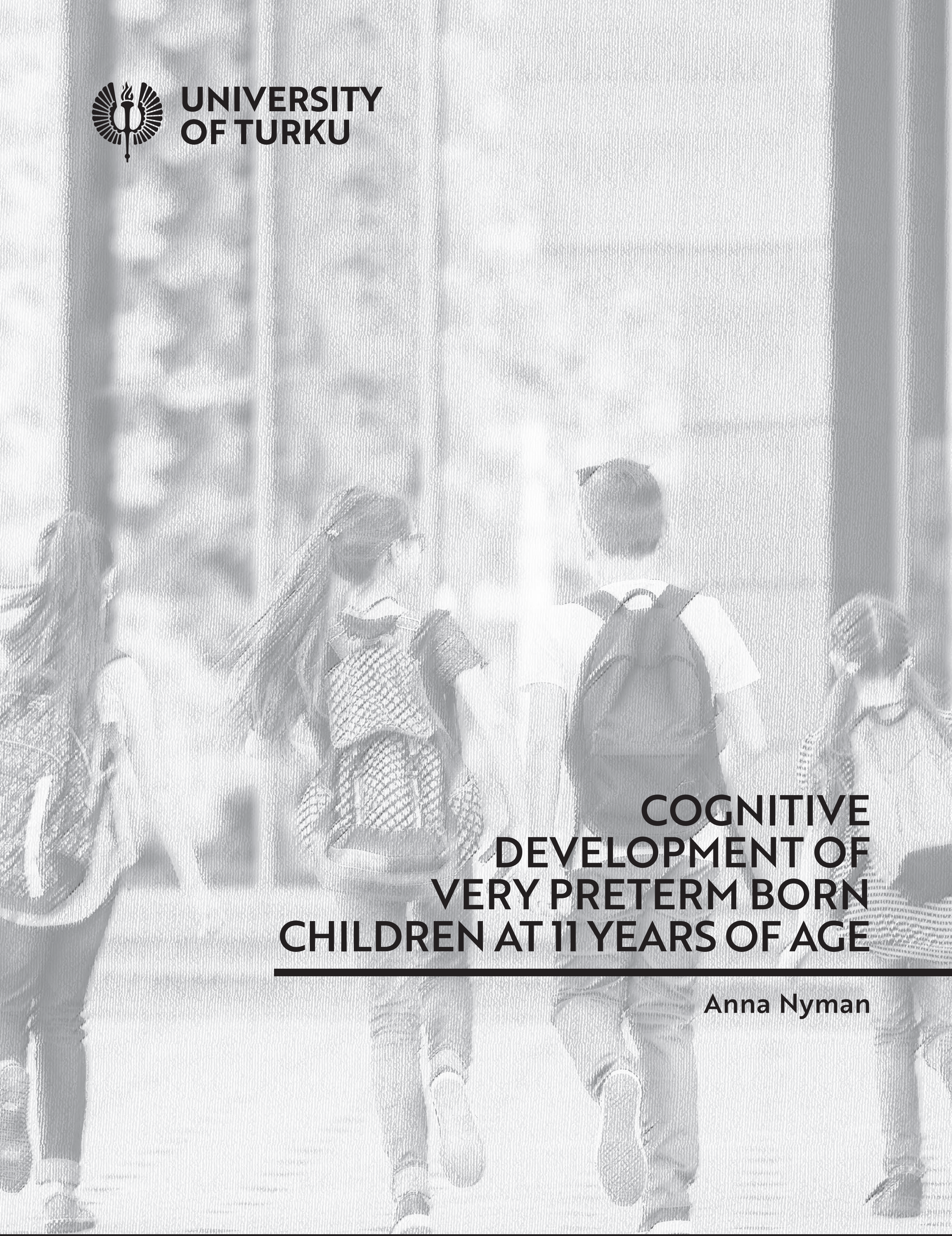

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OF TURKU

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Anna Nyman

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To my family

UNIVERSITY OF TURKU
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ABSTRACT

Very preterm birth poses a risk to adverse neurodevelopment. Specific cognitive impairments can be assessed at five years of age. Milder cognitive impairments, however, may only grow into deficits at school age. This thesis is a part of the regional and multidisciplinary follow-up project PIPARI (PIeniPAinoisten RIskilasten käyttäytyminen ja toimintakyky imeväisiästä kouluikään). The thesis consists of three original studies that present data on 11-year-old very preterm born children (birth weight ≤1500g and/or <32 gestational weeks) born between 2001 and 2004. In Study I, the cognitive profile of the very preterm born children and the associated risk factors were evaluated. In Study II, the educational abilities and received support services of the very preterm born children were compared against the controls. In Study III, the executive functions of the very preterm born children at home and at school were compared against the controls and associated risk factors were evaluated.

The main findings of the thesis were that the cognitive profile of the children born very preterm was within the average range but with results significantly lower than the mean test norms. General cognitive development at five years of age was highly correlated with general cognitive development at 11 years of age. Very preterm born children without severe cognitive impairment had age-appropriate academic and classroom performance at school, but they received significantly more support services than the controls. Compared to the controls, very preterm born children without severe cognitive impairment only had more problems in terms of their working memory at school. In this thesis, the most clinically significant risk factors for adverse cognitive development at 11 years of age were major pathologies observed with brain magnetic resonance imaging at term, low paternal education, surgical necrotizing enterocolitis and male gender. The findings suggest that children born very preterm meet everyday challenges at middle school age better than their cognitive profile would let us to expect. The most important goal in long-term follow-up of school age very preterm children is to evaluate their performance in everyday life and to provide knowledge about how preterm birth may affect learning and to provide detailed cognitive assessments with low threshold if problems emerge.

KEYWORDS: prematurity, neonatal morbidity, follow-up, intelligence, executive function, academic skills, special education, school age

TURUN YLIOPISTO
Yhteiskuntatieteellinen tiedekunta
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TIIVISTELMÄ

Pikkukeskosuuteen liittyy kehityksellisiä riskejä. Kapea-alaiset kognitiivisen kehityksen häiriöt voidaan tutkia viiden vuoden iässä. Lievemmät kognitiivisen kehityksen häiriöt saattavat kuitenkin tulla esille vasta kouluiässä. Tämä väitöskirja on osa alueellista ja moniammatillista PIPARI-projektia (PIeniPAinoisten RIskilasten käyttäytyminen ja toimintakyky imeväisiästä kouluikään). Väitöskirja koostuu kolmesta alkuperäistutkimuksesta, jotka kuvaavat vuosina 2001-2004 syntyneiden pikkukeskosten (syntymäpaino ≤1500g ja/tai <32 raskausviikkoa) suoriutumista 11-vuotiaana. Tutkimuksessa I arvioitiin pikkukeskosten kognitiivinen profiili ja siihen yhteydessä olevia riskitekijöitä. Tutkimuksessa II pikkukeskosten koulusuoriutumista ja heidän saamiaan tukitoimia verrattiin täysiaikaisina syntyneiden verrokkilasten suoriutumiseen ja tukitoimiin. Tutkimuksessa III pikkukeskosten toiminnanohjauksen taitoja kotona ja koulussa verrattiin verrokkilasten suoriutumiseen sekä arvioitiin yhteydessä olevia riskitekijöitä.

Tämän väitöskirjan yhtenä päälöydöksenä oli, että pikkukeskosten kognitiivinen profiili on ikäryhmän normaalialueella, mutta tulokset ovat kuitenkin merkittävästi ikäryhmän keskitasoa heikompia. Yleinen kognitiivinen kehitys viisivuotiaana ennusti hyvin yleistä kognitiivista kehitystä 11-vuotiaana. Pikkukeskoset, joilla ei ollut vaikeaa kognitiivisen kehityksen häiriötä, suoriutuivat ikätasoisesti koulussa, mutta saivat verrokkiryhmää enemmän tukitoimia. Pikkukeskosilla, joilla ei ollut vaikeaa kognitiivisen kehityksen häiriötä, oli koulussa työmuistiongelmia verrokkiryhmää useammin. Tässä väitöskirjassa kliinisesti merkitsevimpiä riskitekijöitä heikolle kognitiiviselle kehitykselle olivat merkittävä aivovamma lasketun ajan magneettikuvauksessa, isän matala koulutustaso, leikkaushoitoa vaatinut keskosen vaikea suolisairaus ja poika sukupuoli. Tutkimustulosten mukaan pikkukeskosten suoriutuminen arkipäivän haasteista alakouluiässä on parempaa kuin heidän kognitiivinen profiilinsa antaisi odottaa. Tärkein tavoite kouluikäisten pikkukeskosten seurannassa on arvioida heidän suoriutumistaan päivittäisistä haasteista, tarjota lisätietoa keskosuuden vaikutuksista oppimiseen sekä tarjota yksityiskohtaisia kognitiivisia tutkimuksia matalalla kynnyksellä, mikäli ongelmia ilmenee.

AVAINSANAT: keskosuus, neonataalisairastavuus, seurantatutkimus, älykkyys, toiminnanohjaus, akateemiset taidot, erityisopetus, kouluikä

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The 11-year cognitive assessments were mainly performed at the Centre for Learning Research, University of Turku. I want to thank Docent Elisa Poskiparta for this opportunity. The last cohort included in this thesis was assessed at the Child and Youth Research Institute, University of Turku. I thank Docent Hanna Lagström for this possibility. Satu Ekbland, thank you for helping me to organize the psychological appointments. Thank you, Pirita Kankaanpää, for reviewing the teacher-rated educational ability questionnaire. I would also like to thank you Timo Tuovinen, Tuomo Lehtonen, Sirkku Setänen, Katri Lahti and Karoliina Uusitalo for your collaboration with the multidisciplinary 11-year assessments, also including neurological and ophthalmological examinations. Camilla Hagelstam and Satu Korpela, I thank you for participating in the BRIEF and working memory data collection at 11 years of age. Annika Lind, I thank you for assessing all the Swedish speaking children. I would like to extend my special thanks to Sirkku Setänen for sharing all the steps of this thesis with me, including ups and downs.

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Turku, October 2019

Anna Nyman

Table of Contents

Tables

Figures

List of Original Publications

This thesis is based on the following publications, which are referred to in the text by the Roman numerals I-III.

I Nyman A, Korhonen T, Munck P, Parkkola R, Lehtonen L, Haataja L. Factors affecting the cognitive profile of 11-year-old children born very preterm. *Pediatric Research*. 2017;82:324–32.

II Nyman A, Korhonen T, Lehtonen L, Haataja L. School performance is age-appropriate with support services in very preterm children at 11 years of age. *Acta Paediatrica.* 2019;108:1669–1676.

III Nyman A, Munck P, Koivisto M, Hagelstam C, Korhonen T, Lehtonen L, Haataja L. Executive function profiles at home and at school in 11-year-old children born very preterm. *Journal of Developmental & Behavioral Pediatrics*. 2019;40:547–554.

1 Introduction

A preterm born infant is defined as an infant whose gestational age is at least 22 but less than 37 weeks. Worldwide, 11% of all infants are born preterm according to the World Health Organization. In Finland, preterm infants account for 6 % of all infants (National Institute for Health and Welfare, 2018). The survival rates of preterm infants have improved due to progress in prenatal and neonatal care practices (Stoll et al., 2015). However, mortality and neurodevelopmental outcomes vary between countries and even between different centres within the same country (Blencowe et al., 2013; Lawn et al., 2013). Despite advances in care practices, children born very preterm still have an increased risk of developmental problems, especially in terms of cognitive development (Aarnoudse-Moens, Weisglas Kuperus, van Goudoever, & Oosterlaan, 2009; Brydges et al., 2018).

Long-term developmental follow-up is needed to monitor the quality of neonatal care, to direct counselling to risk groups, to secure the identification of infants for closer follow-up, and to counsel parents about the developmental prognosis of their newborn. In Finland, the systematic follow-up of children born very preterm varies between five university hospitals. The systematic follow-up of children born very preterm continues for up to two years in the Turku and Helsinki University Hospitals. Children who have developmental problems at the age of two years are referred to the systematic neurodevelopmental follow-up. Additionally, cognitive assessments are recommended for all children born very preterm before they enter school to identify possible risks for learning disorders and support service needs. Mild problems in the different aspects of cognitive development may only grow into deficits at school age. Systematically collected data about the cognitive profile, school performance and executive function profiles of Finnish school age children born very preterm is lacking.

2 Review of Literature

2.1 Preterm birth

In Finland, approximately one in 20 infants is born preterm (National Institute for Health and Welfare, 2018). A newborn infant is defined as preterm when his/her gestational weeks are at least 22+0 and not more than 36+6. A majority of preterm infants are born between 32 and 37 gestational weeks. A very preterm born infant is born before 32 gestational weeks and typically has a birth weight of 1500 grams or below. The birth weight of a newborn infant may be small for gestational age (SGA, below -2 SD), appropriate for gestational age or large for gestational age (above +2 SD).

Globally, 11% of all infants are born preterm, with national rates varying from 5 to 18% (Blencowe et al., 2012). In Finland, 5.9% (n=3008) of live born infants were born preterm in 2017 (National Institute for Health and Welfare, 2018). Birth weight was 1500 grams or below in 0.7% (n=374) of these cases and the infants were considered very low birth weight infants. Birth weight was 1000 grams or less in 0.3% (n=174) of the cases, and the infants were considered extremely low birth weight infants. A total of 420 infants (0.8%) were considered very preterm (<32 gestational weeks or birth weight ≤1500g), and 66 of them were born at the Turku University Hospital in 2017.

2.2 Cognitive development

Cognitive impairment is the most prevalent sequel in the very preterm population, and the prevalence of cognitive impairments has continued to be high (Aarnoudse-Moens et al., 2009; Brydges et al., 2018). The rate of intellectual disability defined as severe cognitive impairment [intelligence quotient (IQ) <70] and significant limitation in adaptive functioning, is reportedly, 2.5% in very preterm and 0.4% in term born children by seven years of age, according to a national register study in Finland that included children born between 1991 and 2008 (Hirvonen et al., 2017).

A recent global meta-analysis reported cognitive outcomes in children aged four to 17 years and born very preterm (<32 gestational weeks, n=6163), including studies that continued up to July 2017 (Brydges et al., 2018). Children born very preterm were reported to be 0.8 SD below the controls, which corresponds to 12 IQ points. Another recent global meta-analysis including extremely or very preterm born children (<32 gestational weeks and/or birth weight <1000g or <1500g, n=7752) found a 0.7 SD difference between preterm born children and controls, corresponding to 13 IQ points (Twilhaar et al., 2018). Mean age at the included assessments ranged from five to 20 years. No improvement in cognitive performance was detected between 1990 and 2008.

There are only a few studies comparing the cognitive outcomes from the same centre or geographic area across the different decades. When the outcomes of three-year old extremely preterm born children (22-25 gestational weeks) in the British-Irish EPICure Study from the 1995 (n=584) and 2006 (n=260) cohorts were compared, survival without disability (i.e. no impairment in motor, cognitive or communication development, no sensory impairment) increased from 23% to 34% (Moore et al., 2012). An Australian Victorian Infant Collaboration Study Group reported that the mean cognitive outcomes remained stable when the outcomes of eight-year-old extremely preterm born children (<28 gestational weeks) from the 1991-92 (n=428), 1997 (n=217) and 2005 (n=270) cohorts were compared (Cheong et al., 2017).

Several methodological considerations need to be taken into consideration when comparing the reports of cognitive outcome of preterm born children. Birth-weight-based cohorts include a proportion of SGA children born later in gestation. On the other hand, the selection of the preterm population may be restricted to a subgroup such as children born extremely preterm (children born <28 gestational weeks) who are expected to have a higher risk for severe developmental deficits compared to the very preterm population (children born <32 gestational weeks). The generalizability of the cognitive outcomes is restricted by the wide variety of exclusion criteria used. For example, if children with severe brain magnetic resonance imaging (MRI) findings or with severe cognitive impairments are excluded, the findings underestimate the population's true level of impairment.

2.2.1 Factors affecting cognitive development

Preterm birth poses a risk to adverse long-term cognitive development, as several neonatal conditions may damage the developing brain. Protecting the vulnerable developing brain is a major goal of perinatal and neonatal care. A recent meta-analysis suggests that the influence of prenatal risk factors on the cognitive development of children born very preterm appears to diminish over time as environmental factors become increasingly prominent contributing factors (Linsell, Malouf, Morris, Kurinczuk, & Marlow, 2015).

2.2.1.1 Neonatal factors

Antenatal corticosteroids are given to mothers at risk of preterm birth to accel-erate fetal lung maturation and to support further development of the infant (Stoll et al., 2015). The risk for developmental problems has been reported to increase if the infant needs postnatal corticosteroids (Barrington, 2001) or prolonged ventilator treatment (Vohr et al., 2004) or has a chronic lung disease (Twilhaar et al., 2018). Lower gestational age, reflecting the immaturity of infant, is reported to associate with adverse cognitive development (Brydges et al., 2018; Johnson et al., 2009; Lemola et al., 2017). Low birth weight in relation to gestational weeks reflects poor prenatal growth and poses a risk for poor cognitive development (Guellec et al., 2011; Kallankari, Kaukola, Olsén, Ojaniemi, & Hallman, 2015). Neonatal morbidities that have been shown to associate with adverse outcomes include serious infections and e.g. necrotizing enterocolitis (NEC) (Mikkola et al., 2005; Munck et al., 2010). Mortality and neonatal complications are more common in boys (Johnson et al., 2009; Peacock, Marston, Marlow, Calvert, & Greenough, 2012).

