REGULAR ARTICLE

Eight-year-old very and extremely preterm children showed more difficulties in performance intelligence than verbal intelligence

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Abstract

Aim: This study determined possible discrepancies between verbal IQ and performance IQ in 8-year-old very preterm (VPT) and extremely preterm (EPT) children, and examined associations between verbal IQ and performance IQ, and sociodemographic factors, perinatal factors, early cognitive outcomes and also with school achievement scores.

Methods: This prospective cohort study included 120 eight-year-old VPT/EPT children. Cognitive development was assessed at the ages of 2, 5 and 8 years. Eight years' school achievement results in arithmetic, reading and spelling were collected. Multiple regression analyses were performed to determine predictors of verbal IQ and performance IQ at the age of 8 years and to determine associations with school achievement scores.

Results: Mean performance IQ (89.8) was significantly lower than mean verbal IQ (99.4; Cohen's d = 0.59) at the age of 8 years. Gestational age (GA), small for GA status, and cognitive scores at the ages of 2 and 5 years significantly predicted verbal IQ and performance IQ at the age of 8 years. Performance IQ at age 8 years was an important predictor for arithmetic scores (β = 0.42).

Conclusion: Performance IQ was more strongly affected than verbal IQ in 8-year-old VPT/EPT children and was strongly related to mathematical difficulties.

KEYWORDS
child development, IQ profiles, prematurity, school achievement, school age

1 | INTRODUCTION

In the Netherlands, approximately 1.1% of the children are born with a gestational age (GA) below 30 weeks. In high-income countries, chances of survival are more than 90% for babies born under 28 weeks of gestation.[1] However, mild-to-severe cognitive deficits of at least one standard deviation (SD) below the mean that persist over time are frequently observed after very preterm (VPT) and

extremely preterm (EPT) birth.[2-7] A meta-analysis reported a mean full scale intelligence quotient (IQ) in VPT/EPT children of approximately 13 IQ points lower than that of term-born peers across an age span of 5-20 years.[3] The full scale IQ score reflects the dynamics within a child between multiple components of intelligence including learning from experiences, reasoning, problem solving, verbal and mathematical knowledge, memory span, visual perceptive functions and speed.[8] In the majority of intelligence tests, these components are divided into verbal and non-verbal subscales.[9-11] Verbal subscales measure a child's ability to reason using words, which is commonly measured using verbally delivered items requiring a verbal response, such as defining, or finding similarities between, words, while the more non-verbal, also called performance subscales measure a child's ability to reason without using words, which is generally measured using visual items, such as symbols and pictures.[9,10] In VPT/EPT children, verbal and performance components may be differentially affected.[5,12-14] Hence, interpreting verbal IQ and performance IQ separately may provide more insight into specific strengths and weaknesses of VPT/EPT children's cognitive functioning.

Indeed, a systematic review and meta-analysis in preterm (GA < 37 weeks) children and young adults found a large deficit in performance IQ, opposed to a moderate deficit in full scale IQ and verbal IQ.[5] With respect to the performance IQ, Gabrielson et al[12] found that more postnatal morbidity was associated with poor performance IQ in VPT/EPT children. Because verbal IQ and performance IQ in VPT/EPT children may be differentially affected, it is interesting to study how previous cognitive outcomes are associated with these separate IQ measures, in addition to sociodemographic and neonatal risk factors. In addition, earlier studies associated full scale IQ to academic achievement in VPT/EPT children.[15] Considering the possible differences in the verbal and performance IQ components, it is important to determine how these components relate to academic achievement separately.

The main aim of our study was to chart cognitive function and possible discrepancies between verbal IQ and performance IQ in a cohort of VPT/EPT children at the age of 8 years and examines whether sociodemographic factors, neonatal factors and early cognitive outcomes were associated with verbal IQ and performance IQ at the age of 8 years. The second aim of our study was to examine the associations between verbal IQ and performance IQ, and achievement in arithmetic, reading and spelling.

