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REGULAR ARTICLE

Cognitive profiles of extremely preterm children: Full-Scale IQ hides strengths and weaknesses

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Abstract

Aim: To study whether a specific cognitive profile can be identified for children born extremely preterm (EPT) by investigating: 1) strengths and weaknesses not revealed by Full-Scale IQ, 2) overlap between different cognitive deficits and 3) proportion of EPT children with multiple deficits.

Methods: We analysed data from the 4th version of Wechsler Intelligence Scales for Children in EPT children (*n* = 359) and matched controls (*n* = 367), collected within the 6.5-year follow-up of a population-based prospective cohort study.

Results: Extremely preterm children performed worse than controls on all measures. Group differences were the largest in Perceptual Reasoning (PRI) and Working Memory (WMI), but differences between indices were small. However, when conducting categorical analyses, deficits in PRI and/or WMI were not more common than other combinations. Many EPT children had no or mild cognitive deficits, although often in multiple domains.

Conclusion: Extremely preterm children had greater weaknesses in working memory and perceptual abilities. However, detailed analyses of cognitive subscales showed large heterogeneity and provided no support for a specific cognitive profile. In conclusion, Full-Scale IQ scores hide strengths and weaknesses and individual profiles for EPT children need to be considered in order to provide appropriate support.

KEYWORDS
cognition, extremely preterm children, index, subtest, WISC-IV

Abbreviations: EPT, Extremely Preterm; EXPRESS, Extremely Preterm Infants in Sweden Study; IQ, Intelligence Quotient; WISC, Weschsler Intelligence Scale for Children.

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1 | INTRODUCTION

During the past decades, survival rates among children born extremely preterm (gestational week ≤27; EPT) have increased substantially,[1-3] which has created a need for in-depth knowledge about their development. Previous reviews and meta-analyses have shown that children born EPT have lower intellectual ability compared with term-born controls, but that a majority of these children develop normally or with mild disabilities only.[4-7] Thus, EPT children constitute a heterogeneous group, and we still know relatively little about their individual strengths and weaknesses.

Previous studies have often only reported composite scores on cognitive functioning. Although composite scores, such as the Full-Scale Intelligence Quotient (IQ), could be argued to give the best overall estimate of a child's intellectual ability, the cognitive profile of children with the same Full-Scale IQ may differ substantially. A more detailed analysis of a child's cognitive profile enables a more in-depth understanding of specific abilities. For children with a Full-Scale IQ score within the average range, specific weaknesses may be present and may entail negative consequences for daily life. For children with moderate or severe intellectual deficits, it is important to identify their strengths. Also, strengths need to be assessed not only in terms of average or high performance, but also in terms of relative strengths (i.e. to what extent performance is better within some intellectual domains compared with what can be expected based on the child's Full-Scale IQ score).

The present study is part of the 6.5-year follow-up conducted within the Extremely Preterm Infant Study in Sweden (EXPRESS). Previous EXPRESS publications have shown that children born EPT perform poorly compared with full-term controls on Full-Scale IQ as well as within subdomains.[8] In the present paper, we first aimed to investigate the cognitive profiles of the EXPRESS children in detail, moving beyond investigating only mean group differences in Full-Scale IQ or indices. More specifically, we aimed to investigate whether a specific cognitive profile could be identified, whether children with average Full-Scale IQ still have deficits within specific cognitive domains, and to what extent children considered to have mild or severe cognitive deficits have relative strengths. Finally, we were interested in determining the proportion of EPT children who had mild deficits, although in multiple cognitive domains.

Key notes

- Detailed analyses of cognitive strengths and weaknesses in extremely preterm (EPT) children have seldom been conducted and have not combined dimensional and categorical analyses.
- Results showed that group differences were the largest for Working Memory and Perceptual Reasoning in the dimensional analyses, but categorical analyses revealed that multiple deficits in any combinations were common among EPT children.
- This study does not support the notion of a specific EPT cognitive profile.

2 | METHODS

2.1 | Participants and procedure

Extremely Preterm Infant Study in Sweden is a national, population-based and longitudinal prospective study on extreme prematurity. It includes all children born <27 gestational weeks in Sweden between April 1, 2004 and March 31, 2007. A total of 462 children were known to be alive at 6.5 years and comprised the eligible study population. At the 6.5-year follow-up, 441 children (78% of the eligible study population) were assessed and 367 children were tested. Complete cognitive data were obtained from 359 children, which comprised the present study sample. A matched control group born full term (n = 367) was recruited from the Swedish Medical Birth Registry as described in previous publications.[8] The reason for choosing this age for the follow-up was that this is the age when children in Sweden start school.

The children were assessed by licensed psychologists at the seven perinatal centres in Sweden. The children's legal guardians provided written informed consent, and the Regional Ethics Review Board in Lund, Sweden, approved the study. The full sample and procedure have been described in previous publications.[3,8,9]

2.2 | Measures

2.2.1 | Wechsler Intelligence Scale for Children

Cognition was assessed using the Wechsler Intelligence Scale for Children—Fourth Edition, Swedish Version (WISC-IV;[10-12]). It includes four indices measuring specific intellectual domains (i.e. Verbal Comprehension Index, Perceptual Reasoning Index, Working Memory Index and Processing Speed Index), which together comprise the Full-Scale IQ. The present study included the 10 core subtests (Table 1). However, the supplemental subtest Arithmetic replaced the core subtest Letter-Number Sequencing, as advised in the user's manual when testing children not yet confident in the alphabet.