2.2.1.2 Brain imaging findings

Multiple complex events that are critical for brain development and cognitive development take place during gestational weeks 22–32. The developing brain is highly vulnerable to pathogenic factors, such as peri- and intraventricular haemorrhages (IVH), hypoxic-ischemic events, and inflammation (Volpe, 2009). Haemorrhagic findings are described using four grades based on the location and width of bleeding (Papile, Burstein, Burstein, & Koffler, 1978). Grade I is described as bleeding occurring in the germinal matrix. Bleeding extending to the ventricles is described as grade II when 10–50% of the ventricles are filled with blood, and as grade III when the ventricles are enlarged and blood has accumulated in over 50% of the ventricles. Grade IV is defined as bleeding that extends into the brain tissue. Cranial ultrasound and MRI are used in imaging the brain of very preterm infants. Cranial ultrasound is the primary method, and it can be performed bedside in a neonatal intensive care unit. It is a very sensitive method for detecting IVH and enlarged ventricles. Brain MRI has been shown to be a more sensitive method for detecting white matter, cerebellar and cortical lesions than cranial ultrasound (Maalouf et al., 2001; Rademaker et al., 2005), but it requires transferring the infant to an MRI unit.

Normal findings or minor pathologies in brain MRI at term, such as the consequences of IVH grade I and II, have been shown to relate to a normal cognitive outcome in very preterm born children (Setänen, Haataja, Parkkola, Lind, & Lehtonen, 2013). Major brain pathologies, such as the consequences of IVH grade

III ja IV, have been shown to relate to cognitive impairment (Setänen et al., 2013). Preterm infants have also been shown to display significant reductions in the growth of the cerebral cortex and subcortical grey matter structures (Back, 2015). Reduced grey matter volume and white matter volume have been reported to associate with deficits in cognitive functions (Lemola et al., 2017). The immaturity of the preterm infant's white matter makes it vulnerable to injuries like IVH, infection and ischemia (Volpe, 2009). The most common of these white matter injuries is a diffuse white matter injury, which occurs in approximately every third infant born between gestational weeks 24 and 32 (Back, 2015; Counsell, S. J., Rutherford, Cowan, & Edwards, 2003). This diffuse white matter injury disturbs the development of whiter matter and neural networks (Kinney et al., 2012) and contributes to cognitive dysfunction (Counsell, Serena et al., 2008).

2.2.1.3 Neurosensory impairment

Severe consequences of preterm birth include cerebral palsy (CP), as well as vision and hearing impairments (Johnson, Fawke et al., 2009) defined as neurosensory impairment (NSI). Over the past decades, the prevalence of CP in children born with very low birth weight has decreased from 7.1% to approximately 3.6% in 20 European countries (Sellier et al., 2016). According to a Canadian CP prevalence study including children born between 2008 and 2010, rates among children born with extremely low birth weight was 4.0% and with low birth weight 2.7% (Robertson et al., 2017). They reported 2.7% for the <28 gestation week group and 3.0% for the 28–31 gestation week group. In Finland, CP incidence was 3.7% by the age of seven in very preterm children born between 2002 and 2008 (Hirvonen et al., 2014). Of the most severe neurosensory impairments, CP is diagnosed at a median age of 1.5 years (1.0–2.3) in Finland (Hirvonen et al., 2014). CP is a heterogeneous condition that includes different causal agents, subtypes and severity. Increased risk for cognitive impairment is associated with CP (Hafström et al., 2018; Stadskleiv, Jahnsen, Andersen, & von Tetzchner, 2018). According to a Finnish national registry study, hearing impairment incidence in very preterm children born between 2002 and 2008 was 1.3% and the median age of the diagnosis of hearing impairment was 2.2 years (0.49–4.76) and similarly, the visual impairment incidence was 3.0% and median age of the diagnosis of visual impairment was 1.8 years (0.49–4.34) (Hirvonen et al., 2018). Risk factors for NSI (Hirvonen et al., 2014; Hirvonen et al., 2018; Linsell, Malouf, Morris, Kurinczuk, & Marlow, 2016) are also risk factors for adverse cognitive development (Hirvonen et al., 2017).

2.2.1.4 Psychosocial factors

Socioeconomic status is commonly regarded as an environmental factor affecting cognitive development. Potential confounding effect of socioeconomic status on cognitive outcome of preterm born children have been assessed using individual-level (e.g. parental level of education), family-structure and contextual (e.g. neighbourhood deprivation) factors (Wong & Edwards, 2013). In a systematic review assessing risk factors for the poor cognitive development of children born very preterm, the level of parental education emerged as a prognostic factor, whereas in most studies where parental socioeconomic status was defined as income or occupation, it did not (Linsell et al., 2015). The influence of parental education on cognitive development is described in both full-term and preterm populations (Böhm et al., 2002; Bradley & Corwyn, 2002; Ko, Shah, Lee, & Asztalos, 2013; Wong & Edwards, 2013). The independent effect of paternal education is less well studied compared to the effect of maternal education.

2.2.2 Follow-up of cognitive development

Since very preterm children are at risk for neurodevelopmental problems, many hospitals have follow-up programs. A recent recommendation implemented in Great-Britain suggests an intensified follow-up until two years of corrected age for all preterm children born below 30 weeks of gestation and for the preterm children born between 30 and 36 weeks of gestation with developmental disabilities or severe risk factors possibly affecting their development (Kallioinen, Eadon, Murphy, & Baird, 2017). Intensified follow-up is defined as at least three visits including a developmental assessment at two years of corrected age. In Finland, intensified follow-up for children born preterm includes at least four visits. However, follow-up does not continue until two years of age in all Finnish university hospitals (Borg, 2018).

The stability of severe cognitive impairment and normal cognitive development has been reported to be good in the present study cohort between two and five years of age (Munck, Niemi, Lapinleimu, Lehtonen, & Haataja, 2012). A Bavarian Longitudinal Study from Germany followed the cognitive development of very preterm children (n=260) and their controls (n=229) born between 1985 and 1986 at 5 and 20 months and at 4, 6, 8 and 26 years of age (Breeman, Jaekel, Baumann, Bartmann, & Wolke, 2015). They found that, over time, IQ scores were more stable for very preterm born individuals than for controls, but the differences in stability disappeared when individuals with severe cognitive impairments were excluded. Regarding the cognitive development of children in general, IQ does not seem to undergo dramatic changes above the age of 12 to 14 years (Schneider, 2014).

The timing of the follow-up, the length of the follow-up period, as well as the assessment methods used, vary between countries and centres, making international and even national comparisons difficult. A growing body of evidence does, however, recommend long-term follow-up of these children (Hintz, Newman, & Vohr, 2016).

2.2.3 Cognitive development at school age

The study designs of very preterm outcome studies vary greatly. Relying only on cognitive test norms is less ideal, as sociodemographic characteristics and the native language of the standardization sample may differ from that of the preterm cohort (Anderson, 2014). Additionally, due to the Flynn effect, the severity of impairment may be underestimated when only using test norms, as normative mean test scores in cognitive measures increase with time (Flynn, 1999). The measurement of IQ in preterm studies is often performed with abbreviated scales so more time can be allocated to specific cognitive domains of interest. However, caution is needed when interpreting IQ scores from abbreviated measures as they are based on fewer tasks and assess fewer abilities.

This review covers cognitive outcome studies reporting complete Wechsler Intelligence Scale for Children, fourth edition (WISC-IV) profiles and full-scale IQs (Wechsler, 2011a; Wechsler, 2011b). The WISC-IV sets higher demands on fluid reasoning than the previous versions. Additionally, it stresses the role of working memory and processing speed more than previous versions.

A small Swiss study reported WISC-IV profiles for 10-year-old preterm children born between 1998 and 2006 (Lemola et al., 2017). Inclusion criteria were enrollment in regular primary school in Switzerland, no severe developmental delay, no major complications during the first year and being born with a birth weight appropriate for the gestational age. Children born at 30–31 completed weeks (n=19) and 32 completed weeks (n=14) of gestation did not show impairments in cognitive profile compared to controls. Children born at 24–27 (n=10) and 28–29 (n=14) weeks of gestation had a significantly lower full-scale IQ compared to the other groups. Additionally, children born at 24–27 weeks of gestation had lower processing speed than children born at 30–31 and 32 weeks of gestation than the controls, as well as lower verbal comprehension than the group born at 32 weeks.

An Australian Victorian Infant Collaboration Study Group reported the WISC-IV profile for eight-year–old children (n=189) born extremely preterm (<28 gestational weeks or birth weight <1000g) in 1997 in the state of Victoria (Hutchinson et al., 2013). The reported cognitive profile suggests a global cognitive deficit rather than impairments in specific domains. Separate indices were close to each other. The mean full-scale IQ was 93.1 (SD 16.1); 11% of children had a full-scale IQ 2SD below the controls (Roberts, Anderson, & Doyle, 2009).

A Swedish population-based prospective cohort study, EXPRESS (The Extremely Preterm Infants in Sweden Study), reported the WISC-IV profile for 6.5-year-old children (n=441) born extremely preterm (<27 gestational weeks) between 2004 and 2007 (Serenius et al., 2016). Their results also suggest a global cognitive deficit in the cognitive profile rather than an impairment in any specific domain. Mean full-scale IQ was 83.4 (SD 14.8). Additionally, 32% of the preterm children had a full-scale IQ -2SD below the controls.

An Irish study from Dublin reported the WISC-IV profile for 10–14-year-old children born at a very low birth weight (birth weight <1500 g) between 1995 and 1997 (McNicholas et al., 2014). Their results also suggest difficulties both in verbal comprehension and perceptual reasoning. They also report that mean full-scale IQ was 89.7 (SD 12.5); 20% of the preterm children had a full-scale IQ -2SD below the controls.

These results suggest a global cognitive deficit in the cognitive profile of very preterm born children rather than impairment in any specific domain. The rate of severe cognitive impairment seems to vary a lot in the two studies, including extremely preterm samples; it is reported to be between 11% and 32% (Roberts et al., 2009; Serenius et al., 2016).

2.3 School performance

The transition from preschool to primary school may be challenging for very preterm born children due to the increasing cognitive, psychosocial and educational demands. Preterm birth has profound consequences at school age and results in significant economic costs associate with education (Petrou, Abangma, Johnson, Wolke, & Marlow, 2009). It has been reported that teachers' knowledge about very preterm birth is limited (Johnson, Gilmore, Gallimore, Jaekel, & Wolke, 2015). However, teacher's concern about pupil's learning may be a critical bottleneck before receiving support services. These aspects highlight the importance of evaluating the school performance of very preterm born children from several perspectives, including academic and behavioural functioning and any support services received.

2.3.1 Academic functioning

Preterm children are at risk for academic difficulties at school age (Aarnoudse-Moens et al., 2009; Twilhaar, de Kieviet, Aarnoudse Moens, van Elburg, & Oosterlaan, 2018). In a recent review, IQ scores explained 46% of the variance in academic tests assessing the reading, spelling, and arithmetic skills of preterm children (<37 gestational weeks) born in 1990 or later indicating a strong relation between their academic skills and intelligence (Twilhaar et al., 2018). This review reported difficulties among preterm children in standardized tests of reading (0.44 SD below controls), spelling (0.52 SD below controls) and arithmetic (0.71 SD below controls) skills. The academic difficulties of very preterm children are reportedly most pronounced in mathematics (Taylor, Espy, & Anderson, 2009). Already preschool mathematical skills comprising numerical reasoning skills are substantially impaired in very preterm children (Aarnoudse-Moens, Oosterlaan, Duivenvoorden, van Goudoever, & Weisglas Kuperus, 2011). The reading difficulties of Finnish very preterm school beginners born between 2001 and 2006 were milder than their difficulties in mathematics (Alanko et al., 2017). Most first graders read as well as controls.

Academic difficulties of very preterm born children in basic academic skills persist, reportedly, throughout primary school (Twilhaar, de Kieviet, van Elburg, & Oosterlaan, 2018). However, their progression in these skills has been reported to be stable between grades one and six, implying that the gap between them and the controls did not increase. The early academic difficulties of very preterm born boys is reported to be comparable with that of the girls (Pritchard et al., 2009).

Teacher ratings are also used in studies evaluating the academic functioning of very preterm born children (Anderson & Doyle, 2003; Jaekel, Strauss, Johnson, Gilmore, & Wolke, 2015; Johnson, Hennessy et al., 2009; Johnson, Wolke, Hennessy, & Marlow, 2011; Pritchard et al., 2009). Findings based on teacher rated skills in mathematics are reported to be in line with those based on the standardized mathematical test scores of preterm born children (Johnson et al., 2011; Pritchard et al., 2009; Anderson & Doyle, 2003). However, it has been argued that even with standardized tests it is impossible to pinpoint the specific problem areas in mathematics (Simms, Cragg, Gilmore, Marlow, & Johnson, 2013). Furthermore, slightly decreased scores in academic tests do not necessarily mean that problems are identified in teacher ratings evaluating everyday academic functioning. To conclude, academic difficulties are assessed using several methods depending on the purpose the results are needed for.

2.3.2 Classroom functioning

Very preterm born children are at risk for behavioural problems affecting their school performance (Jaekel, Wolke, & Bartmann, 2013; Johnson, Kochhar et al., 2016; Ritchie, Bora, & Woodward, 2015). These studies using diagnostic evaluations have reported an increased risk for attention deficit/hyperactivity disorder, autism spectrum disorder and psychiatric disorders compared to controls.

A review of clinical cohort studies report a two- to three-fold increased risk for attention deficit/hyperactivity in very preterm born children (Johnson & Marlow, 2011). The inattentive subtype of attention deficit/hyperactivity disorder is the most common subtype in very preterm born children (Jaekel et al., 2013; Johnson et al., 2016). Inattention reportedly impact negatively on school functioning (Jaekel et al., 2013) and social functioning (Nijmeijer et al., 2008). Moreover, preterm born children are more prone to being bullied by peers (Wolke, Baumann, Strauss, Johnson, & Marlow, 2015).

Children born very preterm show higher rates of autism spectrum symptoms compared to term born children (Johnson & Marlow, 2011). According to a recent meta-analysis, social adjustment difficulties in very preterm born children tend to manifest as social withdrawal and peer relationship problems (Ritchie et al., 2015). Additionally, very preterm born children reportedly show less effective general and pragmatic communication (Bröring et al., 2018). Boundaries between inattention symptoms and autism spectrum symptoms are not always clear especially in preterm children (Bröring et al., 2018; Nijmeijer et al., 2008).

Very preterm born children who meet diagnostic criteria represent the extreme end of these symptoms. The behavioural profile of preterm children is described as "preterm behavioral phenotype" including inattention, social problems and anxiety (Johnson & Marlow, 2011). Even subclinical symptoms may affect their classroom performance and complicate their academic learning (Jaekel et al., 2013).

2.3.3 Educational support services

A recent meta-analysis showed that very preterm born children at the age of five years or older are three times more likely to receive special educational assistance than the controls (Twilhaar et al., 2018). A study from the Netherlands demonstrated that at school entry, between ages five and six, 61% of the very preterm (<30 gestational weeks) born children received healthcare therapies (physical, occupational and speech therapies and behavioural support) and/or educational support (van Veen et al., 2018). A study from Ireland reports that 33% of the 10–14-year-old children born with a very low birth weight (birth weight <1500g) had academic special educational needs compared to 12% of the controls (McNicholas et al., 2014). A French EPIPAGE (Epidemiological study on low gestational age infants) Study group reported that 58% of very preterm (<33 gestational weeks) children born in 1997 had received special care since the age of five years and/or support at school at eight years of age compared to 39% of the controls (Larroque et al., 2011). An British-Irish EPICure Study group reported 61% of the extremely preterm children (≤25 gestational weeks) born in 1995 in United Kingdom and Ireland to have at least one special educational need compared to 11% of the classmates (Johnson et al., 2009). Particularly high educational resource dependency has been reported in very preterm born children with NSI and/or severe cognitive impairment (Pritchard et al., 2009; Wocadlo & Rieger, 2006).

A detailed comparison of the rates of school age support services is complicated due to the differences between school systems and outcome measures. While it is important to study the effects of preterm birth in the context of the birth country and the birth hospital, it is also important to study the educational abilities in relation to received support services in the context of the birth country and its school system.

2.4 Executive functions

Executive functions (EF) encompass several interrelated, higher-order cognitive skills necessary for the goal-directed activity. Inhibition of responses, shifting between tasks or mindsets, and updating working memory representations are regarded as core components of EF (Best & Miller, 2010; Miyake et al., 2000). Problems in EF have been linked to many paediatric (Krivitzky, Walsh, Fisher, & Berl, 2015) and neuropsychiatric disorders (Blijd-Hoogewys, Bezemer, & van Geert, 2014; Mares, McLuckie, Schwartz, & Saini, 2007; McCandless & O' Laughlin, 2007).

Behavioural rating scales of EF and performance-based tests of EF account for a unique variance in the adaptive functioning of preterm born children (Gioia, Gerard & Isquith, 2004; Loe, Chatav, & Alduncin, 2015). Tests of EF are supposed to assess cognitive control, whereas behaviour rating scales of EF assess these skills under less structured conditions and evaluate the child’s skills to meet everyday demands for the self-regulation of behaviour and emotions (Taylor & Clark, 2016). EF tests may underestimate the child’s EF problems in everyday situations due to the quiet and well-structured tests and assessment setting. On the other hand, EF tests may also overestimate the child’s EF problems in everyday life, because they ignore compensatory strategies the child may have developed.

2.4.1 Development of executive functions

EF skills have a long developmental trajectory in cognitive development (Best & Miller, 2010). Development of cognitive skills can be divided into three sequential stages which are emerging, developing and established (Dennis, 1989). Although most cognitive skills emerge in early childhood, this significant developmental period occurs before the skills are fully functional. Inhibition is considered to first mature during the pre-school years (Best & Miller, 2010). Of the other core components of EF, working memory continues maturing up until adulthood (Best & Miller, 2010). Shifting develops over a prolonged period and is the slowest core component of EF to mature. Successful shifting relies on inhibition and working memory resources (Miyake et al., 2000). Children born very preterm are at increased risk of EF problems, over and beyond the risk for lower cognitive ability (Brogan et al., 2014; Taylor & Clark, 2016). Children born very preterm perform 0.3 to 0.7 SD below controls in performance-based EF tests (Aarnoudse-Moens et al., 2009).