2 | METHODS

2.1 | Study design and participants

This prospective cohort study was conducted at the Emma Children's Hospital of the Amsterdam University Medical Centres, The Netherlands. The study used data collected during regular patient care, as part of the Dutch neonatal follow-up programme. Inclusion criteria for the neonatal follow-up programme were being born with a gestational age of below 30 weeks or a birth weight below

Key notes

- It remains unclear how sociodemographic and neonatal risk factors combined with early cognitive outcomes are associated with later cognitive outcomes in very and extremely preterm (VPT/EPT) children.
- Difficulties in performance IQ occur significantly more often than in verbal IQ in 8-year-old VPT/EPT children and were strongly related to mathematical difficulties.
- Further findings or the implications for clinical practice or further research: performance IQ and verbal IQ should be reported when reporting VPT/EPT children's intelligence, for both clinical and research purposes.

1000 g, regardless of gestational age. Children were included if they were seen for follow-up at the age of 8 years between February 1, 2016 and May 1, 2018. Parents provided informed consent for the use of the follow-up data and to contact their child's school to collect academic achievement scores. The institutional review board of the Amsterdam University Medical Centres approved the study protocol.

During the study period, 129 eight-year-old VPT/EPT children visited our neonatal follow-up clinic. Parents of three children did not give consent for the use of their child's follow-up data, three children were unable to complete the cognitive assessment due to severe mental retardation and one child was unable to complete the cognitive assessment due to severe language impairment. Due to a lack of time, two children were not able to complete the cognitive assessment. The final sample comprised 120 VPT/EPT children.

2.2 | Outcome assessments

Cognitive development was assessed by trained child psychologists when the children were 2, 5 and 8 years of age. The assessors were not blinded to the degree of prematurity, neonatal history and previous testing. Sociodemographic data were assessed using parental reports.

2.3 | Measures

Cognitive development at the age of 8 years was assessed with the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) for The Netherlands, which yields a full scale IQ, verbal IQ, performance IQ and processing speed quotient.[9] All IQ scores were calculated according to standard procedures detailed in the manual (mean = 100, SD = 15).

Cognitive development at the age of 5 years was assessed with the Wechsler Preschool and Primary Scale of Intelligence, Third Edition (WPPSI-III) for The Netherlands, which yields a full scale IQ,

verbal IQ, performance IQ and processing speed quotient.[10] All IQ scores were calculated according to standard procedures detailed in the manual and have a mean of 100 (mean = 100, SD = 15).

Cognitive development at the age of 2 years was assessed with the cognitive scale of the Bayley-III.[11] The cognitive composite score was derived according to standardised procedures provided in the manual (mean = 100, SD = 15). American norms were used.

All cognitive test scores were corrected for prematurity.[16]

Academic performance was assessed with the Dutch national pupil monitoring system that is administered by teachers at a vast majority of the Dutch schools in the middle and at the end of each school year in preschool and primary school.[17] The system constitutes of standardised tests for arithmetic, reading and spelling skills that are based on item-response theory. Test performance is depicted in standardised scores on a unidimensional scale. To enable interpretation across the three domains, z-scores were calculated by subtracting the scores from the normative mean scores, divided by the normative SD.

The arithmetic test measures general knowledge of mathematics and arithmetic and comprises computational problems of addition, subtraction, multiplication, division, the notion of time and the use of money. The test can be completed with paper and pencil or on the computer.[18] The reading test measures the ability of fluency of word reading and comprises three different cards that increase in difficulty and complexity and which have to be read aloud by the child in one minute per card.[19] The spelling test measures the ability of children to correctly apply spelling strategies and rules and requires writing down verbally presented (non-verb) words that increase in difficulty level.[20]

Parental educational level was defined on a three-point scale, based on the number of years of post-elementary education, according to the Central Office of Statistics Netherlands, 2004. The cut-off scores were as follows: low in case of education <6 years, intermediate in case of education followed during 6-8 years and high in case of education followed for more than 8 years. Parental education was calculated by combining the maternal and paternal levels of education: low education was both low or one low and one intermediate; intermediate education was both intermediate or one low and one high; and high education was both high or one high and one intermediate.[21]

Multilingualism was defined as being exposed to the Dutch language, as well as being exposed to one or more foreign languages at home. Multilingualism was used as a dichotomous independent variable.