2.3 | Statistical analyses

First, tests for group differences in background variables were conducted using t-tests, chi-square tests and Fisher's exact test, as appropriate. The children born EPT and controls were first compared, and a dropout analysis was performed. We calculated within-individual differences between WISC-IV indices (i.e. discrepancy scores). According to the WISC-IV manual,[12] a discrepancy score

TABLE 1 Description of the indices and subtests included in WISC-IV

Index	Subtest	Construct assessed
Verbal Comprehension	Similarities	Verbal reasoning and concept formation
	Vocabulary	Word knowledge and verbal concept formation
	Comprehension	Ability to use previous experiences in verbal reasoning
Perceptual Reasoning	Block Design	Perceptual analysis and reconstruction of abstract visual patterns
	Picture Concepts	Abstract categorical reasoning and visual concept formation
	Matrix Reasoning	Visual information processing and abstract reasoning
Working Memory	Digit Span	Auditory short term and working memory, and attention
	Arithmetic	Auditory working memory, numeric reasoning and attention
Processing Speed	Coding	Processing speed, short-term visual memory, visual perception and visuomotor coordination, cognitive flexibility and attention
	Symbol Search	Processing speed, short-term visual memory, visual discrimination and attention

≥1.5 SD between at least two indices is too large for the Full-Scale IQ score to be an interpretable measure of the child's overall cognitive ability, meaning that index scores need to be examined instead.

Second, group differences in WISC-IV indices and subtests between children born EPT and controls were investigated using analysis of covariance (ANCOVA), with mother's level of education and mother's country of birth (Nordic/non-Nordic) as covariates. Missing data for level of education were imputed with the mean value for each group. Effect sizes were calculated using partial eta-squared (η^2), where 0.01 is considered a small effect, 0.06 a medium-sized effect and 0.14 a large effect.[13]

Third, z-scores for indices and subtests for the EPT group were computed using the control group's mean and standard deviation. A z-score of 1.00 would indicate that the difference between children born EPT and controls was 1 SD. Paired-sample t-tests were then used to investigate whether the deficits observed among children born EPT were more pronounced for some indices or subtests. To address possible correlations between individual scores due to multiple births for children born EPT, a complex sample design [14] was used in the analyses described above.

Fourth, we classified the EPT children's performance (Full-Scale IQ as well as each of the four indices and subtests) into the following cognitive categories: 1) no deficits (≥−1 SD), 2) mild deficits (<−1 to −2 SD) and 3) moderate/severe deficits (<−2 SD). The categories were based on the performance of the children in the control group and follow the categories proposed in the WISC-IV manual.[12]

Fifth, we used Venn diagrams to illustrate the overlap between different cognitive domains and thereby investigate to what extent there is support for the notion of a specific cognitive profile for EPT children.

Finally, the proportion of children with single versus multiple deficits with regard to the four WISC-IV indices was investigated. As we were especially interested in determining to what extent the EPT children displayed mild deficits on multiple cognitive indices, we distinguished between children with only mild deficits and those with at least one severe deficit in this analysis.

All analyses were performed in SPSS Statistics version 26 (IBM Corp). Graphs were created in Prism8 (GraphPad Prism version 8.00 for MacIntosh, GraphPad software, La Jolla, California, USA, www.graphpad.com).

3 | RESULTS

Table 2 presents data for background variables for the 359 participating children compared with the 103 non-participating EPT children and 367 controls. The rate of moderate or severe developmental disabilities was significantly lower in participating EPT children compared with EPT children who did not participate. No other differences were found. The proportion of children with z-score discrepancies between indices exceeding 1.5 SD was 50% for the EPT group and 48% for the control group.

TABLE 2 Descriptive statistics for background variables and neonatal factors

	Full-term control group (*n* = 367)	Included EPT children (*n* = 359)	Non-included EPT children[i] (*n* = 103)
Background variables			
Age, years (SD)	6.6 (0.2)	6.6 (0.2)	
Sex, n (%) males	201 (54.8)	193 (53.8)	57 (55.3)
Maternal birth country, *n* (%) non-Nordic	19 (5.2)	65 (18.1)[a]	26 (27.7)
Maternal education, *n* (%)[i]			
≤9 years	10 (3.3)	28 (7.9)[a]	13 (19.7)
10–13 years	103 (34.5)	150 (42.1)[a]	27 (40.9)
14–15 years	65 (21.8)	90 (25.3)[a]	12 (18.3)
≥16 years	120 (40.2)	88 (24.7)[a]	14 (25.0)
Unknown	69 (18.8)	3 (0.8)[a]	37 (35.9)
Neonatal factors			
Gestational age, weeks		25.0 (1.0)	24.9 (1.1)
22		3 (0.8)	2 (1.9)
23		34 (9.5)	13 (12.6)
24		69 (19.2)	19 (18.4)
25		125 (34.8)	29 (28.2)
26		128 (35.7)	40 (38.8)
Gestational age, mean (SD), weeks[c]	39.5 (1.1)	25.0 (1.0)[a]	24.8 (1.1)
Birth weight mean (SD), g[c]	3621 (478)	782 (168)[a]	776 (173)
Multiple birth	0 (0.0)	69 (19.2)	20 (19.4)
Small for gestational age[e]	3 (0.8)	56 (15.6)[a]	16 (15.7)
Congenital malformation		37 (10.4)	11 (10.8)
Severe bronchopulmonary dysplasia[f]		75 (21.8)	26 (27.7)
Retinopathy of prematurity ≥ stage 3		117 (32.7)	38 (37.6)
Necrotizing enterocolitis[d]		17/357 (4.8)	9 (8.8)
Antenatal steroids		333 (92.8)	96 (95.0)
Postnatal steroids		98 (27.3)	35 (34.3)
Major neonatal morbidity		185 (51.8)	62 (102 (60.8)
Severe brain injury[g]		44 (12.3)	19 (18.8)
Disabilities at 6.5 years			
Cerebral palsy	0 (0.00)	24 (6.7)	18 (21.9)[b,h]
Moderate and severe CP	0 (0.00)	6 (1.7)	13 (15.5)[b,h]
Moderate or hearing impairment or deaf	1 (0.3)	4 (1.11)[a]	5 (5.43)[b,h]
Deaf	0 (0.00)	0 (0.0)	2 (2.17)
Moderate visual impairment or blind	1 (0.3)	(1.10)	17 (16.8)[b,h]
Blind	0 (0.00)	0 (0.00)	9 (8.7)[b,h]