A recent study from Sweden reports that EF problems in very preterm born children are unlikely to diminish with maturation (Stålnacke, Lundequist, Böhm, Forssberg, & Smedler, 2018). EF was assessed in this study with standardized working memory and shifting tests at the ages of five and 18 years. Working memory performance at the age of five years predicted working memory performance at the age of 18 years. The prediction of shifting was more complex at the age of 18 years, as neonatal factors such as intrauterine growth restriction also had a negative direct impact on outcome. An Australian study reported parent-rated EF outcomes at eight and 18 years of age in extremely preterm born children (Costa et al., 2017). Most of these children had stable EF development. In the present study, EF was assessed with parent-rated Behavior Rating Inventory of Executive Function (BRIEF) (Gioia, G., Isquith, Guy, & Kenworthy, 2000).

Despite high rates of EF problems in very preterm born children, EF is seldom routinely assessed in this population (Taylor & Clark, 2016). Studies from school age children born very preterm indicate that EF problems in higher functioning children may not be evident in early childhood and are frequently overlooked (Brogan et al., 2014; Hayes & Sharif, 2009). It has been suggested, that in addition to intelligence, impairment in EF is an important predictor of poor mathematic abilities following very preterm birth (Aarnoudse-Moens, Weisglas Kuperus, Duivenvoorden, van Goudoever, & Oosterlaan, 2013). Additionally, preterm children show prolonged development of EF throughout childhood up to adolescence compared to controls (Everts, Schöne, Mürner Lavanchy, & Steinlin, 2019).

2.4.2 Behavioural executive functions at school age

In clinical practice, behavioural questionnaires are recommended to be filled by two separate informants to enhance diagnostic reliability (American Psychiatric Association, 2013; Gioia, G. et al., 2000). There are only a few EF rating scales for school age children assessing EF behaviors. BRIEF (Gioia, G. et al., 2000) is a widely used rating scale assessment of EF that includes eight subscales which form two indices. The Behavioral Regulation Index is a composite score of Inhibit, Shift, and Emotional control. The Metacognition Index is a composite score of Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. Working memory and Inhibition scales are clinically useful in differentiating the diagnostic subtypes of attention deficit/hyperactivity disorder. Pre-established cut-off indicates clinically significant problems.

Parent and teacher ratings of EF are reported to be moderately correlated, reflecting different expectations and vulnerabilities in different environments (Gioia, G. et al., 2000). Teachers have been reported to better evaluate behaviours related to cognitive deficits in children with attention deficit/hyperactivity disorder (McCandless 2007). Additionally, teachers' EF ratings have been shown to correlate with academic performance in typically developing children (Dekker, Ziermans, Spruijt, & Swaab, 2017). Despite these findings, teacher-rated BRIEF profiles of preterm children compared to the controls are lacking. Extremely preterm born young adults (Burnett et al., 2015) and adults with very low birth weight (Heinonen et al., 2013) tend to rate their EF in self-reports as similar to that of controls, even if their EF was rated more negatively by their parents. Teachers, especially class teachers teaching several subjects to the child, provide valuable additional information about the child's EF in academically demanding situations.

A study from Switzerland reported an abbreviated version of a parent-rated BRIEF with Inhibit, Shift and Working Memory in 8–12-year-old children born very preterm with a full-scale IQ above 85 (Ritter, Perring, Steinlin, & Everts, 2014). Compared to the controls, children born very preterm only had more clinically significant problems in Working Memory. A study from Canada reported a parent-rated BRIEF profile of very preterm adolescents born between 1989 and 1992 (Luu, Ment, Allan, Schneider, & Vohr, 2011). Compared to the controls, they found more clinically significant problems in the Metacognition Index, and in the subscales of Initiation and Working Memory at 16 years of age.

Several results based on the parent-rated BRIEF have been reported by the Victorian Infant Collaborative Study Group from Australia, including outcomes of the 1991–1992, 1997 and 2005 extremely preterm cohorts at the age of 8 years (Anderson & Doyle, 2004; Anderson et al., 2011; Burnett et al., 2015; Cheong et al., 2017). In a recent report, they compared the outcomes between these three cohorts. Notably, they even observed increasing problems across the eras in Working Memory and Planning/ Organizing (Burnett et al., 2018).

The only study reporting both parent- and teacher-rated BRIEF results is from the Netherlands and includes preterm infants at 4–12 years of age with periventricular haemorrhagic infarction (Roze et al., 2009). The most affected parent rated EF scales were Inhibit (22%), Working Memory (22%), and Monitor (24%). The most affected teacher-rated EF scales were Shift (39%), Initiate (42%), Working Memory (67%), and Monitor (41%).

Results concerning the parent-rated BRIEF results reveal problems in the area of metacognition more clearly. These problems seem to be present even in preterm born children with normal cognitive development (Ritter et al., 2014). With age, working memory problems seem to become more evident (Burnett et al., 2018; Luu et al., 2011).

3 Aims of the Study

The objective of this thesis was to study the cognitive development and performance in everyday life in very preterm born children at 11 years of age. The specific aims of the three publications included are presented below:

In Study I, the aim was to describe the cognitive profile of the very preterm born children at 11 years of age and the associated risks factors. The hypothesis was that mean cognitive profile would be within the average range but lower than the mean test norms. Additionally, we evaluated how known neonatal risk factors, gender and parental education associate with different areas of cognitive profile.

In Study II, the aim was to evaluate the educational abilities and received support services of a cohort of 11-year-old children born very preterm based on teacher rating of classroom and academic functioning. In this study, we evaluated if very preterm born children perform similarly to controls at school despite the fact that their cognitive performance lags behind their own age group.

In Study III, the aim was to assess and compare against the controls, the EF profiles of 11-year-old children born very preterm at home and at school and the associated neonatal risk factors, gender and parental education. The hypothesis was that teacher evaluations would provide additional value in the assessment of EF problems in this group.

4 Methods

4.1 Participants

4.1.1 Children born very preterm

This study is part of the prospective, multidisciplinary follow-up study PIPARI (Development and Functioning of Very Low Birth weight Infants from Infancy to School Age). All very-low-birth-weight (≤1500 g) infants born at the Turku University Hospital between 2001 and 2006 and who lived in the catchment area of the hospital were eligible. From the beginning of 2004, the inclusion criteria were expanded to include all infants born below 32 weeks, regardless of the birth weight. At least one of the parents had to speak either Finnish or Swedish. The data regarding the prenatal period, delivery, neonatal morbidities, and developmental outcomes were systematically collected as a part of the PIPARI study protocol using the Vermont-Oxford Network criteria to enable comparisons between international research centres. Children with severe congenital anomalies or diagnosed genetic syndromes affecting their development were excluded.

The present study included infants born very preterm between 2001 and 2004 (n = 152). Of these children, 128 participated in a cognitive assessment at 11 years of age. Figure 1 outlines the recruitment process of the children born very preterm. The psychosocial variables of maternal and paternal education were included as separate variables using the official classification of education levels in Finland: basic education with a duration of nine years (≤9 years); upper secondary education, three more years (>9–12 years); and higher education, five or more years after basic education (>12 years). In the PIPARI study, the age of the very preterm children was corrected for prematurity until the age of two years. Their chronological age was used thereafter.

4.1.2 Full-term born controls

The control group was recruited by inviting the parents of the first boy and the first girl born on each monday to take part in the study. If they refused, the parents of the next boy and girl were invited. The full-term infants were born ≥37 weeks of gestation, had at least one parent speaking either Finnish or Swedish and were not admitted to a neonatal care unit during their first week of life. The exclusion criteria were any major congenital anomalies or genetic or chromosomal syndromes, the mother's use of illicit drugs or alcohol during the pregnancy, and the infant's birth weight being small for the gestational age according to age and gender-specific Finnish growth charts. The control group consisted of healthy full-term infants born at the Turku University Hospital between 2001 and 2004 (n=198) and was included in Studies II and III. Figure 1 outlines the recruitment process of the controls.

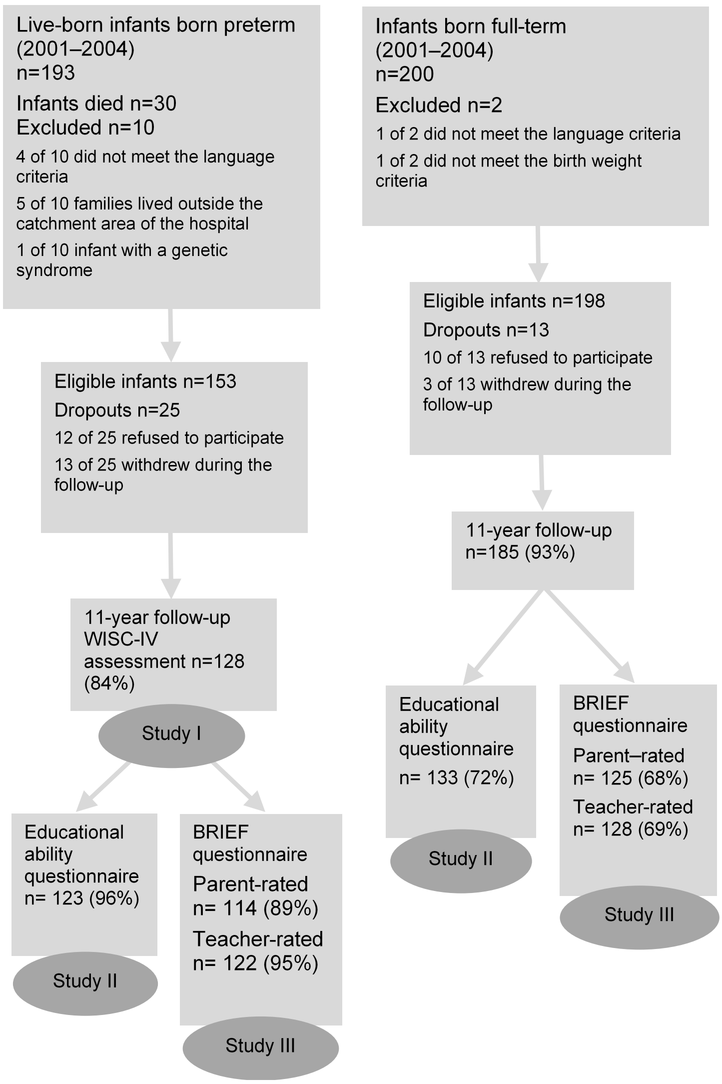

Figure 1. The flow chart of the participants.

4.2 Collection of background data

4.2.1 Brain magnetic resonance imaging at term

Brain MRI was performed at term age with an open 0.23-T Outlook GP (Philips Medical, INC, Vantaa Finland) for very preterm infants born between January 2001 and April 2004 and with a 1.5 Tesla Philips Intera (Philips Medical Systems, Best, The Netherlands) for very preterm infants born thereafter. The MRI findings were categorized into three groups: 1) Normal findings consisted of normal brain anatomy (cortex, basal ganglia and thalami, posterior limb of internal capsule, white matter, germinal matrix, corpus callosum, and posterior fossa structures), a width of extracerebral space of <5 mm, a ventricular/brain (V/B) ratio of <0.35, and no ventriculitis; 2) minor pathologies consisting of consequences from IVH (grades I and II), caudothalamic cysts, a width of the extracerebral space of 5 mm, and a V/B ratio of 0.35; and 3) major pathologies consisting of consequences from IVH (grades III and IV), an injury in the cortex, basal ganglia, thalamus, internal capsule, corpus callosum, cerebellum, or white matter, as well as increased width of extracerebral space of >5 mm, a V/B ratio of >0.35, ventriculitis, or other major brain pathologies (infarctions) (Setänen et al., 2013). These three categories were used to evaluate the relationship between brain pathology and cognitive (Study I) and EF (Study III) outcomes at 11 years of age.

4.2.2 Neurological examination

Neurosensory impairment (NSI) was defined as a child having at least one of the following diagnoses: cerebral palsy (CP), severe hearing impairment, or severe visual impairment. When present, CP was defined using the previously proposed Swedish classification (Himmelmann, Hagberg, Beckung, Hagberg, & Uvebrant, 2005). The diagnosis of CP was determined by the corrected age of 2 years after a systematic clinical follow-up. Severe hearing impairment was defined as a hearing loss requiring amplification in at least one ear. Severe visual impairment was defined as a visual acuity <0.3 or blindness. A group of very preterm born children with NSI was used as a more impaired subgroup in Studies I and II.

4.3 Assessment of cognitive development

4.3.1 Full-scale IQ and cognitive profile

The cognitive development of the very preterm born children was assessed using the Finnish translation of WISC-IV (Wechsler, 2011a; Wechsler, 2011b) at 11 years of age. Furthermore, six (5%) bilingual children preferring Swedish instead of Finnish were assessed using the Finnish translation of WISC-IV, by a native Swedish-speaking psychologist offering instructions and questions in Swedish. Full-scale IQ was used as a measure of general intelligence. Full-scale IQ is a composite score based on the Verbal Comprehension Index, the Perceptual Reasoning Index, the Working Memory and the Processing Speed Index. The description of the separate indices is presented in Study I. One child was unable to finish the processing speed measures due to a severe motor disability was assigned a score representing -4.0 SD. Three children scored so low on the individual indices that a full-scale IQ could not be calculated. Therefore, their full-scale IQ was assigned as -4.0 SD.

The full-scale IQ of the five-year-assessments (Lind et al., 2011; Munck et al., 2012) was used as a measure of general intelligence in Studies I and III. The full-scale IQ of the children born very preterm and controls was assessed at the age of five years using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-R), Finnish translation (Wechsler, 1995). An abbreviated version of the WPPSI-R included three subtests from the verbal scale (Information, Sentences and Arithmetic) and three subtests from the performance scale (Block Design, Geometric Design and Picture Completion). Of the 128 very preterm born children included in the present study, 120 (94%) were also successfully assessed at the age of five years. In the very preterm group, five of the five-year assessments were performed in Swedish using the same translation protocol as in the 11-year assessments. Of the 132 controls, 125 (95%) were successfully assessed at the age of five years.

4.3.2 School performance

The teacher-rated questionnaire covering educational abilities of the children (i.e. academic and classroom functioning) and support services received by the children, was designed for the purposes of the present study (Study II). Each child's teacher was advised to assess whether the pupil had problems in academic and classroom functioning compared to the average age-level expectations. The teachers were also asked to rate the pupil's academic functioning (reading, reading comprehension, spelling, text production, mathematics) and classroom functioning (social skills, group work, independent work, persistency, concentration) using three categories (1= average or above average, 2= mild problems, 3= severe problems). The ratings were dichotomized to average or above average and mild or severe problems. The teacher-rated questionnaire also included questions about support services received by the pupil. In Study II, the following support services were included: studying at one grade below their own age group, full-time special education, part-time special education and assistant services. The teacher-rated educational ability questionnaire is presented in Appendix I.

4.3.3 Executive functions

We measured EF in everyday life in Study III using the parent and teacher forms of the Finnish translation of the Behavior Rating Inventory of Executive Function (BRIEF) (Gioia, G. et al., 2000). BRIEF includes eight subscales that form two indices (86 items, 3-point Likert scale). The Behavioral Regulation Index is a composite score of Inhibit, Shift, and Emotional control. The Metacognition Index is a composite score of Initiate, Working Memory, Plan/Organize, Organization of Materials, and Monitor. The age and gender specific standardized T-scores on the subscales and Index scores were used to measure outcomes. Clinically significant symptoms are defined as T-scores of >64. Only completely and consistently filled-in questionnaires were used in this study (Gioia, G. et al., 2000). Of the BRIEF subscales, parent- and teacher-rated Inhibit, Shift and Working Memory subscales were included in the risk-factor-analyses.

4.4 Data collection

Neonatal data were prospectively collected from the medical records. Information about maternal and paternal education was obtained from the parents when the infant was born. Brain MRI was performed at term age. At two years of age, NSI was screened in the neurological examination that was included in the follow-up visits as a part of the PIPARI follow-up protocol. Cognitive development was assessed during the follow-up visits of five-year-olds and 11-year-olds as a part of the PIPARI follow-up protocol. The 11-year-olds' cognitive assessment was obtained during the first semester of the school year when the children turned 11 years and most of them started their fifth grade.

The parents of the very preterm born children received the teacher-rated educational ability questionnaire and the BRIEF questionnaires at the 11-year psychological assessment visit. Parents filled the BRIEF questionnaire during the appointment or at home. The teachers received the educational ability and BRIEF questionnaires and self-addressed envelopes from the parents. Parents of the controls were first contacted by phone. If they agreed to participate, they received the parent and teacher questionnaires and self-addressed envelopes by mail. Teachers of the control children received the questionnaires and self-addressed envelopes from the parents. The teachers and parents were all asked to return the questionnaires within two weeks. However, if a pupil was new to the teacher, he or she was encouraged to get acquainted with the pupil for two months before filling the questionnaire.

4.5 Statistical analysis

Characteristics of the present study sample are described with mean (SD) [min, max] or with frequencies and percentages as appropriate. Dropout analyses (Study I) were performed using chi-square test or Fisher's exact test, as appropriate. Associations between categorical and ordinal variables were studied using chi-square tests for trends. Differences in background variables between very preterm and the controls were studied using two sample t-test or in case of categorical variable chi-square or Fisher's test were used.

In analyses of cognitive profile in Study I, one sample t-test was used to compare the cognitive scores of all children born very preterm, children born extremely preterm, children born very preterm without NSI, separately for boys and girls born very preterm to the mean level of 100 of the normal population. Two sample t-tests were used to compare the cognitive scores between preterm born boys and girls. Correlation between full-scale IQ at the age of five and 11 years was calculated using the Spearman correlation.