2.4 | Statistics

All analyses were performed using the Statistical Package for Social Science, version 24.0 (IBM Corp). All dependent variables were screened for extreme outliers, defined as ±3 SD from the mean. Two outliers were found for Bayley cognitive composite score (+3 SD), which were replaced by the value of one unit larger than the next most extreme score in the distribution.[22]

To analyse whether mean verbal IQ and performance IQ significantly differed from each other, a paired t test was performed. To analyse whether the number of children with a verbal IQ < 85 significantly differed from the number of children with a performance IQ < 85, McNemar's test was performed. Mean z-scores for arithmetic, reading and spelling were calculated and compared with the normative mean with one-sample t tests.

To determine which sociodemographic and perinatal risk factors and early cognitive outcomes predicted cognitive function at the age of 8 years, first, Pearson or Spearman correlations, or, when appropriate, chi-square tests between all independent and dependent variables were calculated. Next, multiple hierarchical (stepwise) regression analyses were performed. The regression analyses examined the impact of GA, being small for gestational age (SGA status), parental education, multilingualism, postnatal morbidities including bronchopulmonary dysplasia, necrotising enterocolitis, severe brain damage and sepsis, cognitive outcomes at the age of 2 years, and verbal IQ and performance IQ at the age of 5 years, on verbal IQ and performance IQ at the age of 8 years. If main effects were significant, interaction effects between these main factors were checked. To analyse whether verbal IQ and performance IQ at the age of 8 years were significantly related to arithmetic, reading and spelling, multiple regression analyses were performed. P values of <.05 (two-tailed) were considered statistically significant.

2.5 | Missing data

At the age of 5 years, missing data for the WPPSI-III-NL for four children were due to follow-up elsewhere and for one child due to staffing problems. Parents of four children could not be contacted. At the age of 2 years, missing data for the Bayley cognitive composite score of two children were due to child non-compliance. Parents of one child could not be contacted. Missing value analyses (Little's missing complete at random test) indicated that data were missing completely at random (P = .22). Missing data were replaced using the expectation maximisation technique.

Despite our efforts, arithmetic scores were available for 65% (n = 78) of the children, reading scores for 68% (n = 81) and spelling scores for 68% (n = 82). Missing data for academic achievement were not replaced. Children for whom we did not have school achievement results, did not differ from children for whom we did have school achievement results, in terms of parental education, multilingualism, GA, birth weight, SGA status, postnatal morbidities or cognitive outcomes at the ages of 2, 5 and 8 years (all P's > .05).

3 | RESULTS

Table 1 depicts the neonatal and sociodemographic background characteristics and early development. VPT/EPT children had a mean GA of 28.0 weeks (range 25.0-31.4) and a mean birth weight of 1031 grams (range 490-1590).

TABLE 1 Neonatal and sociodemographic background characteristics and early development (n = 120)

Neonatal outcomes			
Boys, n, %	66	55	
Gestational age (weeks), M, SD, range	28.0	1.6	25.0-31.4
<28 wk, n, %	49	41	
28-30 wk, n, %	67	56	
≥30 wk and birth weight <1000 g, n, %	4	3	
Birth weight (grams), M, SD, range	1031	252	490-1590
<1000g, n, %	60	50.0	
Small for gestational age, n, %	22	18	
Oxygen support at 36 wk PMA (BPD), n, %	23	19	
Sepsis, n, %	54	45	
Proven sepsis, n, %	40	33	
Suspected sepsis, n, %	14	12	
Open ductus Botalli, n, %	42	35	
Necrotising enterocolitis (grade II/ III), n, %	10	8.3	
Intraventricular haemorrhage (grade III or more), n, %	4	3.3	
Periventricular leukomalacia (grade II or more), n, %	0	0.0	
Sociodemographic outcomes			
Parental education[a]			
High, n, %	41	34	
Intermediate, n, %	34	28	
Low, n, %	45	38	
Multilingualism, n, %	22	18	
Developmental outcomes at age 2 y			
Bayley-III Cognitive composite score, M, SD, range	98.8	9.6	70-126
<1 SD, n, %	6	5.0	
Developmental outcomes at age 5 y			
WPPSI-III-NL full scale IQ, M, SD, range	95.3	14.4	55-133
<1.0 SD, n, %	28	23	
WPPSI-III-NL verbal IQ, M, SD, range	95.8	14.0	57-134
<1.0 SD, n, %	28	23	
WPPSI-III-NL performance IQ, M, SD, range	97.0	14.4	61-128
<1.0 SD, n, %	18	15	
WPPSI-III-NL PSQ, M, SD, range	95.5	15.6	56-137
<1.0 SD, n. %	29	24	
Sensory impairment at age 8 y			
Wearing glasses, n, %	24	20	
Hearing impairment corrected with aids, n, %	1	0.8	
Cerebral palsy (GMFCS level I), n, %	6	5.0	

Abbreviations: %, percentage; BPD, Bronchopulmonary dysplasia; GMFCS, Gross Motor Function Classification Scale; n, number; PMA, Postmenstrual age; PSQ, processing speed quotient; SD, standard deviation.

