at testing	0.06	0.00	0.05, -0.07	.29	**< .001**
Male[2]	-0.12	0.03	-0.18, -0.05	-.06	**.001**
Pakistani Ethnicity[3]	-0.19	0.04	-0.27, -0.11	-.10	**< .001**
Other Ethnicity[3]	-0.08	0.06	-0.19, 0.04	-.03	.176
Maternal Education: A Levels[4]	-0.09	0.06	-0.21, 0.04	-.03	.172
Maternal Education: 5 GCSEs[4]	-0.14	0.05	-0.23, -0.04	-.07	**.006**
Maternal Education < 5 GCSEs[4]	-0.17	0.05	-0.27, -0.07	-.08	**.001**
Maternal Education: Other[4]	0.01	0.07	-0.14, 0.15	.01	.941
IMD: Category 1[5]	-0.05	0.04	-0.12, 0.02	-.03	.192
Left Handedness[6]	-0.03	0.05	-0.14, 0.08	-.01	.555

Note. n = 2,396. Baseline Model: R^2 = .00, F (3, 2392.00) = 2.33, p = .072. Adjusted Model: R^2 =.10, F (13, 2382) = 21.834, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10; [6]Right handedness. The following variables were not significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time One; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table N-2

Complete Case Analysis Regression Table for Tracking at T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity, Sex and Handedness

Variable	Tracking at T2 (aged 7 to 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.09	0.01	0.07, -0.12		**< .001**
Early Term[1]	0.01	0.03	-0.04 - 0.06	.01	.669
LPT[1]	-0.09	0.06	-0.21, 0.03	-.02	.125
VMPT[1]	-0.21	0.10	-0.41, -0.01	-.03	**.044**
Model 2: Model Adjusted for Covariates					
Intercept	-1.21	0.14	-1.49, -0.93		**< .001**
Early Term[1]	0.02	0.03	-0.03, 0.07	.01	.390
LPT[1]	-0.12	0.06	-0.24, 0.00	-.03	**.046**
VMPT[1]	-0.23	0.10	-0.43, -0.03	-.03	**.026**
Age in Months at testing	0.01	0.00	0.01, -0.02	.15	**< .001**
Male[2]	-0.00	0.02	-0.05, 0.04	-.01	.847
Pakistani Ethnicity[3]	-0.10	0.02	-0.15, -0.05	-.06	**< .001**
Other Ethnicity[3]	0.08	0.04	0.00, 0.15	.03	**.038**
Maternal Education: A Levels[4]	-0.08	0.04	-0.15, -0.01	-.28	**.035**
Maternal Education:5 GCSEs[4]	-0.13	0.03	-0.19, -0.07	-.06	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.16	0.03	-0.22, -0.10	-.07	**< .001**
Maternal Education: Other[4]	-0.07	0.05	-0.16, 0.03	-.01	.158
Left handedness[5]	-0.06	0.03	-0.13, 0.00	-.04	.061

Note. n = 4691.Baseline Model: R^2 = .00, F (3, 4687) = 2.25, p = .081. Adjusted Model: R^2 = .04, F (12, 4678) = 17.51, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 =Time 2; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table N-3

Complete Case Analysis Regression Table for Aiming at T1: Predicted by Gestational Group, Age in Months, Sex, Maternal Education, Ethnicity and IMD