Differences in school performance in Study II between the preterm born children and the controls were analysed using logistic regression. The analyses were repeated after excluding children with a full-scale IQ <70. In addition, the analyses were repeated after adjusting for paternal education. However, since the results remained unchanged, the repeated results were not reported. Logistic regression was also used to analyse school performance between girls and boys in both groups. Differences in school performance between the preterm children with a full-scale IQ <70 and with a full-scale IQ ≥70 and between the preterm children with NSI and without NSI were analysed using chi-square tests.

The clinically significant BRIEF problems (T-scores >64) of the children born very preterm with a full-scale IQ ≥70 and controls were compared using logistic regression (Study III). Since there was a statistically significant difference in paternal education between the children born very preterm and the control children, paternal education was added to the logistic regression models and the analysis was repeated. Associations between parent- and teacher-rated BRIEF T-scores in children born very preterm were studied using the Spearman correlation. The level of agreement between parent- and teacher-rated T-scores was analysed using Cohen's kappa.

Multiple regression analysis was used to study the association between the WISC-IV Indices and *a priori* chosen background variables (maternal education, paternal education, gender, gestational age, birth weight z-score, surgical NEC, and findings in the brain MRI at term) (Study I). All background variables were included as independent variables at the same time in all models. These analyses were repeated after excluding children with NSI. Regression model estimates of statistically significant risk factors are reported as change in test points.

Robust regression analysis was used to study the associations between full-scale IQ and parent- and teacher-rated Inhibition, Shift and Working Memory of the children born very preterm with a full-scale IQ ≥70 (Study III). After that, *a priori* chosen background variables (maternal education, paternal education, gender, gestational age, birth weight z-score, surgical NEC, and findings in the brain MRI at term) were included in the models. Regression model estimates of statistically significant risk factors are reported as change in test scores.

Statistical analyses were performed using the 9.4 version of SAS for Windows; p-values of <.05 were considered to be statistically significant.

4.6 Ethical consideration

The PIPARI study protocol was approved by the Ethics Review Committee of the Hospital District of Southwest Finland in December 2000 and January 2012. All parents who agreed to participate in the study gave written informed consent after they had received written and oral information. At 11 years of age, the children gave their own written informed consent after receiving written information.

5 Results

5.1 Background characteristics

The characteristics of the very preterm (birth weight ≤1500g or gestational age <32 weeks) and full-term born control children included in the study are presented in Table 1. Ten (7.8%) of the children born very preterm had NSI: eight children had CP and two had hearing impairments. None of the children born very preterm had severe visual impairment. Mean (SD) full-scale IQ at the age of five years was 99.0 (17.6) in the very preterm group (n= 117) and 113.2 (14.3) in the control group (n=125).

In Study I, the dropout children born very preterm (n=26, 17%) had a lower maternal education level (<12 years in 65% of the dropouts, 37% of the study infants, p=.004) and were in treatment for retinopathy of prematurity more often than the preterm infants (in 12% of the dropouts, 2% of the preterm infants, p=.034). They were also more often singletons (92% of the dropouts, 66% of preterm infants, p=.007). In Studies II and III, there were no statistically significant differences in gender or maternal education between the very preterm born children and the control children. On average, very preterm born children were less likely to have a father with higher education (≤12 years) than the fathers of the children in the control group.

Table 1. Characteristics of the very preterm born children and their controls.

Characteristics	Children born very preterm (n=128)	Controls (n=133)
Antenatal corticosteroids, n (%)	123 (96)	
Gestational age (weeks) Mean (SD) [min, max]	28.8 (2.7) [23.0, 35.9]	39.6 (1.2) [37–42]
Birth weight (g) Mean (SD) [min, max]	1080 (292) [400, 2025]	3680 (427) [2570, 4810]
Birth weight z-score, Mean (SD)	-1.4 (1.6)	
Small for gestational age[a], n (%)	49 (38)	
<32 weeks/≥32 weeks	112/16	
≤1500g/>1500g	123/5	
Male, n (%)	68 (53)	63 (47)
Multiple birth, n (%)	44 (34)	
Postnatal corticosteroids, n (%)	20 (16)	
Treated retinopathy of prematurity, n (%)	2 (2)	
Surgical necrotizing enterocolitis, n (%)	6 (5)	
Chronic lung disease[b], n (%)	18 (14)	
Brain MRI at term, n (%) Normal findings Minor pathologies Major pathologies	 70 (55) 22 (18) 34 (27)	
Maternal education, n (%) ≤9 years >9-12 years >12 years	 12 (9) 35 (28) 79 (63)	 4 (3) 47 (39) 69 (58)
Paternal education, n (%) ≤9 years >9-12 years >12 years	 13 (10) 73 (58) 40 (32)	 9 (8) 48 (42) 58 (50)

[a]Defined as a birth weight of <-2.0 SD according to the age and gender specific Finnish growth charts. [b]Defined as a need for supplementary oxygen at the corrected age of 36 gestational weeks.

5.2 Full-scale IQ and cognitive profile

The mean age of the children born very preterm at the time of the cognitive assessments reported in Study I was 11 years and 1 month (min 10 years and 8 months, max 11 years and 7 months). For comparison, we also report the cognitive profile results for extremely preterm children (birth weight <1000 g or gestational age <28 weeks), comprising half of the total group of very preterm born children (64/128). Figure 2 demonstrates that most of the 11-year-old children born very preterm (72%) performed within at least the low average range of 80–89 in the assessment of full-scale IQ.

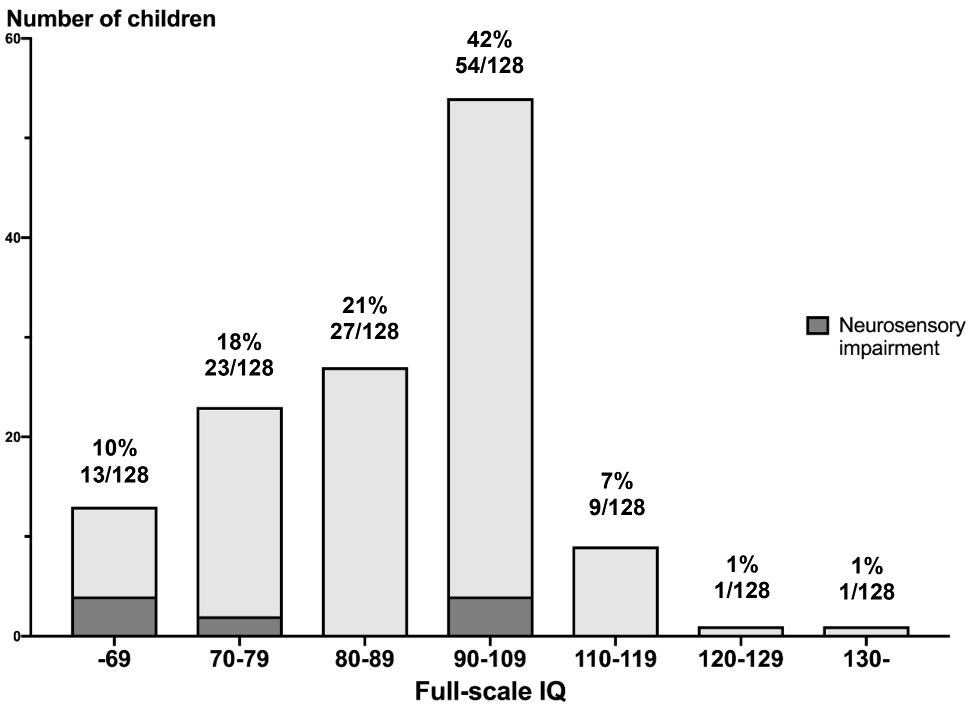

Figure 2. Full-scale IQ distribution of the children born very preterm.

Mean full-scale IQ and the four index scores are presented in Table 2. Working memory [t Value 2.28, $p<.025$, mean difference 6.89 (95% CI 0.9 – 12.9)] and processing speed [t Value 3.06, $p<.002$, mean difference 9.40 (95% CI 3.3 – 15.5)] domains were significantly lower in boys born very preterm compared to the girls born very preterm. Correlation between full-scale IQ at the age of five and 11 years was high and statistically significant ($r=.73$, $p<.001$).

Table 2. Wechsler Intelligence Scale for Children, fourth edition (WISC-IV) scores for all children born very preterm, for boys and girls born very preterm, for children born very preterm without neurosensory impairment (NSI), and for children born extremely preterm.

	Full-scale IQ	**Verbal comprehension**	**Perceptual reasoning**	**Working memory**	**Processing speed**
	Mean (SD) *t* Value	Mean (SD) *t* Value	Mean (SD) *t* Value	Mean (SD) *t* Value	Mean (SD) *t* Value
Mean scores were compared to the normative test mean ± 1 SD: 100 ± 15					
All children born very preterm (n=128)	87.6 (18.0) -7.77 ***	89.8 (15.4) -7.45***	91.2 (17.7) -5.64***	92.6 (17.4) -4.80***	92.9 (17.9) -4.47***
Boys born very preterm (n=68/128)	85.1 (18.0) -6.81***	89.6 (15.9) -5.40***	90.6 (18.9) -4.10***	89.4 (16.3) -5.36***	88.5 (17.0) -5.57***
Girls born very preterm (n=60/128)	90.5 (17.7) -4.16***	90.1 (15.0) -5.11***	91.8 (16.3) -3.87***	96.3 (17.9) -1.60	97.9 (17.7) -0.90
Children born very preterm without NSI (n=118/128)	89.1 (16.8) -7.05***	90.6 (14.9) -6.87***	92.9 (16.2) -4.77***	93.5 (17.0) -4.17***	93.9 (17.0) -3.90***
Extremely preterm children (n=64/128)	85.1 (19.4) -6.13***	87.6 (16.1) -6.19***	89.9 (19.5) -4.15***	90.5 (18.0) -4.24***	90.5 (17.7) -4.30***

* p<.05; ** p<.01; *** p<.001.

5.3 School performance

The teacher-rated educational ability questionnaire was returned by 123/128 (96%) of the teachers of very preterm children who participated in cognitive testing at 11 years of age. The educational ability questionnaire was returned by 133/185 (72%) of the teachers of the controls who were included in the study at 11 years of age. The mean ages at the time of the educational ability assessment reported in Study II were 11 years and 3 months for the very preterm born children and 11 years and 4 months for the controls.

5.3.1 Educational abilities

Problems with academic functioning were more common in the very preterm children than the controls. The differences remained after adjusting for paternal education. After excluding very preterm children with a full-scale IQ <70 (11%, n=13), the preterm group did not differ significantly from the controls in terms of academic problems. Very preterm children with a full-scale IQ <70 had significantly more problems relating to academic performance than the very preterm children with a full-scale IQ ≥70. Very preterm children with NSI only had significantly more problems in text production compared with the other very preterm children. There were no gender differences in the academic functioning of the very preterm group. Table 3 shows academic functioning in whole sample.

Table 3. Frequency of academic functioning below average in all very preterm born children, and separately for very preterm born children with a full-scale IQ <70, a full-scale IQ ≥70, with neurosensory impairment, and boys and girls.

	Academic functioning below average (Mild or severe problems compared to own age group)				
	Reading, n (%)	Spelling, n (%)	Text production, n (%)	Reading comprehension, n (%)	Mathematics, n (%)
Compared with the controls					
Controls (n=133)	20 (15)	36 (27)	27 (20)	30 (23)	34 (26)
All very preterm children (n=123)	33 (27)*	43 (35)	39 (32)*	34 (28)	48 (39)*
Very preterm children with full-scale IQ ≥70 (110/123, 89%)	22 (20)	35 (32)	28 (25)	22 (20)	36 (33)
Compared with the other very preterm born children					
Very preterm children with full-scale IQ <70 (13/123, 11%)	11 (85)***	8 (62)*	11 (85)***	12 (92)***	12 (92)***
Very preterm children with neurosensory impairment (10/123, 8%)	4 (40)	5 (50)	6 (60)*	5 (50)	4 (40)
Boys compared with girls					
Very preterm boys (63/123, 51%)	19 (30)	23 (37)	24 (38)	19 (30)	24 (38)
Very preterm girls (60/123, 49%)	13 (22)	20 (33)	15 (25)	14 (23)	24 (40)

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

Regarding the classroom functioning results, problems with independent work and persistency were more common in very preterm children than the controls. They did not, however, have more problems with social skills or group work than the controls. These differences in classroom functioning remained after adjusting for paternal education. After excluding very preterm born children with a full-scale IQ <70 (n=13, 11%), the very preterm group did not differ significantly from the controls in term of classroom behaviour problems. The classroom functioning of the very preterm children with a full-scale IQ <70 differed significantly from that of the very preterm children with a full-scale IQ ≥70. Very preterm born children with NSI did not have more classroom behaviour problems than the very preterm children without NSI. Classroom functioning was weaker in boys than girls. Table 4 shows classroom functioning in whole study sample.

Table 4. Frequency of classroom functioning below average in all very preterm born children, and separately for very preterm born children with a full-scale IQ <70, with a full-scale IQ ≥70, with neurosensory impairment, and boys and girls.

	Classroom functioning below average (Mild or severe problems compared to own age group)				
	Social skills, n (%)	Group work, n (%)	Independent work, n (%)	Persistency, n (%)	Concentration, n (%)
Compared with the controls					
Controls (n=133)	25 (19)	20 (15)	20 (15)	24 (18)	31 (23)
All very preterm children (n=123)	22 (18)	26 (21)	35 (28)*	35 (28)*	40 (33)
Very preterm children with full-scale IQ ≥70 (110/123, 89%)	17 (15)	20 (18)	24 (22)	25 (23)	30 (27)
Compared with the other very preterm born children					
Very preterm children with full-scale IQ <70 (13/123, 11%)	5 (38)*	6 (46)*	11 (85)***	10 (77)***	10 (77)***
Very preterm children with neurosensory impairment (10/123, 8%)	3 (30)	3 (30)	5 (50)	5 (50)	6 (60)
Boys compared with girls					
Very preterm boys (63/123, 51%)	15 (24)	20 (32)**	26 (41)**	25 (40)**	30 (48)***
Very preterm girls (60/123, 49%)	7 (12)	6 (10)	9 (15)	10 (17)	10 (17)

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

5.3.2 Received support services

The very preterm children received full-time special education and assistant services more often than the controls and were more often one grade below the controls. The differences remained after adjusting for paternal education. Very preterm born children with a full-scale IQ <70 received significantly more support services than the very preterm born children with a full-scale IQ ≥70. Of the children with NSI, eight out of ten had cerebral palsy, and they all received full-time special support. Boys born very preterm were the recipients of at least one support service more often than the girls. Table 5 shows received support services in whole study sample.

Table 5. Frequency of received support services in all very preterm born children, and separately for very preterm born children with a full-scale IQ <70, with a full-scale IQ ≥70, with neurosensory impairment, and boys and girls.

	Received support services				
	Full-time special education, n (%)	Part-time special education, n (%)	Assistant services, n (%)	One grade below, n (%)	Receiving at least one support service, n (%)
Compared with the controls					
Controls (n=133)	4 (3)	22 (17)	20 (15)	7 (5)	34 (26)
All very preterm children (n=123)	20 (16)**	23 (19)	35 (28)*	30 (24)***	57 (46)***
Very preterm children with full-scale IQ ≥70 (110/123, 89%)	11 (10)*	17 (15)	23 (21)	19 (17)**	44 (40)*
Compared with the other very preterm born children					
Very preterm children with full-scale IQ <70 (13/123, 11%)	9 (69)***	6 (46)	12 (92)***	11 (85)***	13 (100)***
Very preterm children with neurosensory impairment (10/123, 8%)	8 (80)***	2 (20)	6 (60)*	6 (60)**	10 (100)***
Boys compared with girls					
Very preterm boys (63/123, 51%)	13 (21)	9 (14)	22 (35)	19 (30)	35 (56)*
Very preterm girls (60/123, 49%)	7 (12)	14 (23)	13 (22)	11 (18)	22 (37)

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

5.4 Executive functions

The BRIEF questionnaire rated by at least parent or teacher was available for 125 very preterm born children and 132 controls. Of the 45 (36%) very preterm born multiples included in the study, 34 (27%) participated with the sibling and 24 (19%) had the same reporter at school.

5.4.1 Executive functions at home and at school

The mean age of the children at the time the parent-rated BRIEF was filled in was 11 years and 2 months for the children born very preterm and 11 years and 4 months for the controls. Group comparisons reported in Study III were performed for the parent-rated BRIEF after the 11 very preterm born children with a full-scale IQ of <70 were excluded. The very preterm born children showed clinically significant problems in parent-rated Behavioral Regulation Index [preterm n=9/103, (9%), controls n=2/125, (2%), OR 5.89, 95% CI 1.24–27.90, p=.03] more often than the controls. After adjusting these comparisons for paternal education, the difference was not statistically significant.

The mean age of the children at the time the teacher-rated BRIEF was filled in was 11 years and 2 months for the very preterm born children and 11 years and 4 months for the controls. Group comparisons were performed for the teacher-rated BRIEF after the 12 very preterm born children with a full-scale IQ of <70 were excluded. The very preterm born children showed clinically significant problems in teacher-rated Working Memory subscale more often than the controls [preterm n=21/110, (19%), controls n=11/128, (8%), OR 2.51, 95% CI 1.15–5.47, p=.02]. After adjusting for paternal education, the difference in Working Memory remained (OR 2.50, 95% CI 1.08–5.79, p=.03). Figure 3 shows the BRIEF profiles of the very preterm born children with full-scale IQ ≥70 at home rated by parents and at school rated by teachers.