[a]Educational level was classified on a 3-point scale (low, intermediate and high) according to the Central Office of Statistics Netherlands (2004): Low indicates primary education or prevocational secondary education; intermediate indicates secondary education or middle vocational education; and high indicates higher professional and university.

Table 2 depicts IQ scores and academic achievement scores at the age of 8 years. Mean performance IQ was significantly lower than mean verbal IQ (P < .01, Cohen's d = 0.59). Eight-year-old VPT/EPT children on average scored 0.46 SD (95% CI: −0.89 to −0.02, P = .04) lower on arithmetic and comparable to the normative mean on reading and spelling.

Pearson and Spearman correlations of associations between all dependent variables are presented in Table S1. Table 3a displays the

TABLE 2 Cognitive function and academic achievement scores at the age of 8 y

Cognitive function (N = 120)	Full scale IQ	Verbal IQ	Performance IQ	PSQ
Mean (SD, range)	94.5 (16.9, 59-142)	99.4 (16.1, 62-139)	89.8 (16.7, 55-139)	99.1 (15.2, 65-140)
<85 (<−1.0 SD), n (%)	35 (29.2)	20 (16.7)	47 (39.2)	15 (12.5)
Academic achievement	**Arithmetic (n = 78)**	**Reading (n = 81)**	**Spelling (n = 82)**	
Mean z-score (SD)	−0.46 (1.93)	−0.15 (1.12)	−0.07 (0.98)	
<−1 z-score, n (%)	27 (34.6)	21 (25.9)	12 (13.4)	

Abbreviations: IQ, intelligence quotient; PSQ, processing speed quotient; SD, standard deviation

hierarchical regression analysis to predict verbal IQ at the age of 8 years. In step one, GA and SGA status explained 11% of the variance in verbal IQ scores. Adding the neonatal risk factors in step two did not significantly improve the model. In step three, Bayley cognitive composite score predicted an additional and significant 13% of the variance in verbal IQ scores, while SGA status lost significance. In step four, the model predicted an additional 31% of the variance in verbal IQ and indicated that 5 years' WPPSI-III verbal IQ and performance IQ were significant predictors. GA and Bayley cognitive composite score then lost their significant association. The final model, with WPPSI-III verbal IQ and performance IQ as significant predictors (with a large and small effect size, respectively), explained 51% of the variance in verbal IQ at the age of 8 years.

Table 3b displays the hierarchical regression analysis to predict performance IQ at the age of 8 years. In step one, GA and SGA status explained 15% of the variance in performance IQ scores. Adding the neonatal risk factors in step two did not change the model. In step three, Bayley cognitive composite score predicted an additional and significant 18% of the variance in performance IQ scores. In step four, the model predicted an additional 21% of the variance in performance IQ scores and indicated that WPPSI-III performance IQ and processing speed quotient were additional significant predictors, and GA, but not SGA status, and Bayley cognitive composite score kept their significance. The final model, with GA, Bayley cognitive composite score, WPPSI-III performance IQ and processing speed quotient as significant predictors (small effect sizes), explained 50% of the variance in performance IQ at the age of 8 years.

Multiple hierarchical regression analyses were performed to calculate associations between verbal IQ and performance IQ and academic achievement at the age of 8 years. Verbal IQ and performance IQ were entered as one block. Arithmetic was better explained by the verbal IQ and performance IQ (36% explained variance) than reading and spelling (4% and 7% explained variance, respectively). For arithmetic, the model indicated that performance IQ was a significant predictor with a medium effect size (β = 0.42, P < .01). For reading, the model was not significant (P = .08), indicating that verbal IQ and performance IQ did not significantly predict reading scores. For spelling, the model was significant (P = .03), indicating that verbal IQ was a significant predictor with a medium effect size (β = 0.35, P = .03). Adding parental education and multilingualism did not significantly improve the predictive ability of the models.