Note: Overall difference calculated using χ^2, if not stated otherwise.

[a]$p < 0.05$ for overall difference between included EPT children and full-term control group.

[b]$p < 0.05$ for overall difference between included and non-included EPT children.

[c]Overall difference calculated using independent *t* test.

[d]Overall difference calculated using fisher exact test.

[e]Less than mean −2 SD of the Swedish intrauterine growth standard.[8]

[f]Oxygen requirements at 36 weeks' CA >30%.

[g]Intraventricular haemorrhage ≥grade 3 and all periventricular leukomalacia.

[h]Includes results obtained at 2.5 years for children not participating at the 6.5-year follow-up.

[i]The children not included in this study comprised 23 EPT children declining participations, 72 agreeing to chart review only and 8 not being able to complete all ten subtests of the WISC-IV. For maternal education, data was only available for 66 children in this group. For all other neonatal background variables, n ranged from 92 to103.

3.1 | Group differences between children born EPT and controls

Group differences in Full-Scale IQ, indices and subtests from the WISC-IV were all statistically significant with medium to large effect sizes (Table 3). Next, we used paired t-tests to investigate whether the deficits observed for EPT children were larger for some indices compared with others (see Figure 1A). Results showed that the z-scores were significantly higher (i.e. larger group differences relative to controls) for Working Memory and Perceptual Reasoning than for the other two indices. However, the differences between indices were all small (≤0.23 SD). Figure 1B shows the same analysis for subtests within each respective index, with significant discrepancies being found between subtests within the Perceptual Reasoning, Working Memory and Processing Speed indices. The largest deficits relative to controls were found for the Block Design, Arithmetic and Symbol Search subtests.

3.2 | Cognitive categories for children born EPT

Next, we investigated the three cognitive categories rather than mean index and subtest scores. Figure 2 shows the WISC-IV indices and subtests according to cognitive performance (ie no deficits, mild deficits, moderate/severe deficits). About one third (37%) of the children born EPT displayed no cognitive deficits when investigating Full-Scale IQ. For separate indices, a majority of the EPT children performed within the no deficit range, except for Perceptual Reasoning, where the proportion was somewhat lower (42%).

Figure 3A shows the proportion of children born EPT within each cognitive category for each index, but split according to the child's Full-Scale IQ score. This analysis shows relative strengths and weaknesses (i.e. the proportion of children performing better or worse on an index compared with Full-Scale IQ). For children born EPT with no deficit on Full-Scale IQ, a smaller proportion (ranging from 5% for Verbal Comprehension and Working Memory to 16% for Processing Speed) had mild deficits and few (≤2%) had moderate/severe deficits on any particular index. Of children born EPT with mild Full-Scale IQ deficits, a majority (50–59%) had no deficits on separate indices, with the most frequent relative strength being found for Verbal Comprehension. The exception was Perceptual Reasoning, where only 27% had no deficits. Moreover, some children (6–15%) with mild deficits on Full-Scale IQ had moderate/severe deficits on separate indices. Finally, for children born EPT with moderate/severe deficits, a proportion (i.e. ranging from 1% for Perceptual Reasoning to 17% for Processing Speed) had no deficits on at least one index, and between 25% and 38% had only mild deficits on separate indices. Figure 3B shows the same type of analyses as in Figure 3A, but here, we present relative strengths and weaknesses on individual subtests rather than on indices.

3.3 | Overlap between different cognitive domains

Figure 4 presents the overlap between mild deficits in different WISC-IV indices. We chose to merge results for the Verbal Comprehension and Processing Speed indices into one circle as Venn diagrams with four circles are difficult to interpret. Based on the results of the dimensional analyses, we were mainly interested in determining whether the

TABLE 3 Results of the ANCOVAs comparing extremely preterm children and full-term controls