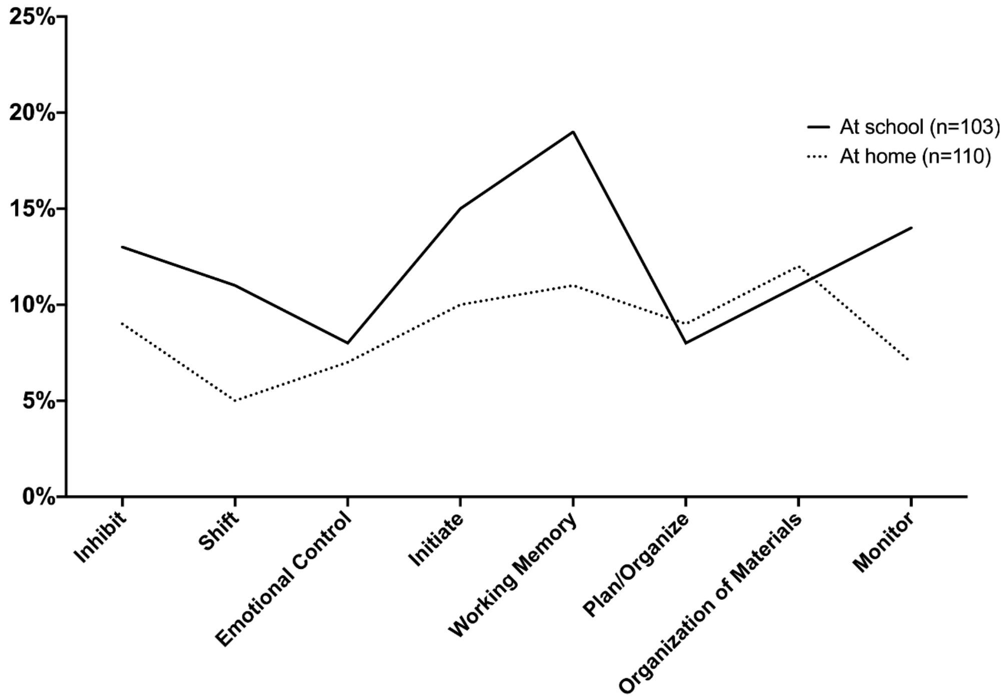

Figure 3. Clinically significant EF problems in children born very preterm with a full-scale IQ ≥70 at home and at school.

5.4.2 Associations between parent and teacher ratings

All children born very preterm with both parent- and teacher-rated questionnaires returned were included (preterm n= 111/125, 89%, control n= 121/132, 92%) in the analyses in Study III. All parent-rated BRIEF scores correlated positively and significantly with teacher-rated BRIEF scores. Agreements between the parents' and teachers' ratings were moderate (Kappa= .40–.60) for the Behavioral Regulation Index and the Metacognition Index, and fair (Kappa= .20–.40) or low (Kappa= 0–0.20) for the subscale ratings.

5.5 Factors affecting cognitive development

The factors potentially affecting the cognitive profile (Study I) and EF (Study III) were chosen *a priori* based on clinical judgement and previous literature. Gestational weeks, birth weight *z*-score, gender, surgical NEC, and brain MRI findings a term were used as neonatal factors and maternal and paternal education as sociodemographic factors.

5.5.1 Factors affecting cognitive profile

Overall regression models for full-scale IQ ($p<.001$, $\omega^2=0.28$), verbal comprehension ($p<.001$, $\omega^2=0.20$), perceptual reasoning ($p<.001$, $\omega^2=0.17$), working memory ($p<.001$, $\omega^2=0.26$), and processing speed ($p<.001$, $\omega^2=0.18$) were performed using the neonatal and psychosocial factors. Statistically significant associations are shown in Figure 4. Having a major brain MRI pathology at term was clinically the most important (a 15-point reduction) risk factor for the weaker cognitive performance associated with full-scale IQ and for all four domains (an 8-point reduction in verbal comprehension, a 14-point reduction in perceptual reasoning, a 13-point reduction in working memory, and a 9-point reduction in processing speed). The clinically important impact of low paternal education on lower verbal comprehension was also evident (a 15-point reduction). Lower birth weight z-score was associated with lower processing speed (a 3-point reduction). Male gender was associated with lower working memory (a 10-point reduction) and lower processing speed (a 10-point reduction). After excluding the children with NSI from the analyses, major pathologies in brain MRI decreased ($p<.001$, $\omega^2=0.28$) the estimated mean full-scale IQ by 11 points, but it was no longer significantly associated with verbal comprehension and processing speed.

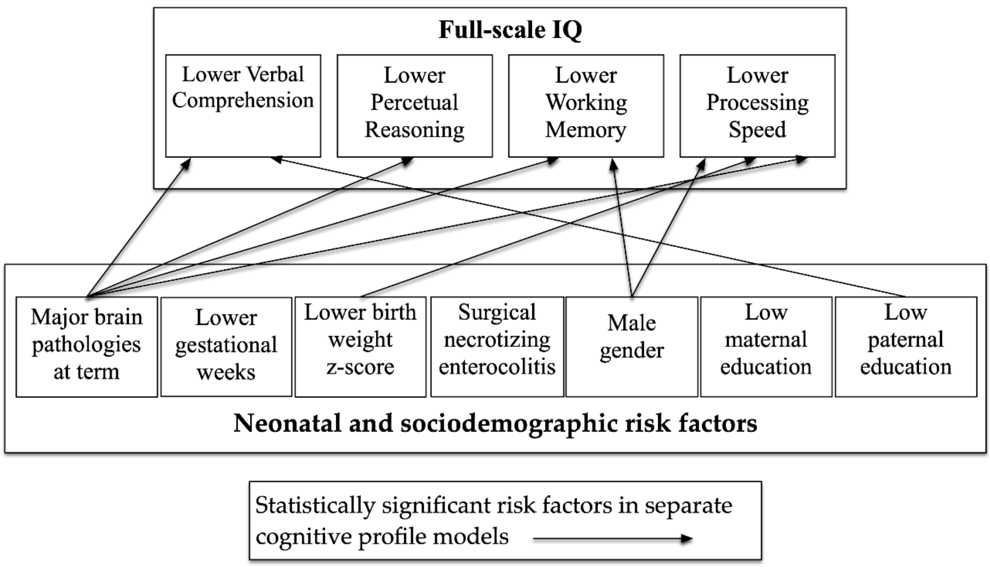

Figure 4. Statistically significant neonatal and sociodemographic risk factors in separate cognitive profile models.

5.5.2 Factors affecting executive functions

All very preterm born children with a full-scale IQ ≥70 were included in the analyses of factors affecting EF. Robust regression analysis was used to study the associations between full-scale IQ and parent- and teacher-rated Inhibition, Shift and Working Memory. Lower full-scale IQ associated with higher parent-rated Inhibition scores (a 0.09-score deficit) and with higher parent- (a 0.22-score increase) and teacher-rated (a 0.20-score increase) Working Memory scores. Regression analysis was repeated after including neonatal (gestational weeks, birth weight z-score, surgical NEC, and brain MRI findings at term) and sociodemographic (maternal and paternal education) factors and full-scale IQ in the Inhibition, Shift and Working Memory models. Several statistically significant predictors were identified and are shown in Figure 5. Surgical NEC (a 7-score increase) and low paternal education (a 5-score increase) were associated with higher parent-rated Inhibition scores. Lower gestational age at birth (a 0.44-score increase) and low maternal education (a 2-score increase) were associated with higher teacher-rated Inhibition scores. Lower birth weight z-score (a 2-score increase) was associated with higher parent-rated Shift scores. Lower full-scale IQ was associated with higher parent- (a 0.26-point increase) and teacher-rated (a 0.24-score increase) Working Memory scores.

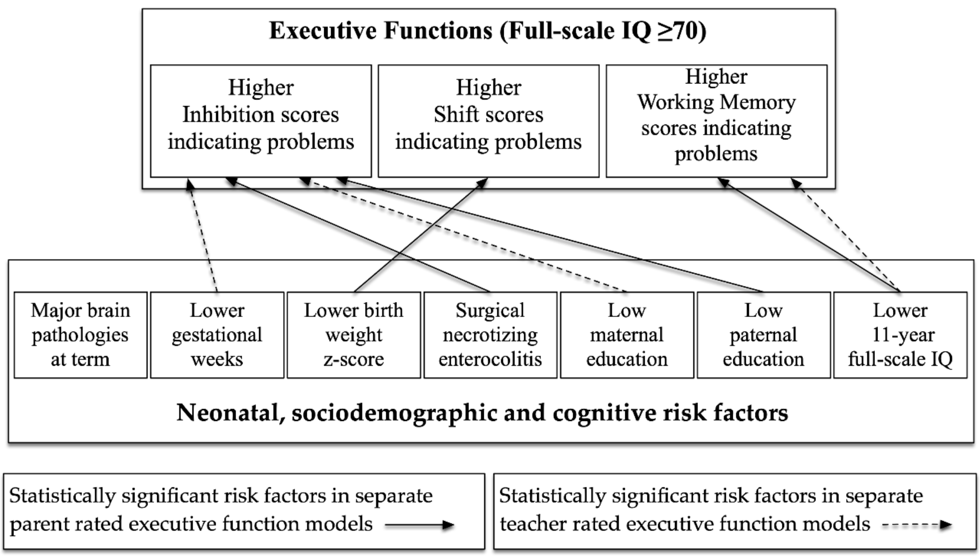

Figure 5. Statistically significant risk factors affecting executive functions at home and at school.

6 Discussion

This thesis describes the different aspects of cognitive development of the middle school age very preterm children born between 2001 and 2004 in Turku University Hospital. These different aspects were studied using the WISC-IV (Wechsler, 2011a; Wechsler, 2011b) assessment, a teacher-rated educational ability questionnaire and parent and teacher-rated BRIEF questionnaires (Gioia, G. et al., 2000). Additionally, risk factors affecting cognitive development were evaluated using WISC-IV Indices, full-scale IQ and selected BRIEF subscales.

6.1 Cognitive profile at 11 years of age

At the time when the cognitive follow-up of 11 year old very preterm born children started as a part of the PIPARI study protocol in 2012, updated WISC-IV was implemented in the Finnish clinical field including updated Finnish norms (Wechsler, 2011b). Performance of the present preterm study cohort in WISC-IV was compared to this updated standardization sample.

6.1.1 Usability of WISC-IV full-scale IQ and profile

In Study I, the full-scale IQ distribution of the preterm group was shifted to the left compared to the normative distribution. The difference to the normative test mean was 12 points. At the age of five years in the PIPARI Study cohort, the difference to the controls was 9 points (Munck et al., 2012). A recent meta-analysis has reported cognitive outcomes of very preterm born children aged 4 to 17 years (n=6163), including studies up to July 2017 (Brydges et al., 2018). Children born very preterm were found to be 0.82 SD below controls, corresponding to 12 IQ points. Age at assessment was not associated with cognitive impairment suggesting no catch-up with controls with age. Another recent meta-analysis including extremely and very preterm born children (n=7752) found a 0.86 SD difference between preterm children and controls, corresponding to 13 IQ points (Twilhaar et al., 2018). Mean age at the included assessments ranged from 5 to 20 years. Improvement in cognitive outcomes was not detected between 1990 and 2008. The mean difference found in Study I is in line with the findings of these two meta-analyses.

Severe cognitive impairment (full-scale IQ <70, -2SD) in general cognitive development was found in 11% of the children born very preterm and in 13% of the subgroup of extremely preterm born children in the present study. The other two comparable studies defined their cognitive categories according to the mean (SD) of their control groups (Roberts et al., 2009; Serenius et al., 2016). Using the -2SD cut-off relative to the controls, 11% (Roberts et al., 2009) and 32% (Serenius et al., 2016) had severe cognitive impairment in these two extremely preterm study samples. In the latter Swedish EXPRESS study, cognitive categories were defined based on other medical records for those who were not assessed using WISC-IV. This may partly explain the relatively high proportion of severe cognitive impairments, as this method is probably not able to differentiate milder impairments. To conclude, the rate of severe cognitive impairments in the present study is in line with the Australian Victorian Infant Collaboration Study outcome of severe cognitive impairment (Roberts et al., 2009), even though the comparison to controls may increase the rate of cognitive impairment. If the Swedish study had used test norms the rate of severe cognitive disability would have decreased from 32% to 19% (Serenius et al., 2016).

The cognitive profile reported in Study I was found to be significantly below the normative mean in all four domains. This is in line with other studies reporting the WISC-IV profile of the preterm children (Hutchinson et al., 2013; McNicholas et al., 2014; Serenius et al., 2016). WISC-IV highlights fluid reasoning in perceptual reasoning more than previous versions and may mask the specific visuospatial and visuo-motor difficulties that are previously reported in the present study sample (Lind et al., 2011) and in other (Anderson, 2014) preterm samples. Additionally, even though WISC-IV highlights the role of working memory more than previous versions, working memory tests are verbal and do not reveal the visual working memory deficits reported in the PIPARI Study cohort at 11 years of age (Korpela et al., 2016).

Neuropsychological performance in preterm children has been shown to correspond to their cognitive level, although not as clearly as in term born children (Lundequist, Böhm, & Smedler, 2013). Additional neuropsychological tests are needed to find out their specific weaknesses. In particular, visual memory functions, visuospatial processing, visuomotor functions, attention and processing speed reportedly account for variability in very preterm born children's learning abilities and need to be assessed with specific cognitive tests in the cognitive assessment of very preterm born children (Geldof, van Wassenaer, de Kieviet, Kok, & Oosterlaan, 2012; Korpela et al., 2016; Mulder, Pitchford, Hagger, & Marlow, 2009; Simms et al., 2013). In the PIPARI Study cohort, neuropsychological performance of the very preterm born children in NEPSY-II (Korkman, Kirk, & Kemp, 2008) assessment at 11 years of age, was mostly within the average range, yet poorer than the normative mean (Lind, Nyman, Lehtonen, & Haataja, in press). Performance of the very preterm children was poorest in tasks assessing visual memory and visuomotor functions.

6.1.2 Stability of cognitive development from five to 11 years

From two to five years of age, the stability of general cognitive development has been found to be good in both normally developing and significantly delayed children in the PIPARI Study cohort (Munck et al., 2012). Similarly, results of the Study I demonstrate good stability of general cognitive impairment between the ages of five and 11 years. Full-scale IQ correlated highly (r=.73) between these ages. Furthermore, the results of the present study support previous suggestions (Lind et al., 2011; Munck et al., 2012) that cognitive assessments before school entry are a reliable way to predict later development and that they are clinically valuable for identifying those children who need developmental and academic support. However, there were also children whose cognitive development declined from the normal range of variation to the cognitive impairment range between the ages five and 11. This is not surprising considering the IQ stability findings from early childhood to early adulthood. Even among typically developing children, results show better stability for shorter intervals between measurement points and with increasing age of the children (Schneider, 2014).

6.2 School performance at 11 years of age

The school performance of the very preterm born children was assessed in Study II using teacher ratings. When the 11-year-assessments were designed for the PIPARI Study, there was no Finnish standardized questionnaire for teachers for clinical screening purposes that would have covered academic and behavioural performance at school. Additionally, a new Special Education Act was implemented in 2011 in the Finnish schools that included three stages of support (Björn, Aro, Koponen, Fuchs, & Fuchs, 2016). The first level of support, general support, is intended for students needing occasional help, including assistant services and part-time special education. The second level, intensified support, is for students in need of a longer period of support in a specific area, including the same support services as in general support. The third level, special support, is long-lasting support for students receiving full-time special education. A Finnish questionnaire for clinical needs covering these three stages of support was also missing. As a whole, a comprehensive view of school performance of the very preterm children born in the 2000s was missing in Finland. Our intention was to evaluate the academic and classroom functioning of very preterm born children in relation to the controls. Moreover, we assessed the type and magnitude of the support services they received.

6.2.1 Usability of teacher rated educational abilities

6.2.1.1 Academic functioning

Many children born very preterm have been reported to fall behind their peers in a wide variety of academic skills, most prominently in mathematics assessed with academic tests (Aarnoudse-Moens et al., 2011) and with teacher ratings covering basic academic subjects (Anderson & Doyle, 2003; Johnson et al., 2011; Pritchard et al., 2009). In Study II, children's problems mentioned in teacher-rated academic functioning were evenly distributed across different skills. After we repeated the analyses with only the very preterm born children with a full-scale IQ ≥70, the differences did not remain statistically significant in any aspect of academic performance. In Study I, 18% of the children had a full-scale IQ of 70–79 and 21% of them had a full-scale IQ of 80–89 (in the normal population these are 7% and 16%, respectively). One could argue that the academic performance of the very preterm born children with a full-scale IQ ≥70 was better than their general cognitive performance would lead us to expect. It has been reported that IQ scores explain 46% of the variance between different academic domains in very preterm born children, indicating a strong relationship between academic performance and intelligence (Twilhaar et al., 2018). The results of the Study II suggest that very preterm born children have protective factors that compensate for their cognitive impairments, leading to average school performance. Preterm children reportedly have personality traits like dutifulness and cautiousness (Pesonen et al., 2008) that may compensate for their cognitive impairments.

Very preterm born children were found to receive more support services than the controls (Study II). It has been reported that teachers and educational psychologists have poor knowledge of the impact of preterm birth on children's support service needs (Johnson et al., 2015). The prospective follow-up protocol of the PIPARI study may have increased knowledge about preterm birth for families and teachers of very preterm children. Referrals for further parental support or assessments were provided after early deviant findings at two and five year follow-up visits. Cognitive assessments at five years of age also provided information on the areas that needed practicing at preschool age, i.e. pre-reading skills and early mathematic skills.

In addition to several protective factors, our results may also suggest that teacher-rated academic performance using three categories (average or above, mild problems, and severe problems) is not sensitive enough to identify very preterm born children with mild academic problems. Teachers may be better at recognizing higher-achieving than lower-achieving pupils (Demaray & Elliott, 1998). This phenomenon may also appear in the present study suggesting that very preterm born children with mild academic problems are overwhelmed in classes. Finally, there is a possibility that some of the teachers have had lower expectations for the pupils that are receiving support services. This could have contributed to the lack of group differences in teacher ratings.