4 | DISCUSSION

In this prospective cohort study, we examined verbal IQ and performance IQ scores in VPT/EPT children at the age of 8 years and associations thereof with sociodemographic factors, neonatal risk factors, early cognitive outcomes and academic achievement scores. Reporting verbal IQ and performance IQ separately for VPT/EPT children is standard procedure in clinical practice. For research purposes, the reporting of cognitive outcomes varies, although nowadays the verbal and performance components are more often reported separately instead of, or as an addition to the full scale IQ. Our results hereby underpin that also from a scientific perspective these separate reports are important, since we found a significant and substantial difference between both components with more than twice as many children with performance IQ score <−1 SD (39%) compared to verbal IQ < −1 SD (17%). GA, SGA status and cognitive outcomes at the ages of 2 and 5 years were important predictors for both verbal IQ and performance IQ at the age of 8 years. However, still 50% of the variance remained unexplained. Performance IQ at the age of 8 years strongly predicted arithmetic achievement.

Our results are in line with the study by Gabrielson et al and the meta-analysis by Allotey et al[5,12] Intelligence is a multifaceted trait that can be conceptualised in crystallised and more fluid components.[8] Subtests incorporated in verbal IQ mostly capture abilities that reflect the crystallised part of intelligence, measuring children's verbal knowledge.[8,9] Subtests incorporated in performance IQ mostly reflect fluid intelligence, defined as the ability to solve problems using reasoning.[8,9] Fluid intelligence has been strongly associated with executive functioning.[23] Problems in executive functioning have frequently been reported in VPT/EPT children.[12] These problems often become apparent at primary school age, when these higher order functions rapidly develop and become increasingly important.[24] The difficulties in performance IQ at the age of 8 years were not yet apparent at earlier ages and may reflect growing into deficit in part due to executive dysfunction.

Our prediction models showed that GA and SGA status were important predictors of cognitive functioning at the age of 8 years, together explaining 11% and 15% of the variance in verbal IQ and performance IQ, respectively. In our study, adding other neonatal factors did not significantly improve the model in explaining variance in verbal IQ and performance IQ. Other studies did find associations between neonatal morbidities, such as intraventricular haemorrhage, bronchopulmonary dysplasia or sepsis and cognitive

outcomes.[3] These differences may be due to differences in sample sizes and statistical methods used.

Parental education did not independently predict cognitive functioning. In literature, it is suggested that the independent effects of sociodemographic factors and biological factors on cognition differ with age.[25,26] At younger age, biological factors, such as GA or SGA status, are deemed more important in predicting cognitive functioning, but the effect of parental education becomes stronger at later ages.[25,26] Multilingualism did not affect cognitive outcomes at the age of 8 years. We previously showed

TABLE 3 (a) Hierarchical regression with verbal IQ at the age of 8 y as dependent variable. (b) Hierarchical regression with performance IQ at the age of 8 y as dependent variable

Independent variables	B	SE B	β	P	Adj. R^2	ΔR^2	P
(a)							
Step 1							
Constant	16.91	26.81			0.11		.00
GA	0.44	0.14	0.30	.00			
SGA status	−10.24	3.81	−0.25	.00			
Low parental education	−4.65	2.88	−0.14	.11			
Multilingualism	−2.67	3.61	−0.07	.46			
Step 2							
Constant	8.06	31.26			0.10	0.03	.44
GA	0.47	0.16	0.32	.00			
SGA status	−9.24	3.99	−0.22	.02			
BPD	−3.40	3.96	−0.08	.39			
NEC	6.39	5.15	0.11	.22			
Brain damage	−2.16	7.83	−0.02	.78			
Sepsis	2.72	3.02	−0.09	.37			
Step 3							
Constant	−33.62	26.20			0.22	0.13	.00
GA	0.37	0.13	0.26	.00			
SGA status	−6.45	3.68	−0.16	.08			
Bayley cognitive composite score	0.62	0.14	0.37	.00			
Step 4							
Constant	−20.48	20.79			0.51	0.31	.00
GA	0.15	0.10	0.11	.12			
Bayley CCS	0.04	0.13	0.03	.74			
WPPSI verbal IQ	0.53	0.10	0.47	.00			
WPPSI performance IQ	0.30	0.10	0.27	.00			
WPPSI processing speed quotient	0.06	0.08	0.06	.47			
Step 5							
Constant	11.96	7.98			0.51		.00
WPPSI verbal IQ	0.58	0.09	0.51	.00			
WPPSI performance IQ	0.33	0.09	0.29	.00			
(b)							
Step 1							
Constant	−6.67	27.36			0.15		.00
GA	0.51	0.14	0.34	.00			
SGA status	−12.88	3.89	−0.30	.00			
Low parental education	−5.67	2.94	−0.17	.06			
Multilingualism	0.12	3.69	0.00	.97			
Step 2							