	Extremely preterm (*n* = 359) Mean (SD)	Full-term controls (*n* = 367) Mean (SD)	Mean difference (95% CI)[a]	Effect size (η^2)
Verbal Comprehension	92.2 (14.4)	104.0 (11.5)	10.0 (8.1–12.0)	0.
Similarities	8.9 (3.9)	11.5 (2.9)	2.2 (1.7–2.8)	0.10
Vocabulary	9.1 (2.1)	10.7 (1.9)	1.3 (1.0–1.6)	0.10
Comprehension	8.2 (3.0)	10.3 (2.5)	1.8 (1.4–2.2)	0.10
Perceptual Reasoning	89.7 (14.2)	104.8 (12.7)	13.8 (11.7–15.8)	0.20[b]
Block Design	8.8 (3.0)	11.4 (2.6)	2.4 (2.0–2.8)	0.15
Picture Concepts	8.5 (3.2)	11.2 (3.0)	2.4 (1.9–2.9)	0.13
Matrix Reasoning	7.7 (2.3)	9.7 (2.6)	1.9 (1.5–2.6)	0.13
Working Memory	78.3 (13.1)	90.7 (11.0)	11.2 (9.2–13)	0.18
Digit Span	6.2 (2.7)	8.0 (2.3)	1.6 (1.2–2.0)	0.09
Arithmetic	6.4 (2.5)	8.9 (2.3)	2.3 (1.9–2.6)	0.18[b]
Processing Speed	85.0 (14.4)	96.9 (12.7)	11.5 (9.4–13.6)	0.15[b]
Coding	7.6 (3.2)	9.6 (2.9)	1.9 (1.4–2.4)	0.08
Symbol Search	7.0 (2.7)	9.4 (2.2)	2.2 (1.8–2.6)	0.16[b]
Full-Scale IQ	83.9 (14.6)	100.3 (11.7)	14.8 (12.8–16.8)	0.24[b]

[a]All comparisons between extremely preterm children and controls were significant, $p < 0.001$.
[b]Indicating a large effect size (ie $\eta^2 > 0.14$). All other are considered medium effect size (ie $\eta^2 > 0.06$).

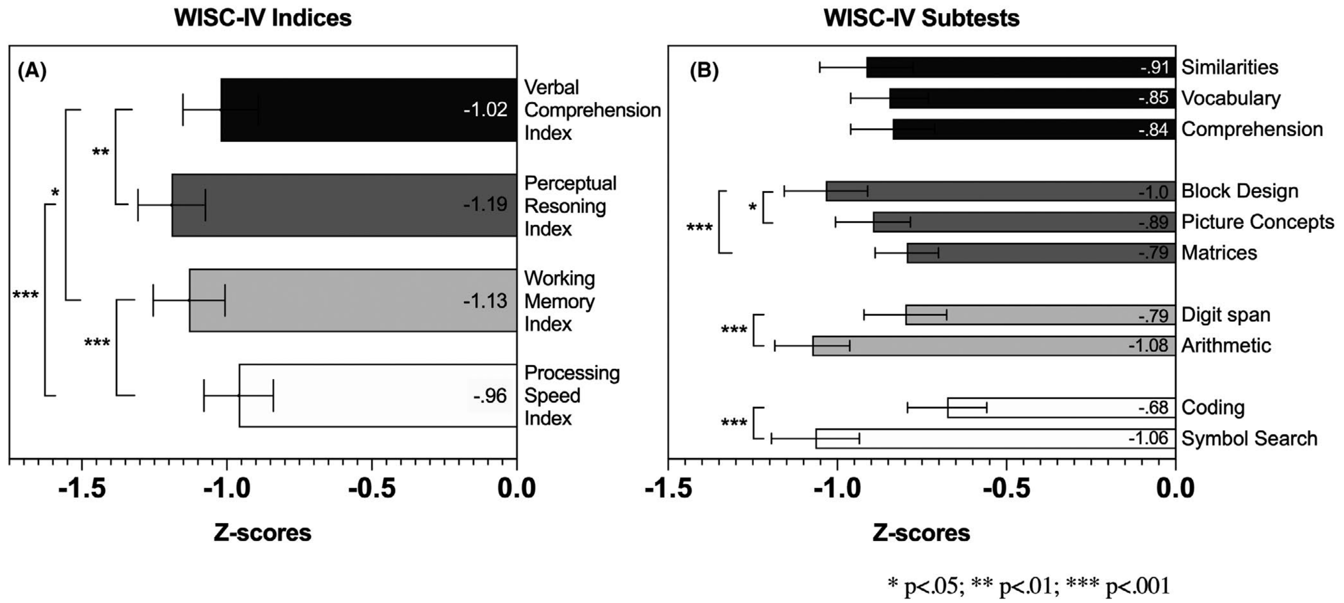

FIGURE 1 Panel A, Paired t-tests between indices of the WISC-IV, with brackets indicating statistically significant discrepancies. Panel B, Paired t-tests between subscale scores within each index