6.2.1.2 Classroom functioning

Classroom functioning problems reported in Study II were especially common among very preterm born children in the areas of independent work and persistency, which is consistent with attention problems. However, after we repeated the analyses with only very preterm born children with a full-scale IQ ≥70, the differences did not remain significant in any aspects of classroom performance. According to the results, children born very preterm seem to cope well with social situations during the structured school day. In the teacher-rated questionnaire, we asked teachers to rate the pupil's social and group work skills in general. It is possible that social adjustment difficulties in very preterm children may be more pronounced during the spare time. Additionally, self-rated social adjustment like social competence and loneliness would reveal additional information about the specific social performance problems of very preterm born children. Furthermore, these findings may associate with inattention symptoms.

6.3 Executive functions at 11 years of age

In Study III we evaluated clinically significant EF problems in the everyday life of very preterm born children. BRIEF (Gioia, G. et al., 2000) is designed to capture behavioral manifestations of EF by dividing behaviour into eight separate skills. It detects problems that occur at home and school settings and provides real world targets for intervention (Isquith, Roth, & Gioia, 2013). Due to these features, BRIEF has been called an ecological assessment of EF.

6.3.1 Usability of parent and teacher rated BRIEF

The parents of very preterm born children with a full-scale IQ ≥70 reported no clinically significant problems in any specific areas at home compared to the controls. The lack of clinically significant differences at home was surprising when compared to the previously reported results. The high parental education level of the present study cohort may partly explain this. Additionally, early referrals for parental counselling may have served as a protective factor in terms of the development of EF in this cohort of very preterm born children. In previous research, a shortened version of parent-rated BRIEF with Inhibit, Shift, and Working Memory was reported in 8-12 year-old children born very preterm with a full-scale IQ >85 (Ritter et al., 2014). They found that, compared to controls, children born very preterm had more clinically significant problems in Working Memory at home. According to the complete parent-rated BRIEF profile, children born very preterm without NSI showed more clinically significant problems in the Metacognition Index and the Emotional Control, Initiation, Working Memory, and Monitor subscales at 8 years of age (Anderson & Doyle, 2004). At 16 years of age, clinically significant differences were found in the complete parent-rated BRIEF in the Initiation and Metacognition Index after children with a full-scale IQ <70 and/or NSI were excluded (Luu et al., 2011). With age, working memory problems at home may become clearer, as more independence is expected.

The teacher-rated BRIEF provided important additional information about the clinically significant problems of children born very preterm in school settings. Teachers most commonly reported clinically significant problems in Working Memory. Very preterm born children with a full-scale IQ ≥70 had average school performance and classroom behavior according to the teacher rating. Thus, the present results suggest that clinically significant Working Memory problems do not necessarily affect any specific academic skills in very preterm born children. Moreover, results of the present study suggest that clinically significant working memory problems are difficult to screen with general questions focusing on the pupil's independent work skills, persistency and concentration. A lower full-scale IQ of the very preterm born children with a full-scale IQ ≥70 was related to Working Memory problems. However, the association was weak and may not have clinical relevance.

6.4 Factors affecting cognitive development at 11 years of age

Data on the neonatal morbidity and sociodemographic factors were systematically collected as a part of the PIPARI study protocol. Study I assessed associations between the selected neonatal factors, gender and parental education and the cognitive profile of the children born very preterm at 11 years of age. Additionally, Study III assessed how these factors affect the EF of the present preterm study cohort. Support services received at school were systematically recorded at 11 years of age and reported in Study II.

6.4.1 Neonatal factors

Poor prenatal growth, which is highlighted by SGA status, was found to be a risk factor for decreased processing speed (Study I). Processing speed refers to the ability to process information quickly and efficiently. Poor prenatal growth was a risk factor for difficulties in shifting (Study III). Shifting refers to the ability to make flexible transitions between tasks and mindsets. In the same study cohort at the age of five years, poor prenatal growth was associated with more immature white matter at term age (Lepomäki et al., 2013). The poor prenatal growth associated with the delay in white matter maturation might affect decreased processing speed and difficulties in shifting at 11 years of age. Lower gestational age, which is connected to the most immature infants, was not a risk factor for any aspect of the cognitive profile (Study I). Lower gestational age was a risk factor for difficulties in inhibition (Study III). Surgical NEC seems to increase, in particular, the risk for difficulties in inhibition. According to a recent review, influence of prenatal risk factors on the cognitive development of children born very preterm diminishes over time (Linsell et al., 2015). The results of Studies I and III suggest that factors related to preterm birth still affect the different aspects of cognitive development at middle school age, but as individual risks their clinical significances are relatively weak.

6.4.2 Gender

In the cognitive profile reported in Study I, mean scores in working memory and processing speed were lower for the boys born very preterm compared to the girls born very preterm. The subtests of Working Memory and Processing Speed Indices require good attentional skills which are especially vulnerable to impairment in preterm born children (Brogan et al., 2014). Moreover, boys are known to have an increased risk for these symptoms compared to girls (Willcutt, 2012). The assessment of processing speed in WISC-IV also places demands on visuomotor functions. Impairments in visuomotor functions are reportedly more pronounced in very preterm boys than in very preterm girls (Geldof et al., 2012). The gender difference in the general cognitive development of very preterm born children has been suggested to diminish with age (Linsell et al., 2015). However, male gender continued to be a risk factor for working memory and processing speed functions up to later school age.

Processing speed and working memory are important factors underlying academic attainments (Mulder et al., 2009). However, gender differences were not found in academic performance. These results are in line with the finding that the early academic performance of the very preterm boys is comparable to the academic performance of the girls (Pritchard et al., 2009). Very preterm and control boys had more problems with group work, independent work and persistency compared to very preterm and control girls reflecting boys general vulnerability to problems in classroom behavior. Very preterm boys received more support services compared to the control boys. To conclude, gender seems to serve as an additional factor in increasing the risk for specific cognitive impairments and problems in school performance. Of all Finnish children receiving intensified or special support in elementary school in 2017, two thirds were boys (Official Statistics of Finland, 2018).

6.4.3 Brain magnetic resonance imaging findings

In Study I, major pathologies in brain MRI at term were found to be a risk factor for lower full-scale IQ and lower individual test indices. In the PIPARI Study cohort, major brain pathologies at term were associated with lower cognitive development also at two and five years of age (Munck et al., 2010; Setänen et al., 2013). In Study III, major brain pathologies at term were not associated with the Inhibition, Shift or Working Memory scores of the very preterm born children with a full-scale IQ ≥70. Brain MRI at term was not a common practice when the PIPARI study was launched. Classification used in PIPARI Study was created in 2000. The applied definition for major brain pathologies covers a wide spectrum of brain injuries, and accordingly, does not differentiate the severity of e.g. white matter lesions. Recent studies have applied more detailed classifications. In future studies, more advanced imaging techniques could be used to study, for example, white matter involvement in more detail. This could also be used to create more specific risk groups for adverse cognitive development in preterm infants.

6.4.4 Neurosensory impairment

Ten children with NSI were diagnosed as an impaired subgroup of very preterm born children. In terms of their school performance, they only had significantly more problems in text production than the other very preterm born children. Children with NSI are offered a close follow-up protocol by the Finnish health care system. Additionally, they are usually provided special support, including full-time special education and an individualized education plan. Problems in school performance accumulated most clearly among those very preterm born children who had full-scale IQ <70.

Children born preterm with CP have an increased risk for comorbidities including cognitive impairment (Hafström et al., 2018). Of the eight children with CP in the present study, four had a full-scale IQ <70. One child who was unable to finish the processing speed tests due to a severe motor disability was assigned a score representing -4.0 SD. Adapting the assessment protocol is rarely included in cognitive outcome studies of very preterm born children. In clinical practices, the cognitive development of children with CP including the most severe speech and motor disorders can, in most cases, be assessed by adapting the response mode to achieve a valid evaluation (Stadskleiv et al., 2018). To conclude, most of the very preterm born children with CP in the present study cohort were successfully assessed with tests of the follow-up protocol.

6.4.5 Psychosocial factors

Low paternal education was associated with poor verbal comprehension of the WISC-IV profile. The association between maternal education and verbal comprehension was in the same direction, but not statistically significant. The independent effects of paternal education are less well studied than the effects of maternal education. Previous results have suggested that fathers more often require clarifications and use more questions when talking with their children (Leech, Salo, Rowe, & Cabrera, 2013). The diversity and quantity of vocabulary inputs are important factors for children's language acquisition (Rowe, 2012) and this may explain the special effects of paternal education on verbal comprehension of very preterm born children at 11 years of age. In Study III, low paternal and maternal education was significantly associated with difficulties in inhibition. Even if their clinical significance is relatively weak, these results are in line with the previous study, according to which low parental education is associated with hyperactivity-impulsivity symptoms but not with inattention symptoms in 11-year-old children born extremely preterm (Johnson et al., 2016).

Sensitive parenting is found to protect academic resilience especially in very preterm born children (Wolke, Jaekel, Hall, & Baumann, 2013). High maternal sensitivity reportedly boosts children's self-control and attention regulation and is especially beneficial for task persistence in children with cognitive deficits (Jaekel, Wolke, & Chernova, 2012). Cognitively stimulating parenting is found to protect academic resilience equally in very preterm and term born children (Wolke et al., 2013). Elements of parenting and genetic factors potentially explain the significant associations observed in the present study between parental education and the reported aspects of cognitive development.

6.4.6 Educational support services

Children born very preterm received more support services than controls. In Study II, 40% of the very preterm children with full-scale IQ ≥70 and 26% of the controls received at least one support service. Children born very preterm received full-time special education more often (10%) and were more often one grade below their age group in school (17%) than their controls (3% and 5%, respectively). An increased need for support services in preterm children compared to their peers has commonly been reported (Johnson et al., 2009; Larroque et al., 2011). In the French EPIPAGE cohort study, more than half (58%) of the eight-year-old children born before 33 weeks of gestation in France in 1997 and 39% of the controls received at least one of the following services: support at school, therapist visit(s) at the age of five to eight years, or grade repetition (Larroque et al., 2008). The rate of support services received would probably been even higher in the present sample as well, if support services received before 11 years of age had been systematically recorded. Interestingly, in Finland, the support services received by very preterm born children seem to have persisted across decades, because half (49%) of the adults who were born very preterm between 1978 and 1985 and 19% of the controls received remedial education even after excluding individuals with NSI from the preterm group (Pyhälä et al., 2011).

In Study III, 19% of the children born very preterm with a full-scale IQ ≥70 and 9% of the controls had clinically significant problems in Working Memory. The support services the very preterm born children received may have compensated for their working memory problems. However, children born very preterm who have cognitive and EF difficulties but academic skills within average range, may still have unmet needs and may benefit from additional support in the classroom (Johnson, Strauss et al., 2016). To conclude, these results highlight the importance of screening working memory problems and inattention symptoms at school.

Updated support services that meet pupil's current needs are crucial factors that protect the learning and mental well-being of very preterm born children. In evaluating school performance of very preterm born children, it is valuable to include information about support services. In Finland, the eligibility for special education services is mainly determined within schools, based on a multi-professional evaluation that includes the views of teachers, special needs teachers and parents. A formal diagnosis is not needed for a child to receive special educational services. Psychological assessments are often needed to target support efficiently. In these evaluations, it is necessary to consider the cognitive vulnerability of very preterm born children and the fact that their typical problems are silent.

6.5 Strengths and limitations of the study

One strength of the present study is its population-based cohort including very preterm and full-term infants born in the same region served by Turku University Hospital. Additionally, their development has been followed from birth until 11 years of age and their neonatal and developmental follow-up data has been collected systematically. Secondly, the follow-up rate of the PIPARI Study has remained high until 11 years of age. Moreover, teachers also filled-in the questionnaires commendably. The third strength of the present study is that the measures for evaluating different aspects of cognitive development were selected on a clinical basis and provided clinically usable information. Additionally, the measures are widely used and comparable with other studies. Fourthly, a narrow age-range allowed us to describe the school performance of the very preterm born children with comparable expectations in their everyday life. From a clinical point of view, the fifth grade already brings out many types of difficulties in learning.

One limitation of the present study is that a control group was not assessed with WISC-IV at 11 years of age. Due to this, the cognitive outcome of the very preterm born children could only be compared to the standardized mean and deviation values. However, the WISC-IV norms were up to date at the time when the data collection was initiated. Secondly, due to the psychometric properties of the WISC-IV, the mean full-scale IQ is lower compared to the separate indices. Accordingly, the full-scale IQ of the WISC-IV is not recommended for use in clinical practices without indices. Thirdly, a possible technical limitation is created by the brain MRI equipment used in the first part of the cohort study, since more advanced imaging techniques can detect white matter lesions in more detail. The fourth limitation is that, due to the sample size, the number of several neonatal morbidities was relatively small, possibly restricting the findings. Lastly, there are also other concurrent sociodemographic factors in addition to parental education that may have an impact on cognitive outcomes at school age, such as parenting stress, maternal and paternal well-being, family structure (Huhtala et al., 2011) and the above discussed sensitive parenting (Wolke et al., 2013).

6.6 Future perspectives and clinical implications

Very preterm birth is a risk factor for adverse cognitive development at middle school age. A cognitive assessment at five years of age is a good predictor of the results of a cognitive assessment performed at 11 years of age. Our study supports earlier suggestions from the PIPARI Study that a cognitive assessment including specific cognitive tests should be provided for all very preterm born children at five years of age. The specific cognitive tests should cover at least visual and verbal memory functions, visuo-motor functions and EF questionnaires. In addition, questionnaires screening for inattention symptoms are recommended.

The present study suggests that favorable socioeconomic conditions have a positive effect on the cognitive development of very preterm born children, especially in the areas of verbal comprehension and inhibition. Based on our results we could also speculate that fathers have a special role in providing a verbally stimulating growth environment. Protective factors in very preterm born children’s growth environment and the special role of both parents demand further research. All very preterm born children should be provided with parental counselling to also support their specific needs. The previously reported specific role of sensitive parenting in the development of very preterm born children's academic resilience (Wolke et al., 2013) would be a valuable target of early intervention and counselling.

In future research, it is essential to study which support services are effective in each context in order to provide evidence-based support for preterm children, who seem to benefit from support systems at school. For example, delayed school entry is not necessarily recommended for very preterm born children with cognitive impairments (Jaekel et al., 2015). Additionally, it seems essential to study the effectiveness of support services received before school age. These protective factors may partly explain the children's better-than-expected performance at school reported in the present study. As mentioned earlier, PIPARI follow-up protocol may have functioned as a significant support for the children, since the support service needs of the children in this cohort were more thoroughly screened before school age than those of the other preterm cohorts who have not participated in a systematic follow-up protocol.

Our results suggest that screening for working memory problems at school is valuable in finding the very preterm born children whose learning may require additional support. More research is needed to determine the effectiveness of the different support services recommended to enhance working memory in classroom. Verbal support and guidance may be more effective than visual support, as very preterm born children have strengths in the area of verbal working memory (Korpela et al., 2016).

It has been reported that education professionals have poor knowledge of the impact of very preterm birth on children's learning and development, even if these children may require long-term support for cognitive and behavioural problems (Johnson et al., 2015). Updated knowledge is important for all the adults working with very preterm born children. Our results raise a concern that very preterm born children struggle to meet age-appropriate expectations and that they may be at an elevated risk for stress symptoms and tiredness during the later school years more often than their classmates. Preterm children may have developed compensatory strategies to cope with increasing demands. A wait-and-see strategy is not suggested for these children if any problems occur at any stage of their school career. This highlights the importance of knowledge regarding the long-term effects of preterm birth also for health care professionals working with adults. Identifying developmental problems in preterm children as early as possible is important, since it enables targeted interventions and developmental support in order to strengthen their skills and to prevent the intensification of difficulties and the development of possible secondary problems.

The reasons leading to preterm birth and the complications related to preterm birth vary widely. One main goal in the studies evaluating this population has been to find factors that could help in recognizing those very preterm born children who face a high developmental risk. In this study, major brain pathology at term, SGA, surgical NEC and gender were associated with different aspects of adverse cognitive outcome. However, to gain more generalizable information about specific risk groups, large-scale international data and international collaboration are needed.

This study suggests that the most important goals in the long-term follow-up of school age very preterm born children are to evaluate their performance in everyday life, to provide knowledge about how preterm birth may affect learning and to provide detailed cognitive assessments with a low threshold followed by targeted interventions if problems emerge.

7 Conclusions

The following conclusions can be drawn from Studies I-III:

In Study I, the full-scale IQ distribution was shifted to the left compared to the normative distribution of full-scale IQ. The indices were significantly below the normative mean in all four cognitive profile domains. Less than one-third of the children born very preterm had clinically significant cognitive difficulties. Extremely preterm born children and very preterm born boys had the lowest scores at group level. When considering full-scale IQ and all four domains of the cognitive profile, it was found that major brain pathology at term, low paternal education, male gender, and growth restriction were significant risk factors for adverse cognitive development.

In Study II, academic and classroom functioning did not differ between the very preterm born children with a full-scale IQ ≥70 and the controls. However, they still received full-time special education and were one grade below their own age group more often than the controls. Educational problems were more common in the very preterm born children with severe cognitive impairment (full-scale IQ <70) and, to a lesser degree, in the very preterm born children with NSI. Boys had more classroom functioning problems than girls irrespective of the gestational age.

In Study III, the only clinically significant difference in EF between very preterm born children with a full-scale IQ ≥70 and the controls was seen in working memory at school. Parent-rated EF correlated significantly with teacher-rated EF. Combined teacher and parent rated EF provided a comprehensive picture of their multidimensional EF problems. Lower gestational age at birth, growth restriction, surgical NEC, and low paternal and maternal education were risk factors for higher Inhibition or Shift scores indicating problems. Higher Working Memory scores indicating problems were related to lower full-scale IQ. The associations were relatively weak and may not have clinical significance.