Variable	Aiming at T1 (aged 4 to 5 years)				
	B	SE[a]	95% CI LL – UL	β	p
Model 1: Baseline Model					
Intercept	0.06	0.03	0.02, 0.11		**.010**
Early Term[1]	-0.02	0.05	-0.11, 0.08	-.01	.756
LPT[1]	-0.18	0.13	-0.43, 0.07	-.03	.151
VMPT[1]	-0.61	0.23	-1.06, -0.15	-.06	**.009**
Model 2: Model Adjusted for Covariates					
Intercept	-3.05	0.27	-3.57, -2.52		**< .001**
Early Term[1]	-0.03	0.05	-0.12, 0.06	-.12	.574
LPT[1]	-0.18	0.12	-0.41, 0.05	-.03	.132
VMPT[1]	-0.59	0.22	-1.02, -0.17	-.06	**.006**
Age in Months at testing	0.06	0.00	0.05, 0.07	.29	**< .001**
Male[2]	-0.31	0.04	-0.39, -0.24	-.18	**< .001**
Pakistani Ethnicity[3]	-0.14	0.05	-0.23, -0.05	-.08	**.002**
Other Ethnicity[3]	0.08	0.07	-0.05, 0.21	.03	227
Maternal Education: A Levels[4]	-0.06	0.07	-0.20, 0.08	-.02	.430
Maternal Education: 5 GCSEs[4]	-0.15	0.05	-0.26, -0.05	-.08	**.005**
Maternal Education: 5 GCSEs[4]	-0.20	0.06	-0.31, -0.08	-.10	**.001**
Maternal Education: Other[4]	-0.12	0.09	-0.28, 0.05	-.04	.172
IMD:1[5]	-0.09	0.04	-0.17, -0.01	-.05	**.029**
Left Handedness[6]	-0.17	0.06	-0.29, 0.04	-.06	**.009**

Note. n = 1,813. Baseline Model: R^2 = 0.01, F (3, 1809) = 2.93, p = .03. Adjusted Model: R^2 = .15, F (13, 1799.00) = 23.60, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10; [6]Right handedness. The following variables were not significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time 1; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table N-4

Complete Case Analysis Regression Table for Aiming in T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity and Handedness

Variable	Aiming at T2 (aged 7 to 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.06	0.01	0.04, 0.09		**< .001**
Early Term[1]	0.01	0.03	-0.05, 0.07	.01	.685
LPT[1]	0.02	0.07	-0.12, 0.16	.00	.781
VMPT[1]	0.06	0.13	-0.19, 0.31	-.06	.630
Model 2: Model Adjusted for Covariates					
Intercept	-2.51	0.16	-2.83, -2.20		**< .001**
Early Term[1]	0.02	0.03	-0.03, 0.08	.01	.426
LPT[1]	-0.01	0.07	-0.14, 0.12	00	.909
VMPT[1]	-0.01	0.12	-0.24, 0.23	-.01	.943
Age in Months at testing	0.03	0.00	0.02, 0.03	.26	**< .001**
Male[2]	-0.00	0.02	-0.05, 0.05	.00	.935
Pakistani Ethnicity[3]	-0.09	0.03	-0.14, -0.03	-.05	**.002**
Other Ethnicity[3]	0.10	0.04	0.02, 0.18	.04	**.015**
Maternal Education: A Levels[4]	-0.11	0.04	-0.19, -0.03	-.04	**.009**
Maternal Education:5 GCSEs[4]	-0.15	0.03	-0.21, -0.08	-.07	**< .001**
Maternal Education:< 5 GCSEs[4]	-0.19	0.00	-0.26, -0.12	-.08	**< .001**
Maternal Education: Other[4]	-0.08	0.05	-0.18, 0.02	-.02	.131
Left Handedness[5]	-0.13	0.04	-0.21, -0.06	-.04	**.001**

Note. n = 4123. Baseline Model: R^2 = 0.00, F (3, 4119) = 0.14, p = .934. Adjusted Model: R^2 = .09, F (12, 4110) = 34.85, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 = Time Two B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table N-5

Complete Case Analysis Regression Table for Tracing at T1: Predicted by Gestational Group, Age in Months, Sex, Maternal Education, Ethnicity and IMD