TABLE 3 (Continued)

Independent variables	B	SE B	β	P	Adj. R²	ΔR²	P
Constant	1.20	31.96			0.13	0.03	.44
GA	0.47	0.16	0.31	.00			
SGA status	−11.90	4.08	−0.28	.00			
BPD	−5.98	4.05	−0.14	.14			
NEC	−0.52	5.27	−0.01	.92			
Brain damage	−8.63	8.00	−0.09	.28			
Sepsis	1.59	3.08	0.05	.61			
Step 3							
Constant	−65.82	25.64			0.31	0.18	.00
GA	0.41	0.13	0.27	.00			
SGA status	−7.78	3.60	−0.18	.03			
Bayley cognitive composite score	0.77	0.14	0.44	.00			
Step 4							
Constant	−62.53	22.10			0.51	0.21	.00
GA	0.28	0.11	0.18	.02			
SGA status	−5.65	3.08	−0.13	.07			
Bayley cognitive composite score	0.29	0.14	0.17	.04			
WPPSI verbal IQ	0.11	0.10	0.09	.28			
WPPSI performance IQ	0.34	0.10	0.29	.00			
WPPSI processing speed quotient	0.29	0.09	0.26	.00			
Step 5							
Constant	−57.63	21.75			0.50		.00
GA	0.22	0.10	0.15	.03			
Bayley Cognitive composite score	0.39	0.13	0.22	.00			
WPPSI performance IQ	0.39	0.10	0.33	.00			
WPPSI processing speed quotient	0.30	0.09	0.28	.00			

Abbreviations: BPD, bronchopulmonary dysplasia; GA, gestational age; IQ, intelligence quotient; NEC, necrotising enterocolitis; SE, standard error; SGA, small for gestational age.

that multilingualism negatively affected VPT/EPT children's cognitive outcomes at the ages of 2 and 5 years.[27] The results of the current study may indicate that the effect of multilingualism on cognitive outcomes diminishes over time which is in line with the study by Doyle et al[25]

Gestational age, SGA and the Bayley cognitive composite score at the age of 2 years together predicted 22% and 31% of the 8 years' verbal IQ and performance IQ, respectively. At the next follow-up moment at the age of 5 years, 51% and 50% of the verbal IQ and performance IQ could be predicted, respectively. Although at each follow-up moment we were able to make a better prediction of later outcomes, half of the variance in verbal IQ and performance IQ remained unexplained. This underpins the importance of multiple longitudinal assessments in neonatal follow-up and pleads for prudence in making predictions for future outcomes.[28]

VPT/EPT children showed borderline arithmetic scores at the age of 8 years, but no difficulties in reading or spelling as compared to normative means. Performance IQ was an important predictor for these arithmetic scores, explaining a considerable amount of the variance.

In literature, visual motor skills, visual perceptive skills and executive functions have been associated with arithmetic in VPT/EPT children.[29] Many of these neurocognitive functions are to some extent represented in the performance IQ. Reading and spelling were, in our study, much less than arithmetic related to cognitive capacities. For reading, we did not find any association with IQ scores. For spelling, only a small amount of the variance was explained by verbal IQ. Previous research in extremely low birth weight children showed that working memory and phonological processing were important predictors for reading and spelling, independent of intelligence.[30]