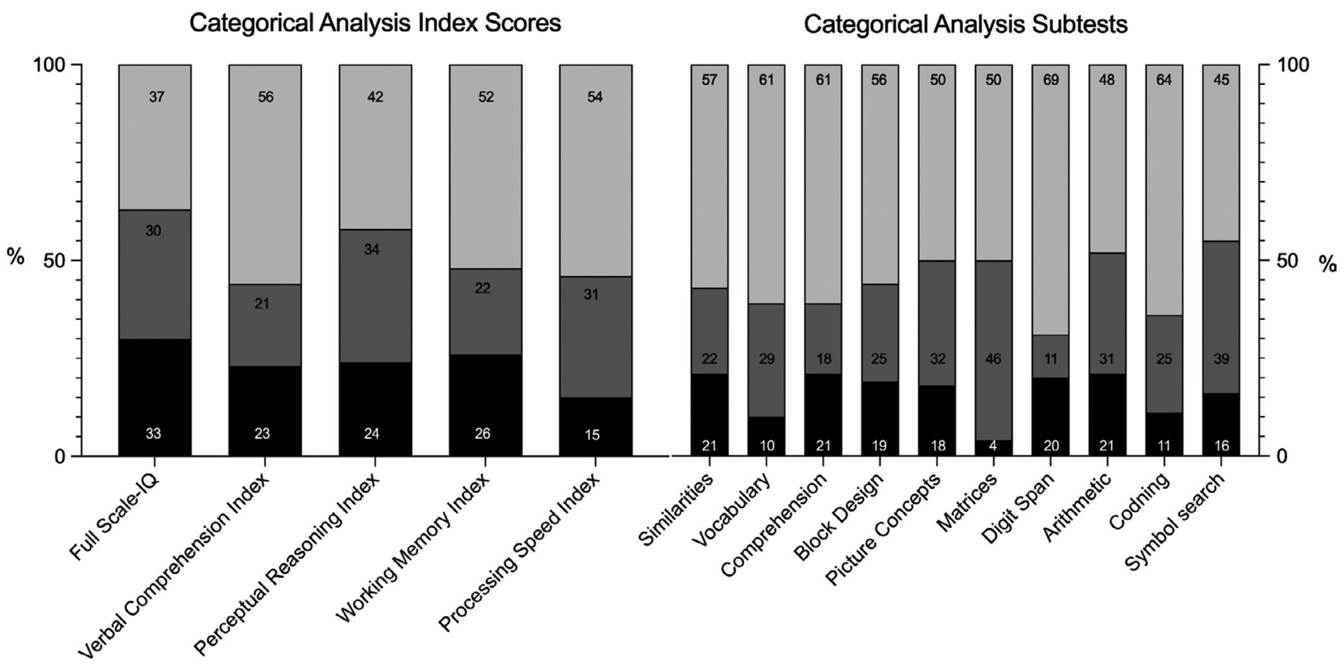

FIGURE 2 Distribution of WISC-IV Full-Scale IQ (to the left), and the individual WISC-IV indices and subtests (to the right) according to cognitive performance: 1) no deficits (≥−1 SD) presented in light grey, 2) mild deficits (<−1 to −2 SD) presented in grey and 3) moderate/severe deficits (<−2 SD) presented in black

combination of deficits in Working Memory and Perceptual Reasoning was especially common in relation to other combinations. Results showed that 6% had deficits in Working Memory only, 2% had deficits in Perceptual Reasoning only and 3% had the combination of these two deficits. Thus, only a small minority (11%) had deficits in one or both of these cognitive domains (without also having deficits in other domains). This can be compared with 12% having deficits in either Processing Speed and/or Verbal Comprehension. Similar results were found when only including children with severe deficits.

3.4 | Single versus multiple deficits

Figure 5 presents the number of children with single versus multiple deficits on the four indices, separately for children with mild deficits only and children with at least one moderate/severe deficit. Of 359 children born EPT, 59 (16%) had a single mild deficit and 66 (18%) had multiple mild deficits. The corresponding figures for the controls were 65 (18%) and 32 (9%). Further, 8 children born EPT (2%) had a single moderate/severe deficit, and 143 (40%) had multiple