Abbreviations

BRIEF	Behavior Rating Inventory of Executive Function
CP	Cerebral palsy
EF	Executive functions
IQ	Intelligence quotient
IVH	Intraventricular haemorrhage
MRI	Magnetic resonance imaging
NEC	Necrotizing enterocolitis
NSI	Neurosensory impairment
SGA	Small for gestational age
WISC-IV	Wechsler Intelligence Scale for Children-Fourth Edition
WPPSI-R	Wechsler Preschool and Primary Scale of Intelligence-Revised

List of References

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, 51-6.

Aarnoudse-Moens, C. S. H., Weisglas Kuperus, N., Duivenvoorden, H., van Goudoever, J., Oosterlaan, J. (2013). Executive function and IQ predict mathematical and attention problems in very preterm children. *PLoS ONE*, 8(2), e55994.

Aarnoudse-Moens, C. S. H., Weisglas-Kuperus, N., van Goudoever, J., Oosterlaan, J. (2009). Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*, 124(2), 717-728.

Alanko, O., Niemi, P., Munck, P., Matomäki, J., Turunen, T., Nurmi, J., Lehtonen, L., Haataja, L., Rautava, P. (2017). Reading and math abilities of Finnish school beginners born very preterm or with very low birth weight. *Learning and Individual Differences*, 54, 173-183.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders: DSM-V, 5th edition. Washington, D.C.

Anderson, P. (2014). Neuropsychological outcomes of children born very preterm. *Seminars in Fetal and Neonatal Medicine*, 19(2), 90-96.

Anderson, P., De Luca, C., Hutchinson, E., Spencer-Smith, M., Roberts, G., Doyle, L. (2011). Attention problems in a representative sample of extremely pre-term/extremely low birth weight children. *Developmental Neuropsychology*, 36(1), 57-73.

Anderson, P., & Doyle, L. (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.

Anderson, P., & Doyle, L. (2003). Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. JAMA, 289(24), 3264-3272.

Back, S. (2015). Brain injury in the preterm infant: New horizons for pathogenesis and prevention. *Pediatric Neurology*, 53(3), 185-192.

Barrington, K. J. (2001). The adverse neurodevelopmental effects of postnatal steroids in the preterm infant: A systematic review of RCTs. *BMC Pediatrics*, 1(1).

Best, J., & Miller, P. (2010). A developmental perspective on executive function. *Child Development*, 81(6), 1641-1660.

Björn, P., Aro, M., Koponen, T., Fuchs, L., Fuchs, D. (2016). The many faces of special education within RTI frameworks in the United States and Finland. *Learning Disability Quarterly*, 39(1), 58-66.

Blencowe, H., Cousens, S., Oestergaard, M., Chou, D., Moller, A., Narwal, R., Adler, A., Garcia, C., Rhode, S., Say, L., Lawn, J. (2012). National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: A systematic analysis and implications. *Lancet*, 379(9832), 2162-2172.

Blencowe, H., Lee, A. C. C., Cousens, S., Bahalim, A., Narwal, R., Zhong, N., Chou, D., Say, L., Modi, N., Katz, J., Vos, T., Marlow, N., Lawn, J. (2013). Preterm birth-associated neurodevelopmental impairment estimates at regional and global levels for 2010. *Pediatric Research*, 74 (S1), 17-34.

Blijd-Hoogewys, E., Bezemer, M., van Geert, P. (2014). Executive functioning in children with ASD: An analysis of the BRIEF. *Journal of Autism and Developmental Disorders*, 44(12), 3089-3100.

Böhm, B., Salamon, M., Smedler, A., Lagercrantz, H., Forssberg, H. (2002). Developmental risks and protective factors for influencing cognitive outcome at 5 1/2 years of age in very-low-birthweight children. *Developmental Medicine and Child Neurology*, 44(8), 508-516.

Borg, E. (2018). Pikkukeskosten neurologinen kehitysseuranta. Master's thesis. University of Helsinki, Faculty of Medicine.

Bradley, R., Corwyn, R. (2002). Socioeconomic status and child development. *Annual Review of Psychology*, 53, 371-399.

Breeman, L., Jaekel, J., Baumann, N., Bartmann, P., Wolke, D. (2015). Preterm cognitive function into adulthood. *Pediatrics*, 136(3), 415-423.

Brogan, E., Cragg, L., Gilmore, C., Marlow, N., Simms, V., Johnson, S. (2014). Inattention in very preterm children: Implications for screening and detection. *Archives of Disease in Childhood*, 99(9), 834-839.

Bröring, T., Oostrom, K., van Dijk-Lokkart, E. M., Lafeber, H., Brugman, A., Oosterlaan, J. (2018). Attention deficit hyperactivity disorder and autism spectrum disorder symptoms in school-age children born very preterm. *Research in Developmental Disabilities*, 74, 103-112.

Brydges, C., Landes, J., Reid, C., Campbell, C., French, N., Anderson, M. (2018). Cognitive outcomes in children and adolescents born very preterm: A meta-analysis. *Developmental Medicine and Child Neurology*, 60(5), 452-468.

Burnett, A., Anderson, P., Lee, K., Roberts, G., Doyle, L., & Cheong, J. L. Y. (2018). Trends in executive functioning in extremely preterm children across 3 birth eras. *Pediatrics*, 141(1), e20171958.

Burnett, A., Scratch, S., Lee, K., Cheong, J., Searle, K., Hutchinson, E., De Luca, C., Davey, M-A., Roberts, G., Doyle, L., Anderson, P. (2015). Executive function in adolescents born <1000 g or <28 weeks: a prospective cohort study. *Pediatrics*, 135(4), e834.

Cheong, J. L. Y., Anderson, P., Burnett, A., Roberts, G., Davis, N., Hickey, L., Carse, E., Doyle, L. (2017). Changing neurodevelopment at 8 years in children born extremely preterm since the 1990s. *Pediatrics*, 139(6), e20164086.

Costa, D., Miranda, D., Burnett, A., Doyle, L., Cheong, J. L. Y., Anderson, P. (2017). Executive function and academic outcomes in children who were extremely preterm. *Pediatrics*, 140(3), e20170257.

Counsell, S. J., Rutherford, M. A., Cowan, F. M., Edwards, A. D. (2003). Magnetic resonance imaging of preterm brain injury. *Archives of Disease in Childhood*, 88(4), F269-F274.

Counsell, S., Edwards, A. D., Chew, A. T. M., Anjari, M., Dyet, L., Srinivasan, L., Boardman, J., Allsop, J., Hajnal, J., Rutherford, M., Cowan, F. (2008). Specific relations between neurodevelopmental abilities and white matter microstructure in children born preterm. *Brain*, 131(12), 3201-3208.

Dekker, M., Ziermans, T., Spruijt, A., Swaab, H. (2017). Cognitive, parent and teacher rating measures of executive functioning: Shared and unique influences on school achievement. *Frontiers in Psychology*, 8, 48.

Demaray, M., Elliott, S. (1998). Teachers' judgements of students' academic functioning: A comparison of actual and predicted performances. *School Psychology Quarterly*, 13(1), 8-24.

Dennis, M. (1989). Language and young damaged brain. In Boll, T., Bryant, B. (Eds.), Clinical neuropsychology and brain function: Research, measurement and practice (pp. 89-123). American Psychological Association, Washington.

Everts, R., Schöne, C., Mürner Lavanchy, I., Steinlin, M. (2019). Development of executive functions from childhood to adolescence in very preterm-born individuals - A longitudinal study. *Early Human Development*, 129, 45-51.

Flynn, J. (1999). Searching for justice: The discovery of IQ gains over time. *American Psychologist*, 54(1), 5-20.

Geldof, C. J. A., van Wassenaer, A. G., de Kieviet, J. F., Kok, J. H., Oosterlaan, J. (2012). Visual perception and visual-motor integration in very preterm and/or very low birth weight children: A meta-analysis. *Research in Developmental Disabilities*, 33(2), 726-736.

Gioia, G., Isquith, P., Guy, S., Kenworthy, L. (2000). Behavior rating inventory of executive function (BRIEF): Professional manual. Psychological Assessment Resources, Lutz, FL.

Gioia, G., Isquith, P. (2004). Ecological assessment of executive function in traumatic brain injury. *Developmental Neuropsychology*, 25(1-2), 135-158.

Guellec, I., Lapillonne, A., Renolleau, S., Charkaluk, M-L., Roze, J., Marret, S., Vieux, R., Kaminski, M., Ancel, P. (2011). Neurologic outcomes at school age in very preterm infants born with severe or mild growth restriction. *Pediatrics*, 127(4), e883-e891.

Hafström, M., Källén, K., Serenius, F., Marlsál, K., Rehn, E., Drake, H., Ådén, U., Farooqi, A., Thorngren-Jenneck, K., Strömberg, B. (2018). Cerebral palsy in extremely preterm infants. *Pediatrics*, 141(1), e20171433.

Hayes, B., Sharif, F. (2009). Behavioural and emotional outcome of very low birth weight infants- literature review. *Journal of Maternal - Fetal & Neonatal Medicine*, 22(10), 849-856.

Heinonen, K., Pesonen, A., Lahti, J., Pyhälä, R., Strang-Karlsson, S., Hovi, P., Järvenpää, A., Eriksson, J., Andersson, S., Kajantie, E., Raikkonen, K. (2013). Self- and parent-rated executive functioning in young adults with very low birth weight. *Pediatrics*, 131(1), e243-e250.

Himmelmann, K., Hagberg, G., Beckung, E., Hagberg, B., Uvebrant, P. (2005). The changing panorama of cerebral palsy in Sweden. IX. prevalence and origin in the birthyear period 1995-1998. *Acta Paediatrica*, 94(3), 287-294.

Hintz, S., Newman, J., Vohr, B. (2016). Changing definitions of longterm follow-up: Should "long term" be even longer? *Seminars in Perinatology*, 40(6), 398-409.

Hirvonen, M., Ojala, R., Korhonen, P., Haataja, P., Eriksson, K., Gissler, M., Luukkaala, T., Tammela, O. (2014). Cerebral palsy among children born moderately and late preterm. *Pediatrics*, 134(6), e1584-e1593.

Hirvonen, M., Ojala, R., Korhonen, P., Haataja, P., Eriksson, K., Gissler, M., Luukkaala, T., Tammela, O. (2018). Visual and hearing impairments after preterm birth. Pediatrics, 142(2), e20173888.

Hirvonen, M., Ojala, R., Korhonen, P., Haataja, P., Eriksson, K., Rantanen, K., Gissler, M., Luukkala, T., Tammela, O. (2017). Intellectual disability in children aged less than seven years born moderately and late preterm compared with very preterm and termborn children - a nationwide birth cohort study. *Journal of Intellectual Disability Research*, 61(11), 1034-1054.

Huhtala, M., Korja, R., Lehtonen, L., Haataja, L., Lapinleimu, H., Munck, P., Rautava, P. (2011). Parental psychological well-being and cognitive development of very low birth weight infants at 2 years. *Acta Paediatrica*, 100(12), 1555-1560.

Hutchinson, E. A., De Luca, C. R., Doyle, L. W., Roberts, G., Anderson, P. J. (2013). School-age outcomes of extremely preterm or extremely low birth weight children. *Pediatrics*, 131(4), e1061.

Isquith, P., Roth, R., Gioia, G. (2013). Contribution of rating scales to the assessment of executive functions. *Applied Neuropsychology: Child*, 2(2), 125-132.

Jaekel, J., Strauss, V., Johnson, S., Gilmore, C., Wolke, D. (2015). Delayed school entry and academic performance: A natural experiment. *Developmental Medicine and Child Neurology*, 57(7), 652-659.

Jaekel, J., Wolke, D., Bartmann, P. (2013). Poor attention rather than hyperactivity/impulsivity predicts academic achievement in very preterm and full-term adolescents. *Psychological Medicine*, 43(1), 183-196.

Jaekel, J., Wolke, D., Chernova, J. (2012). Mother and child behaviour in very preterm and term dyads at 6 and 8 years. *Developmental Medicine and Child Neurology*, 54(8), 716-723.

Johnson, S., Fawke, J., Hennessy, E., Rowell, V., Thomas, S., Wolke, D., Marlow, N. (2009). Neurodevelopmental disability through 11 years of age in children born before 26 weeks of gestation. *Pediatrics*, 124(2), e257.

Johnson, S., Gilmore, C., Gallimore, I., Jaekel, J., Wolke, D. (2015). The long-term consequences of preterm birth: What do teachers know? *Developmental Medicine and Child Neurology*, 57(6), 571-577.

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*, 94(4), F283-F289.

Johnson, S., Kochhar, P., Hennessy, E., Marlow, N., Wolke, D., Hollis, C. (2016). Antecedents of attention-deficit/hyperactivity disorder symptoms in children born extremely preterm. *Journal of Developmental and Behavioral Pediatrics*, 37(4), 285-297.

Johnson, S., Marlow, N. (2011). Preterm birth and childhood psychiatric disorders. *Pediatric Research*, 69(5), 11R-18R.

Johnson, S., Strauss, V., Gilmore, C., Jaekel, J., Marlow, N., Wolke, D. (2016). Learning disabilities among extremely preterm children without neurosensory impairment: Comorbidity, neuropsychological profiles and scolastic outcomes. *Early Human Development*, 103, 69-75.

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.

Kallankari, H., Kaukola, T., Olsén, P., Ojaniemi, M., Hallman, M. (2015). Very preterm birth and foetal growth restriction are associated with specific cognitive deficits in children attending mainstream school. *Acta Paediatrica*, 104(1), 84-90.

Kallioinen, M., Eadon, H., Murphy, M.S., Baird, G. (2017). Developmental follow-up of children and young people born preterm: summary of NICE guidance. *BMJ*, 358.

Kinney, H., Haynes, R., Xu, G., Andiman, S., Folkerth, R., Sleeper, L., Volpe, J. (2012). Neuron deficit in the white matter and subplate in periventricular leukomalacia. *Annals of Neurology*, 71(3), 397-406.

Ko, G., Shah, P., Lee, S., Asztalos, E. (2013). Impact of maternal education on cognitive and language scores at 18 to 24 months among extremely preterm neonates. *American Journal of Perinatology*, 30(9), 723-729.

Korkman, M., Kirk, U., Kemp, S. (2008). NEPSY-II Lasten neuropsykologinen tutkimus. Käsikirja I. Esitys- ja pisteytysohjeet (Handbook I. Administration and scoring). Psykologien Kustannus Oy, Vaajakoski.

Korpela, S., Nyman, A., Munck, P., Ahtola, A., Matomäki, J., Korhonen, T., Lehtonen, L., Haataja, L. (2016). Working memory in very-low-birthweight children at the age of 11 years. *Child Neuropsychology*, 24(3), 338-353.

Krivitzky, L., Walsh, K., Fisher, E., Berl, M. (2015). Executive functioning profiles from the BRIEF across pediatric medical disorders: Age and diagnosis factors. *Child Neuropsychology*, 22(7), 870-888.

Larroque, B., Ancel, P. Y., Marret, S., Marchand, L., Andre, M., Arnaud, C., Pierrat, V., Rozé, J., Messer, J., Thiriez, G., Burguet, A., Picaud, J., Bréart, G., Kaminski, M. (2008). Neurodevelopmental disabilities and special care of 5-year-old children born before 33 weeks of gestation (the EPIPAGE study): A longitudinal cohort study. *Lancet*, 371(9615), 813-820.

Larroque, B., Ancel, P., Marchand Martin, L., Cambonie, G., Fres-son, J., Pierrat, V., Rozé, J., Marpeau, L., Thiriez, G., Alberge, C., Bréart, G., Kaminski, M., Marret, S. (2011). Special care and school difficulties in 8-year-old very preterm children: The Epipage cohort study. *PLoS ONE*, 6(7), e21361.

Lawn, J., Davidge, R., Paul, V., von Xylander, S., de Graft Johnson, J., Costello, A., Kinney, M., Segre, J., Molyneux, L. (2013). Born too soon: Care for the preterm baby. *Reproductive Health*, 10(Suppl 1), S5.

Leech, K., Salo, V., Rowe, M., Cabrera, N. (2013). Father input and child vocabulary development: The importance of Wh questions and clarification requests. *Seminars in Speech and Language*, 34(4), 249-259.

Lemola, S., Oser, N., Urfer Maurer, N., Brand, S., Holsboer Trachsler, E., Bechtel, N., Datta, A. (2017). Effects of gestational age on brain volume and cognitive functions in generally healthy very preterm born children during school-age: A voxel-based morphometry study. *PLoS ONE*, 12(8), e0183519.

Lepomäki, V., Leppänen, M., Matomäki, J., Lapinleimu, H., Lehtonen, L., Haataja, L., Komu, M., Rautava, P., Parkkola, R. (2013). Preterm infants' early growth and brain white matter maturation at term age. *Pediatric Radiology*, 43(10), 1357-1364.

Lind, A., Korkman, M., Lehtonen, L., Lapinleimu, H., Parkkola, R., Matomäki, J., Haataja, L. (2011). Cognitive and neuropsychological outcomes at 5 years of age in preterm children born in the 2000s. *Developmental Medicine and Child Neurology*, 53(3), 256-262.

Lind, A., Nyman, A., Lehtonen, L., Haataja, L. Predictive Value of Psychological Assessment at Five Years of Age in the Long-Term Follow-Up of Very Preterm Children. *Child Neuropsychology*, in press.

Linsell, L., Malouf, R., Morris, J., Kurinczuk, J. J., Marlow, N. (2015). Prognostic factors for poor cognitive development in children born very preterm or with very low birth weight: A systematic review. *JAMA Pediatrics*, 169(12), 1162-1172.

Linsell, L., Malouf, R., Morris, J., Kurinczuk, J., Marlow, N. (2016). Prognostic factors for cerebral palsy and motor impairment in children born very preterm or very low birthweight: A systematic review. *Developmental Medicine and Child Neurology*, 58(6), 554-569.