The strengths of our study include the large complete follow-up cohort up to the age of 8 years, with scores corrected for prematurity at all ages, and the use of well-standardised measures and different informants.[15] A limitation of the current study was that school achievement scores were only available for approximately two-third of the study group, despite our efforts to obtain these results from the children's teachers. Our study cohort was not compared with a control cohort, which may limit interpretation of our data. However, we used Dutch-normed versions of intelligence tests at the ages of 5 and 8 years. In

addition, the academic tests used in our study are administered regularly at most Dutch elementary schools, for which extensive normative data are available. Lastly, our assessors were not blinded to the degree of prematurity. Although the experienced assessors had not been involved in the neonatal care of the infant and closely followed the instructions of the test manual during assessments, they are aware of developmental outcome in relation to gestational age, which may have caused some bias in collecting data and consequently in our results.

5 | CONCLUSION

In conclusion, our study showed that VPT/EPT birth differentially affects verbal IQ and performance IQ. VPT/EPT children at the age of 8 year showed difficulties in performance IQ, but not in verbal IQ. This finding may reflect growing into deficit for the more fluid or executive parts of their intelligence. GA and SGA status were important predictors of cognitive functioning at the age of 8 years. A large proportion of verbal IQ and performance IQ scores remained unexplained, which pleads for prudence in making predictions for future outcomes. Performance IQ was strongly related to mathematical difficulties at the age of 8 years. Given the substantial differences between verbal IQ and performance IQ, we suggest to always report on the cognitive components assessed when reporting VPT/EPT children's cognitive skills.

CONFLICT OF INTEREST
None.

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REFERENCES
1. Blencowe H, Cousens S, Oestergaard MZ, et al. 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*. 2012;379(9832):2162-2172.
2. Anderson PJ. Cognitive outcomes in children born very preterm are not improving. *Acta Paediatr*. 2018;107(11):1846-1847.
3. Twilhaar ES, Wade RM, de Kieviet JF, van Goudoever JB, van Elburg RM, Oosterlaan J. Cognitive outcomes of children born extremely or very preterm since the 1990s and associated risk factors: a meta-analysis and meta-regression. *JAMA Pediatr*. 1990s;172(4):361-367.
4. Brydges CR, Landes JK, Reid CL, Campbell C, French N, Anderson M. Cognitive outcomes in children and adolescents born very preterm: a meta-analysis. *Dev Med Child Neurol*. 2018;60(5):452-468.
5. Allotey J, Zamora J, Cheong-See F, et al. Cognitive, motor, behavioural and academic performances of children born preterm: a meta-analysis and systematic review involving 64 061 children. *BJOG*. 2018;125(1):16-25.
6. Cheong JLY, Anderson PJ, Burnett AC, et al. Changing neurodevelopment at 8 years in children born extremely preterm since the 1990s. *Pediatrics*. 1990s;139(6):e20164086.
7. Hutchinson EA, De Luca CR, Doyle LW, Roberts G, Anderson PJ; Victorian Infant Collaborative Study Group. School-age outcomes of extremely preterm or extremely low birth weight children. *Pediatrics*. 2013;131(4):e1053-e1061.
8. Ackerman PL, Heggestad ED. Intelligence, personality, and interests: evidence for overlapping traits. *Psychol Bull*. 1997;121(2):219-245.
9. Wechsler D. *Wechsler Intelligence Scale for Children-III-NL*, 3rd edn. Amsterdam: Harcourt Test Publishers; 2005.
10. Wechsler D. *WPPSI-III-NL Nederlandstalige Bewerking: Technische Handleiding* [Dutch version of the WPPSI-III-NL: Technical and interpretive manual], 2nd edn. Amsterdam: Pearson Assessment and Information BV; 2010. (Dutch adaptation by: Hendriksen, J., & Hurks, P).
11. Bayley N. *Bayley Scales of Infant and Toddler Development*, 3rd edn. San Antonio, TX: Pearson Assessment and Information; 2005.
12. Gabrielson J, Hard AL, Ek U, Svensson E, Carlsson G, Hellstrom A. Large variability in performance IQ associated with postnatal morbidity, and reduced verbal IQ among school-aged children born preterm. *Acta Paediatr*. 2002;91(12):1371-1378.
13. Sansavini A, Pentimonti J, Justice L, et al. Language, motor and cognitive development of extremely preterm children: modeling individual growth trajectories over the first three years of life. *J Commun Disord*. 2014;49:55-68.
14. Aarnoudse-Moens CS, Weisglas-Kuperus N, van Goudoever JB, Oosterlaan J. Meta-analysis of neurobehavioral outcomes in very preterm and/or very low birth weight children. *Pediatrics*. 2009;124(2):717-728.
15. Hansen BM, Dinesen J, Hoff B, Greisen G. Intelligence in preterm children at four years of age as a predictor of school function: a longitudinal controlled study. *Dev Med Child Neurol*. 2002;44(8):517-521.
16. van Veen S, Aarnoudse-Moens CS, van Kaam AH, Oosterlaan J, van Wassenaer-Leemhuis AG. Consequences of correcting intelligence quotient for prematurity at age 5 years. *J Pediatr*. 2016;173:90-95.
17. Gillijns P, Verhoeven L. Het CITO leerlingvolgsysteem: met het oog op de praktijk. [The CITO pupil monitoring system: focus on practice] *Pedagogische Studiën*. 1992;69:291-296.
18. Janssen J, Verhelst N, Engelen R, Scheltsen F. *Wetenschappelijke verantwoording van de toetsen LOVS rekenen-wiskunde voor groep 3 tot en met 8* [Scientific justification of the mathematics test for grade 1 until grade 6]. Arnhem: Cito; 2010.
19. Krom R, Jongen I, Verhelst N, Kamphuis F, Kleintjes F. *Wetenschappelijke verantwoording van de toetsen LOVS Drie-Minuten-Toets voor groep 3 tot en met 6* [Scientific justification of the reading test for grade 1 until grade 4]. Arnhem: Cito; 2010.
20. De Wijs A, Kamphuis F, Kleintjes F, Tomesen M. *Wetenschappelijke verantwoording van de toetsen LOVS spelling voor groep 3 tot en met 6* [Scientific justification of the spelling test for grade 1 until grade 4]. Arnhem: Cito; 2010.
21. Potharst ES, van Wassenaer AG, Houtzager BA, van Hus JW, Last BF, Kok JH. High incidence of multi-domain disabilities in very preterm children at five years of age. *J Pediatr*. 2011;159(1):79-85.
22. Tabachnick BG, Fidell LS. *Using Multivariate Statistics: International Ed*. Boston, MA: Pearson; 2012.
23. van Aken L, Kessels RP, Wingbermuhle E, van der Veld WM, Egger JI. Fluid intelligence and executive functioning more alike than different? *Acta Neuropsychiatr*. 2016;28(1):31-37.
24. Aarnoudse-Moens CS, Weisglas-Kuperus N, Duivenvoorden HJ, van Goudoever JB, Oosterlaan J. Executive function and IQ predict