Variable	Tracing at T1 (aged 4 to 5 years)				
	B	SE[a]	95% CI LL – UL	β	p
Model 1: Baseline Model					
Intercept	0.10	0.01	0.07, 0.12		**< .001**
Early Term[1]	-0.06	0.03	-0.11, 0.00	-.04	.055
LPT[1]	0.06	0.07	-0.07, 0.20	.02	.375
VMPT[1]	-0.40	0.14	-0.68, -0.12	-.06	**.005**
Model 2: Model Adjusted for Covariates					
Intercept	-0.52	0.16	-0.84, -0.20		**.002**
Early Term[1]	-0.05	0.03	-0.11, 0.00	-.04	.057
LPT[1]	0.06	0.07	-0.08, 0.19	.02	.412
VMPT[1]	-0.40	0.14	-0.68, -0.13	-.06	**.004**
Age in Months at testing	0.01	0.00	0.01, 0.02	.11	**< .001**
Male[2]	-0.14	0.02	-0.18, -0.09	-.12	**< .001**
Pakistani Ethnicity[3]	-0.21	0.03	-0.26, -0.16	-.18	**< .001**
Other Ethnicity[3]	-0.03	0.04	-0.11, 0.05	-.02	.462
Maternal Education: A Levels[4]	-0.04	0.04	-0.12, 0.05	-.02	.394
Maternal Education: 5 GCSEs[4]	-0.09	0.03	-0.15, -0.02	-.07	**.008**
Maternal Education: < 5 GCSEs[4]	-0.05	0.04	-0.11, 0.02	-.03	.202
Maternal Education: Other[4]	0.02	0.05	-0.08, 0.12	.01	.731
IMD Category 1[5]	-0.03	0.02	-0.07, 0.02	-.02	.308
Left Handed[6]	-0.03	0.04	-0.11, 0.04	-.18	.365

Note. n = 2,379. Baseline Model: R^2 = .01, F (3, 2375.00) = 4.07, p = .001. Adjusted Model: R^2 = .07, F (13, 2365.00) = 12.93, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]IMD categories 2 to 10; [6]Right handedness. The following variables were not significant in any T1 model and were therefore excluded from the model: parity, cohabitation, smoked during pregnancy, means tested benefit, mother's age at the child's birth. Abbreviations: T1 = Time One; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.

Table N-6

Complete Case Analysis Regression Table for Tracing at T2: Predicted by Gestational Group, Age of Child, Maternal Education, Ethnicity, and Handedness

Variable	Tracing at T2 (aged 7 – 10 years)				
	B	SE[a]	95% CI LL, UL	β	p
Model 1: Baseline Model					
Intercept	0.10	0.01	0.08, 0.12		**< .001**
Early Term[1]	0.00	0.02	-0.04, 0.05	.00	.819
LPT[1]	0.09	0.05	0.00, 0.19	.03	.061
VMPT[1]	-0.13	0.09	-0.30,0.04	-.02	.131
Model 2: Model Adjusted for Covariates					
Intercept	0.53	0.12	-0.76, -0.31		**< .001**
Early Term[1]	0.02	0.02	-0.02, 0.06	.02	.313
LPT[1]	0.10	0.05	-0.00, 0.19	03	.054
VMPT[1]	-0.15	0.08	-0.32, 0.01	-.03	.064
Age in Months at testing	0.01	0.00	0.01, 0.01	.10	**< .001**
Male[2]	-0.16	0.02	-0.19, -0.12	-.13	**< .001**
Pakistani Ethnicity[3]	-0.08	0.02	-0.12, -0.04	-.07	**< .001**
Other Ethnicity[3]	-0.01	0.03	-0.07, 0.05	.01	.757
Maternal Education: A Levels[4]	-0.04	0.03	-0.10, 0.02	-.02	.189
Maternal Education 5 GCSEs[4]	-0.04	0.02	-0.09, 0.01	-.03	.095
Maternal Education < 5 GCSEs[4]	-0.08	0.03	-0.13, 0.03	-.06	**.001**
Maternal Education Other[4]	0.03	0.04	-0.04, 0.11	.01	.362
Left Handedness[5]	0.07	0.03	0.01, 0.12	-.03	**.017**

Note. n = 4678. Baseline Model: R^2 = 0.00, F (3, 4674.00) = 1.198, p = .114. Adjusted Model: R^2 = 0.04, F (12, 4665.00) = 15.90, p < .001. [a]The Standard Error shown relates to the unstandardized beta coefficient. Comparator: [1]Full Term; [2]Female; [3]White British; [4]Higher Education; [5]Right handedness. The following variables were removed as they were not significant in any T2 model: means tested benefit, IMD, parity, mother smoked in pregnancy, mother's age at the child's birth. Abbreviations: T2 = Time Two; B = Unstandardized Beta; β = Standardised Beta; SE = Standard Error; CI = confidence interval; LL = lower limit; UL = Upper Limit; LPT = Late Preterm; VMPT = Very or Moderately Preterm.