Loe, I., Chatav, M., Alduncin, N. (2015). Complementary assessments of executive function in preterm and full-term preschoolers. *Child Neuropsychology*, 21(3), 331-353.

Lundequist, A., Böhm, B., Smedler, A. (2013). Individual neuropsychological profiles at age 5½ years in children born preterm in relation to medical risk factors. *Child Neuropsychology*, 19(3), 313-331.

Luu, T., Ment, L., Allan, W., Schneider, K., Vohr, B. (2011). Executive and memory function in adolescents born very preterm. *Pediatrics*, 127(3), e646.

Maalouf, E. F., Duggan, P. J., Counsell, S. J., Rutherford, M. A., Cowan, F., Azzopardi, D., Edwards, A. D. (2001). Comparison of findings on cranial ultrasound and magnetic resonance imaging in preterm infants. *Pediatrics*, 107(4), 719-727.

Mares, D., McLuckie, A., Schwartz, M., Saini, M. (2007). Executive function impairments in children with attention-deficit hyperactivity disorder: Do they differ between school and home environments? *Canadian Journal of Psychiatry*, 52(8), 527-534.

McCandless, S., O' Laughlin, L. (2007). The clinical utility of the behavior rating inventory of executive function (BRIEF) in the diagnosis of ADHD. *Journal of Attention Disorders*, 10(4), 381-389.

McNicholas, F., Healy, E., White, M., Sherdian Pereira, M., O'Connor, N., Coakley, S., Dooley, B. (2014). Medical, cognitive and academic outcomes of very low birth weight infants at age 10-14 years in Ireland. *Irish Journal of Medical Science*, 183(4), 525-532.

Mikkola, K., Ritari, N., Tommiska, V., Salokorpi, T., Lehtonen, L., Tammela, O., Pääkkönen, L., Olsen, P., Korkman, M., Fellman, V. (2005). Neurodevelopmental outcome at 5 years of age of a national cohort of extremely low birth weight infants who were born in 1996-1997. *Pediatrics*, 116(6), 1391-1400.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A., Wagner, T. (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.

Moore, T., Hennessy, E. M., Myles, J., Johnson, S., 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, e7961.

Mulder, H., Pitchford, N., Hagger, M., Marlow, N. (2009). Development of executive function and attention in preterm children: A systematic review. *Developmental Neuropsychology*, 34(4), 393-421.

Munck, P., Haataja, L., Maunu, J., Parkkola, R., Rikalainen, H., Lapinleimu, H., Lehtonen, L. (2010). Cognitive outcome at 2 years of age in Finnish infants with very low birth weight born between 2001 and 2006. *Acta Paediatrica*, 99(3), 359-366.

Munck, P., Niemi, P., Lapinleimu, H., Lehtonen, L., Haataja, L. (2012). Stability of cognitive outcome from 2 to 5 years of age in very low birth weight children. *Pediatrics*, 129(3), 503-508.

National Institute for Health and Welfare. (2018). Perinatal statistics: parturients, deliveries and newborns 2017 [e-publication]. Retrieved from http://urn.fi/URN:NBN:fi-fe2018103146930.

Nijmeijer, J., Minderaa, R., Buitelaar, J., Mulligan, A., Hartman, C., Hoekstra, P. (2008). Attention-deficit/hyperactivity dis-order and social dysfunctioning. *Clinical Psychology Review*, 28(4), 692-708.

Official Statistics of Finland. (2018). Special education [e-publication]. Retrieved from http://www.stat.fi/til/erop/index_en.html.

Papile, L. A., Burstein, J., Burstein, R., Koffler, H. (1978). Incidence and evolution of subependymal and intraventricular hemorrhage: A study of infants with birth weights less than 1,500 gm. *The Journal of Pediatrics*, 92(4), 529-534.

Peacock, J., Marston, L., Marlow, N., Calvert, S., Greenough, A. (2012). Neonatal and infant outcome in boys and girls born very prematurely. *Pediatric Research*, 71(3), 305-310.

Pesonen, A., Räikkönen, K., Heinonen, K., Andersson, S., Hovi, P., Järvenpää, A., Eriksson, J., Kajantie, E. (2008). Personality of young adults born prematurely: The Helsinki study of very low birth weight adults. *The Journal of Child Psychology and Psychiatry*, 49(6), 609-617.

Petrou, S., Abangma, G., Johnson, S., Wolke, D., Marlow, N. (2009). Costs and health utilities associated with extremely preterm birth: Evidence from the EPI-Cure study. *Value in Health*, 12(8), 1124-1134.

Pritchard, V. E., Clark, C. A. C., Liberty, K., Champion, P. R., Wilson, K., Woodward, L. (2009). Early school-based learning difficulties in children born very preterm. *Early Human Development*, 85, 215-224.

Pyhälä, R., Lahti, J., Heinonen, K., Pesonen, A., Strang-Karlsson, S., Hovi, P., Järvenpää, A., Eriksson, J., Andersson, S., Kajantie, E., Räikkönen, K. (2011). Neurocognitive abilities in young adults with very low birth weight. *Neurology*, 77, 2052-2060.

Rademaker, K. J., Uiterwaal, C S P M, Beek, F. J. A., van Haastert, I. C., Lieftink, A. F., Groenendaal, F., Grobbee, D., de Vries, L. S. (2005). Neonatal cranial ultrasound versus MRI and neurodevelopmental outcome at school age in children born preterm. *Archives of Disease in Childhood*, 90(6), F489-F493.

Ritchie, K., Bora, S., Woodward, L. (2015). Social development of children born very preterm: A systematic review. *Developmental Medicine and Child Neurology*, 57(10), 899-918.

Ritter, B., Perring, W., Steinlin, M., Everts, R. (2014). Cognitive and behavioral aspects of executive functions in children born very preterm. *Child Neuropsychology*, 20(2), 129-144.

Roberts, G., Anderson, P., Doyle, L. (2009). Neurosensory disabilities at school age in geographic cohorts of extremely low birth weight children born between the 1970s and the 1990s. *The Journal of Pediatrics*, 154(6), 829-834.

Robertson, C. M. T., Ricci, M. F., O'Grady, K., Oskoui, M., Goez, H., Yager, J., Andersen, J. (2017). Prevalence estimate of cerebral palsy in Northern Alberta: Births, 2008-2010. *Canadian Journal of Neurological Sciences*, 44(4), 366-374.

Rowe, M. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, 83(5), 1762-1774.

Roze, E., Van Braeckel, Koenraad N J A, van der Veere, Christa N, Maathuis, C. G. B., Martijn, A., Bos, A. (2009). Functional outcome at school age of preterm infants with periventricular hemorrhagic infarction. *Pediatrics*, 123(6), 1493-1500.

Schneider, W. (2014). Intellectual development from early childhood to early adulthood: The impact of early IQ differences on stability and change over time. *Learning and Individual Differences*, 32, 156-162.

Sellier, E., Platt, M., Andersen, G., Krägeloh Mann, I., De La Cruz, J., Cans, C. (2016). Decreasing prevalence in cerebral palsy: A multisite European population based study, 1980 to 2003. *Developmental Medicine and Child Neurology*, 58(1), 85-92.

Serenius, F., Ewald, U., Farooqi, A., Fellman, V., Hafström, M., Hellgren, K., Marsál, K., Ohlin, A., Olhager, E., Stjernqvist, k., Strömberg, B., Ådén, U., Källén, K. (2016). Neurodevelopmental outcomes among extremely preterm infants 6.5 years after active perinatal care in Sweden. *JAMA Pediatrics*, 170(10), 954-963.

Setänen, S., Haataja, L., Parkkola, R., Lind, A., Lehtonen, L. (2013). Predictive value of neonatal brain MRI on the neurodevelopmental outcome of preterm infants by 5 years of age. *Acta Paediatrica*, 102(5), 492-497.

Simms, V., Cragg, L., Gilmore, C., Marlow, N., Johnson, S. (2013). Mathematics difficulties in children born very preterm: Current research and future directions. *Archives of Disease in Childhood*, 98(5), F457-F463.

Stadskleiv, K., Jahnsen, R., Andersen, G., von Tetzchner, S. (2018). Neuropsychological profiles of children with cerebral palsy. *Developmental Neurorehabilitation*, 21(2), 108-120.

Stålnacke, J., Lundequist, A., Böhm, B., Forssberg, H., Smedler, A. (2018). A longitudinal model of executive function development from birth through adolescence in children born very or extremely preterm. *Child Neuropsychology*, 25(3), 318-335.

Stoll, B., Hansen, N., Bell, E., Walsh, M., Carlo, W., Shankaran, S., Laptook, A., Sánchez, P., Van Meurs, K., Wyckoff, M., Das, A., Hale, E., Ball, M.B., Newman, N., Schibler, K., Poindexter, B., Kennedy, K., Cotton, C.M., Watterberg, K., D'Angio, C., DeMauro, S., Truog, W., Devaskar, U., Higgins, R. (2015). Trends in care practices, morbidity, and mortality of extremely preterm neonates, 1993-2012. *JAMA*, 314(10), 1039-1051.

Taylor, H. G., Clark, C. A. C. (2016). Executive function in children born preterm: Risk factors and implications for outcome. *Seminars in Perinatology*, 40(8), 520-529.

Taylor, H. G., Espy, K., Anderson, P. (2009). Mathematics deficiencies in children with very low birth weight or very preterm birth. *Developmental Disabilities Research Reviews*, 15(1), 52-59.

Twilhaar, E. S., de Kieviet, J., Aarnoudse Moens, C., van Elburg, R., Oosterlaan, J. (2018). Academic performance of children born preterm: A meta-analysis and meta-regression. *Archives of Disease in Childhood*, 103(4), F322-F330.

Twilhaar, E. S., de Kieviet, J., van Elburg, R., Oosterlaan, J. (2018). Academic trajectories of very preterm born children at school age. Archives of Disease in Childhood. *Fetal and Neonatal Edition,* Sep 27, [Epub ahead of print].

Twilhaar, E. S., Wade, R., de Kieviet, J., van Goudoever, J., van Elburg, R., Oosterlaan, J. (2018). Cognitive outcomes of children born extremely or very preterm since the 1990s and associated risk factors: A meta-analysis and meta-regression. *JAMA Pediatrics*, 172(4), 361-367.

van Veen, S., Aarnoudse-Moens, C. S. H., Oosterlaan, J., van Sonderen, L., de Haan, T. R., van Kaam, A. H., van Wassenaer-Leemhuis, A. G. (2018). Very preterm born children at early school age: Healthcare therapies and educational provisions. *Early Human Development*, 117, 39-43.

Vohr, B., Wright, L., Dusick, A., Perritt, R., Poole, W. K., Tyson, J., Steicen, J., Bauer, C., Wilson-Costello, D., Mayes, L. (2004). Center differences and outcomes of extremely low birth weight infants. *Pediatrics*, 113(4), 781-789.

Volpe, J. (2009). Brain injury in premature infants: A complex amalgam of destructive and developmental disturbances. *The Lancet Neurology*, 8(1), 110-124.

Wechsler, D. (Ed.). (1995). Wechsler preschool and primary scale of intelligence-reviced. Käsikirja (Handbook). Psykologien Kustannus, Helsinki.

Wechsler, D. (2011a). Wechsler intelligence scale for children -IV. Käsikirja I. Esitys- ja pisteytysohjeet (Handbook I. Administration and scoring). Psykologien Kustannus, Jyväskylä.

Wechsler, D. (2011b). Wechsler intelligence scale for children -IV. Käsikirja II. Teoriatausta, standardointi ja tulkinta (Handbook II. Theoretical background, standardization and interpretation). Psykologien Kustannus, Jyväskylä.

Willcutt, E. G. (2012). The prevalence of DSM-IV attention-deficit/hyperactivity disorder: A meta-analytic review. *Neurotherapeutics*, 9(3), 490-499.
Wocadlo, C., Rieger, I. (2006). Educational and therapeutic resource dependency at early school-age in children who were born very preterm. *Early Human Development*, 82(1), 29-37.
Wolke, D., Baumann, N., Strauss, V., Johnson, S., Marlow, N. (2015). Bullying of preterm children and emotional problems at school age: Cross culturally invariant effects. *The Journal of Pediatrics*, 166(6), 1417-1422.
Wolke, D., Jaekel, J., Hall, J., Baumann, N. (2013). Effects of sensitive parenting on the academic resilience of very preterm and very low birth weight adolescents. *Journal of Adolescent Health*, 53(5), 642-647.
Wong, H., Edwards, P. (2013). Nature or nurture: A systematic review of the effect of socio-economic status on the developmental and cognitive outcomes of children born preterm. *Maternal and Child Health Journal*, 17(9), 1689-1700.

Appendix 1.

1.5.2012/AN

KYSELYLOMAKE OPETTAJALLE OPPILAAN OPETUSJÄRJESTELYISTÄ JA KOULUSUORIUTUMISESTA

Oppilaan nimi: ____ Syntymäaika: _____ / _____ / 200___

Koulu: ____

Päivämäärä: _____ /_____ / 20_______

Opettajan nimi: ____ Puh: ___________________________

1. Luokka: ___________

2. Onko oppilas kerrannut jonkin luokan (ympyröi sopiva numero)?

    1. Ei

    2. Kyllä, Minkä luokan? ____________________

3. Minkälainen rooli kyselyn täyttävällä opettajalla on oppilaan opetuksessa (ympyröi sopiva numero)?

    1. Luokanopettaja

    2. Erityisluokanopettaja

    3. Laaja-alainen erityisopettaja (luokaton)

    4. Kiertävä erityisopettaja

    5. Muu ______________________________

PIPARI -jatkotutkimushanke

OPPILAAN OPPIMISYMPÄRISTÖ

4. Kuinka monta oppilasta luokalla on? _______________

5. Minkälainen luokkaympäristö oppilaalla on (ympyröi sopiva numero)?

1. Yleisopetuksen tavallinen luokka
2. Yleisopetuksen tavallinen luokka, jossa oppilas opiskelee integroituna erityisoppilaana
3. Jotakin oppisisältöä painottava yleisopetuksen luokka (esim. musiikki), Mitä? _______________
4. Erityisluokka erityiskoulussa
5. Pienluokka tavallisessa koulussa

6. Minkälaiseksi oppilaan tuen tarve on määritelty (ympyröi sopiva numero)?

1. Yleinen tuen tarve
2. Tehostettu tuen tarve ja laadittu OPS
3. Erityinen tuen tarve ja laadittu HOJKS

7. Onko lapsella henkilökohtainen avustaja (ympyröi sopiva numero)?

1. Ei
2. Kyllä, Miksi? ____

8. Mikäli lapsella ei ole henkilökohtaista avustajaa, niin tarvitseeko hän kuitenkin avustajan tukea oppitunneilla (ympyröi sopiva numero)?

1. Ei lainkaan
2. Vain tietyssä/tietyissä oppiaineessa, Missä? ____
3. Useimmilla oppitunneilla

9. Saako oppilas avustamista riittävästi (ympyröi sopiva numero)?

1. Ei tarvitse avustamista
2. Saa tarvitessaan riittävästi
3. Ei saa riittävästi avustamista

10. Minkälaiset ovat oppilaan koulupäivät (ympyröi sopiva numero)?

1. Samanpituiset kuin muulla luokalla
2. Lyhennetty, Miten? ____

11. Onko oppilaan oppimisympäristössä jotain muita erityisjärjestelyitä ja/tai käyttääkö hän oppimiseen apuvälineitä (ympyröi sopiva numero)?

1. Ei
2. Kyllä, Mitä (Esim. kuvien käyttö, paikka luokan edessä, tietokone jne.)?

____

____

____

12. Minkälainen oppilaan oppivelvollisuuden pituus on (ympyröi sopiva numero)?

1. Tavallinen yhdeksänvuotinen
2. Pidennetty 11- vuotinen

13. Saako oppilas osa-aikaista erityisopetusta (ympyröi sopiva numero)?

1. Ei
2. Kyllä, Miksi? ____

OPPILAAN OPPIMISTAVOITTEET

14. Minkälaiset oppimistavoitteet oppilaalla on (ympyröi sopiva numero)?

1. Yleisopetuksen tavoitteet
2. Yksilölliset tavoitteet yhdessä tai useammassa aineessa, Missä?___________________________
3. Yksilölliset tavoitteet kaikissa oppiaineissa
4. Oppilaan opetus on järjestetty toiminta-alueittain (ent. EHA)

OPPILAAN OPPIMISVAIKEUDET

Onko oppilaalla oppimis- tai koulunkäyntivaikeuksia ikätovereihin verrattuna (ympyröi sopiva numero)?

	Ei lainkaan	Lieviä vaikeuksia	Huomattavia vaikeuksia
15. Tekninen lukutaito	1	2	3
16. Oikeinkirjoitus	1	2	3
17. Vapaan tekstin tuottaminen	1	2	3
18. Luetun ymmärtäminen	1	2	3
19. Kuullun ymmärtäminen	1	2	3
20. Matematiikka	1	2	3
21. Ensimmäinen vieras kieli, Mikä?_______	1	2	3
22. Puheilmaisu	1	2	3
23. Itsenäinen työskentely	1	2	3
24. Ryhmässä toimiminen	1	2	3
25. Pitkäjännitteinen työskentely	1	2	3
26. Keskittyminen	1	2	3
27. Sosiaaliset taidot	1	2	3

OPPILAAN ARVOSANAT KEVÄÄLLÄ 2012 (sanallinen tai numeroarvostelu)

28. Matematiikka: __________________________________

29. Äidinkieli: ______________________________

30. Ensimmäinen vieras kieli : ______________________________

34. Liikunta: ___________________________

35. Käsityö/ tekninen työ: _________________________________

PIPARI -jatkotutkimushanke

36. Onko oppilaan opetusjärjestelyihin tai kouluoppimiseen liittyen vielä jotain, mitä haluaisit tuoda esille?

____
____
____
____

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