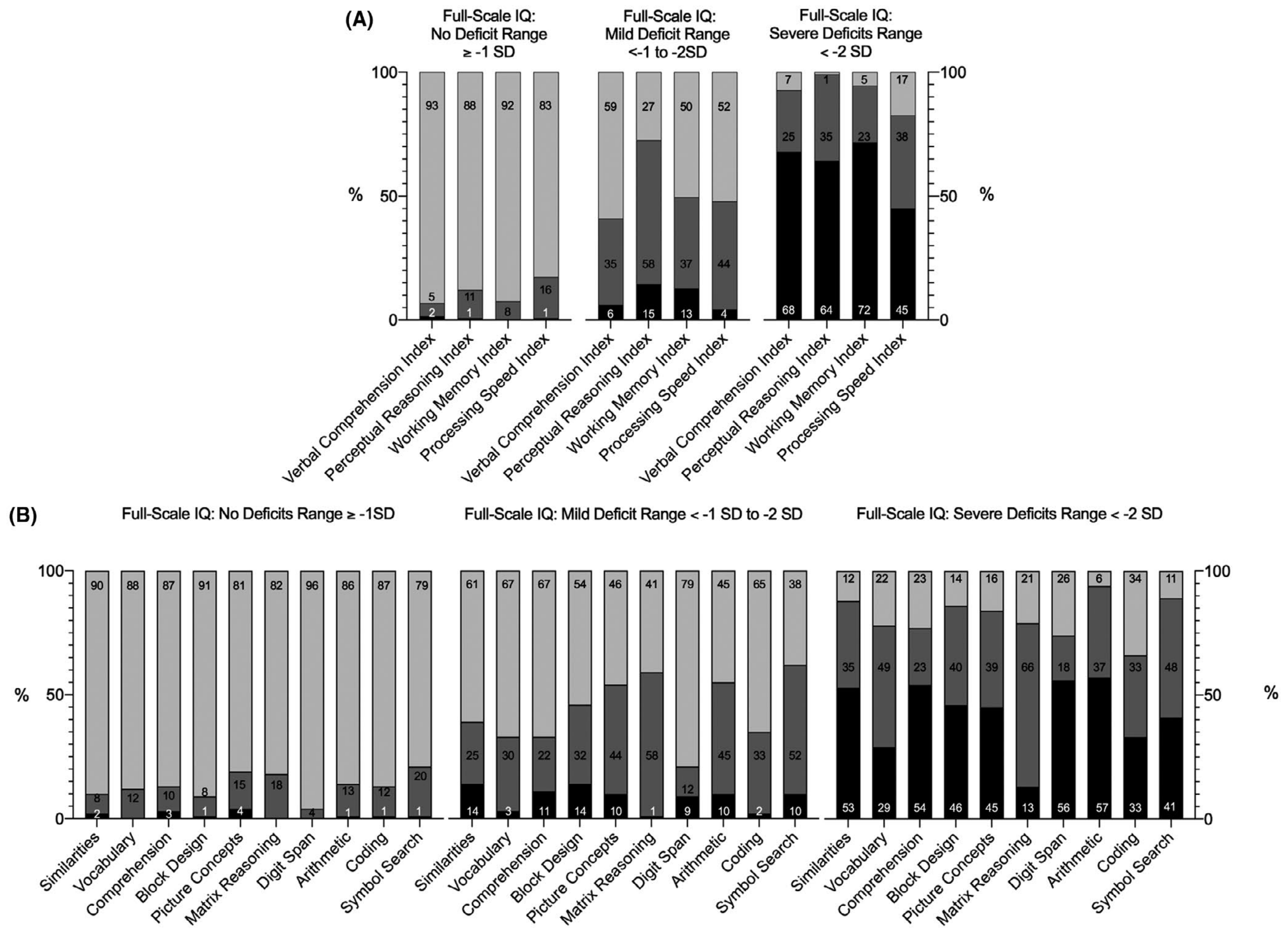

FIGURE 3 A, Distribution of WISC-IV index scores for EPT children within three different ranges of intellectual ability based on Full-Scale IQ. 1) no deficits (≥−1 SD) presented in light grey, 2) mild deficits (<−1 to −2 SD) presented in grey and 3) moderate/severe deficits (<−2 SD) presented in black. B, Distribution of WISC-IV subscale scores for EPT children within three different ranges of intellectual ability based on Full-Scale IQ. 1) no deficit (≥−1 SD) presented in light grey, 2) mild deficits (<−1 to −2 SD) presented in grey and 3) moderate/severe deficits (<−2 SD) presented in black

moderate/severe deficits. The corresponding figures for the 367 controls were 12 (3%) and 16 (4%). Thus, in total, 23% of EPT children did not have a deficit on any index, 34% of children born EPT had only mild deficits and 42% had moderate/severe deficits.

4 | DISCUSSION

The present study showed significant group differences between the EPT group and controls for all WISC-IV indices and subtests, with moderate or large effect sizes. Relative to controls, the EPT group showed significantly larger difficulties with Perceptual Reasoning and Working Memory compared with the two other indices, but these differences were small. In addition, categorical analyses of the overlap between different indices (i.e. the Venn diagram) indicated that deficits in working memory only, perceptual reasoning only, or the combination of both these deficits, were not more common than other combinations. About half of the participants in both groups showed large discrepancies (i.e. ≥1.5 SD) between the WISC-IV indices, which indicates that scores on overall cognitive functioning hide specific strengths and weaknesses. When investigating these individual differences within the EPT group, children with mild deficits on Full-Scale IQ often showed a relative weakness in Perceptual Reasoning (Figure 3A), whereas children born EPT with <−2 SD on Full-Scale IQ often showed a relative strength in Processing Speed. When investigating multiple versus single deficits for each index, almost one fifth of EPT children showed mild deficits on multiple indices.

When investigating group mean values on the indices and subtests, our results showed that, relative to controls, children born EPT had significantly larger deficits in Perceptual Reasoning and Working Memory compared with the other two indices. For individual subtests, the largest differences were found for Block Design, Arithmetic and Symbol Search, which are described in the WISC-IV manual as primarily targeting visuospatial construction, working memory and search of abstract symbols.[12] In addition, previous research has shown that the Symbol Search subtest also taps into visual processing.[15] Thus, analyses of individual subtests may support the notion that, when examining differences between indices for the whole group, EPT birth seems to be most strongly related to deficits in perceptual skills and working memory. These findings are also in line with some previous research.[16,17] However, although this could be interpreted as indicating a cognitive profile, it is important to note that the differences between indices were all small. We would therefore like to emphasise that the main finding of the present study is that children born EPT, as a group, performed worse than controls on all indices and that about one fourth of children born EPT did not have any cognitive deficits at all. These findings are in line with the few previous studies that have examined separate cognitive indices in EPT children.[7,8,18,19]

When investigating behavioural problems in EPT children, it has been argued that there is a specific preterm behavioural phenotype, characterised by emotional problems and difficulties with attention and social communication.[20,21] However, a recent study [22] identified several subgroups within the preterm group, with only 20% of EPT children having problems that fit the preterm behavioural phenotype, whereas 55% had no behavioural problems, and 26% had problems in most or all behavioural domains. The results of the present study could be taken to suggest that similar reasoning may be applied to cognitive functioning, as it does not appear to be possible to identify a specific cognitive profile for EPT children. Instead, EPT children may have deficits within any domain relative to controls or may have a single, no or multiple deficits. In sum, when differences between children born EPT and controls are examined, deficits appear to be somewhat larger for perceptual skills and working memory, which could be interpreted as an indication of a specific EPT cognitive profile. However, when investigating the overlap between different cognitive deficits, it became evident that a specific cognitive profile that fit a majority of EPT children could not be established as deficits in working memory only, perceptual reasoning only or the combination of both these deficits, were not more common than deficits in processing speed and/or verbal comprehension. Consequently, EPT children constitute a very heterogeneous group, some having a specific deficit within one domain, some having more generalised deficits in multiple domains and some having no deficits at all.