mathematical and attention problems in very preterm children. *PLoS ONE*. 2013;8(2):e55994.

25. Doyle LW, Cheong JL, Burnett A, et al. Biological and social influences on outcomes of extreme-preterm/low-birth weight adolescents. *Pediatrics*. 2015;136(6):e1513-e1520.

26. Wong HS, Edwards P. Nature or nurture: a systematic review of the effect of socio-economic status on the developmental and cognitive outcomes of children born preterm. *Matern Child Health J*. 2013;17(9):1689-1700.

27. van Veen S, Remmers S, Aarnoudse-Moens CSH, Oosterlaan J, van Kaam AH, van Wassenaer-Leemhuis AG. Multilingualism was associated with lower cognitive outcomes in children who were born very and extremely preterm. *Acta Paediatr*. 2019;108:479-485.

28. Luttikhuizen dos Santos ES, de Kieviet JF, Konigs M, van Elburg RM, Oosterlaan J. Predictive value of the Bayley scales of infant development on development of very preterm/very low birth weight children: a meta-analysis. *Early Hum Dev*. 2013;89(7):487-496.

29. Simms V, Gilmore C, Cragg L, Clayton S, Marlow N, Johnson S. Nature and origins of mathematics difficulties in very preterm children: a different etiology than developmental dyscalculia. *Pediatr Res*. 2015;77(2):389-395.

30. Downie AL, Frisk V, Jakobson LS. The impact of periventricular brain injury on reading and spelling abilities in the late elementary and adolescent years. *Child Neuropsychol*. 2005;11(6):479-495.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.