Another important research question addressed in the present study concerns the proportion of EPT children with deficits evident in single versus multiple indices. Children with no deficits or mild deficits on only one index will likely fair relatively well and stand for roughly 40% of the EPT population in the study. However, having deficits in several domains is likely to affect daily functioning to a larger extent, as compensatory strategies are less readily available, and difficulties may interact. EPT children with multiple moderate/severe deficits will most likely receive special educational support. However, there is a risk that children with multiple mild deficits (18%) will go unnoticed by teachers. As argued by Pennington and Ozenoff,[23] good verbal abilities, which was a relative strength among

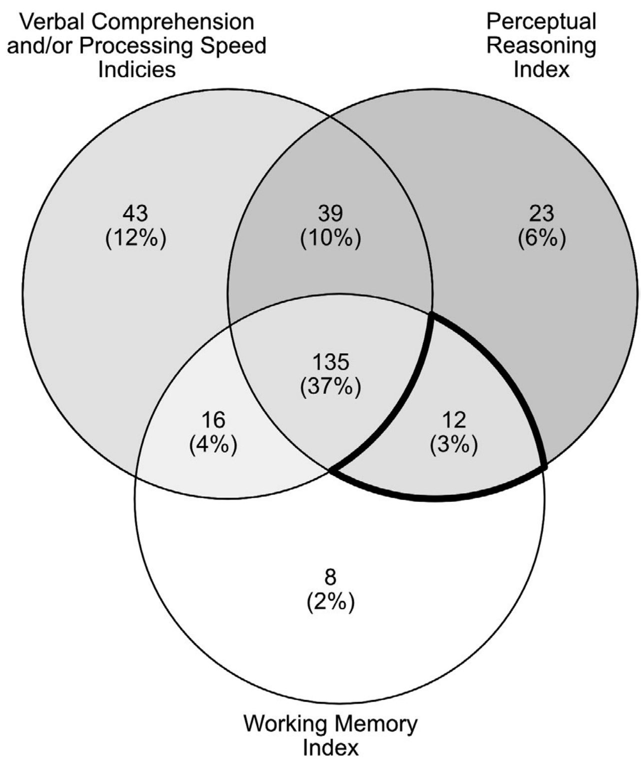

FIGURE 4 Venn diagram depicting how deficits overlap for EPT children. Numbers and percentages are given, n = 359. Please note that Verbal Comprehension Index and Processing Speed Index are merged into one circle. The proportion with deficits within both Perceptual Reasoning Index and Working Memory Index and no other areas is highlighted

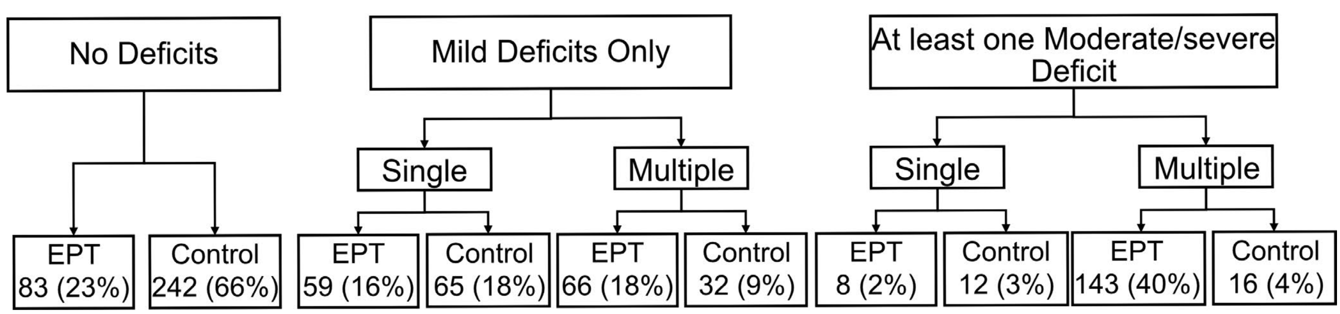

FIGURE 5 Number of children with no deficits; single or multiple deficits on the four WISC-IV indices. For the EPT group n = 359 and the full-term group n = 367, respectively

many children born EPT with mild overall deficits in the present study, may mask a child's specific weakness within other domains.

4.1 | Practical/clinical implications of the present study

Previous research on children born at full-term has shown that cognitive abilities are important for academic achievement[10] and for forming and maintaining social relationships.[24] Similar associations have been found in studies of children born preterm.[25-27] Thus, the cognitive deficits displayed by EPT children may have important implications for daily life functioning. However, our results also showed large heterogeneity within the EPT group and that many EPT children have relative strengths. For example, for children with the most severe cognitive deficits (Full-Scale IQ <−2 SD) the proportion with no or mild deficits ranged from 28% to 55% for the different indices. As argued previously,[28] Full-Scale IQ scores cannot be used to adequately predict individual academic performance if there are significant intra-individual differences between WISC indices. It should therefore be considered essential for schools to carefully assess individual strengths and weaknesses in EPT children so that interventions can target the specific cognitive deficits of each student.[29,30] The EPICure study has shown that two thirds of children born EPT had special education needs at age 11, although only 13% attended special schools.[25] Thus, interventions for EPT children most often need to be implemented within regular classrooms, which may make adaptations to the individual needs of each child a challenge.

4.2 | Strengths, limitations and future directions

The limitations of the present study mainly concern generalisability issues. First, the dropout analysis showed differences between the full EXPRESS cohort and the participants in the present study. Second, the analyses included in this study do not include participating children who were unable to complete the WISC-IV, although this number was small (n = 8). However, the proportions of children with no deficits, mild deficits and moderate/severe deficits were similar to figures found in a previous study[8] also including those children, suggesting that this should be less of a concern.

The present study should be considered an important first step in investigating individual strengths and difficulties in children born EPT. However, it should be noted that there are additional aspects of functioning not included in the present study, which should be considered in follow-up of children born EPT. For instance, neuropsychiatric disorders[31] and motor coordination problems[32] are common in children born EPT.

The strengths of the present study include its prospective, longitudinal design. An additional strength is that the EXPRESS study is a cohort study, whereas most other studies have used more selective samples. The retention rate of 78% should be considered satisfactory, although a larger proportion of non-participating children had neurodevelopmental disabilities at follow-up. Taken together, the generalisability of our findings is probably acceptable to high. We, therefore, feel that our results can be generalised to extremely preterm populations receiving active perinatal care.

Regarding future directions, the study clearly indicates that children born EPT constitute a heterogeneous group with regard to their cognitive profiles. Moreover, further studies need to explore how different cognitive profiles are related to daily life functioning concurrently, and how these potential subgroups can predict later outcomes.

5 | CONCLUSIONS

Being born EPT increases the risk of deficits in any cognitive domain—but not necessarily in all. Only reporting mean values and Full-Scale IQ scores does not depict relative strengths and weaknesses in the cognitive performance of EPT children. The results of the present study demonstrate that children born EPT constitute a heterogeneous group with individual strengths and weaknesses. This has important practical implications, as successful interventions in school build on relative strengths and target specific weaknesses. Thus, it should be important to do a follow-up around the time when the child starts school. In addition, it should be considered important that schools not only provide support for children with moderate/severe deficits, but also acknowledge the relatively large subgroup of EPT children who have mild deficits in multiple domains.

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CONFLICT OF INTEREST

None.

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REFERENCES

1. Stoll BJ, Hansen NI, Bell EF, et al. Trends in care practices, morbidity, and mortality of extremely preterm neonates, 1993–2012. JAMA. 2015;314(10):1039-1051.
2. Riley K, Roth S, Sellwood M, Wyatt JS. Survival and neurodevelopmental morbidity at 1 year of age following extremely preterm delivery over a 20-year period: a single centre cohort study. Acta Paediatr. 2008;97(2):159-165.

3. Fellman V, Hellström-Westas L, Norman M, et al. One-year survival of extremely preterm infants after active perinatal care in Sweden. JAMA. 2009;301(21):2225-2233.
4. Sharp M, French N, McMichael J, Campbell C. Survival and neurodevelopmental outcomes in extremely preterm infants 22–24 weeks of gestation born in Western Australia. J Paediatr Child Health. 2018;54(2):188-193.
5. Moore GP, Lemyre B, Barrowman N, Daboval T. Neurodevelopmental outcomes at 4 to 8 years of children born at 22 to 25 weeks' gestational age: a meta-analysis. JAMA Pediatr. 2013;167(10):967-974.
6. Arpino C, Compagnone E, Montanaro ML, et al. Preterm birth and neurodevelopmental outcome: a review. Childs Nerv Syst. 2010;26(9):1139-1149.
7. Kerr-Wilson CO, Mackay DF, Smith GCS, Pell JP. Meta-analysis of the association between preterm delivery and intelligence. J Public Health (Oxf). 2012;34(2):209-216.
8. Serenius F, Ewald U, Farooqi A, et al. Neurodevelopmental outcomes among extremely preterm infants 6.5 years after active perinatal care in Sweden. JAMA Pediatr. 2016;170(10):954-963.
9. Serenius F, Källén K, Blennow M, et al. Neurodevelopmental outcome in extremely preterm infants at 2.5 years after active perinatal care in Sweden. JAMA. 2013;309(17):1810-1820.
10. Wechsler D. Weschsler Intelligence Scale for Children-Fourth Edition (WISC-IV). San Antonio, TX: The Psychological Corporation; 2003.
11. Tideman E. Hur ska WISC-IV användas? WISC-IV Svensk version Manual Del I. Stockholm: NCS Pearson Inc; 2007:91-138.
12. Wechsler D. Wechsler Intelligence Scale for Children - Fourth Edition, Svensk version. Stockholm: NCS Pearson Inc; 2007.
13. Cohen J. Statistical Power Analysis for the Behavioral Sciences, Revised edition. New York: Academic press; 2013.
14. Cochran WG. Sampling Techniques, 3rd edn. New York, NY: John Wiley and Sons; 1977.
15. Keith T, Fine J, Taub G, Reynolds M, Kranzler J. Higher order, multisample, confirmatory factor analysis of the Wechsler Intelligence Scale for Children-Fourth Edition: what does it measure? Sch Psychol Rev. 2006;35:108-127.
16. Anderson P, Doyle LW, Group and the VICS. Neurobehavioral outcomes of school-age children born extremely low birth weight or very preterm in the 1990s. JAMA. 2003;289(24):3264-3272.
17. Lundequist A, Böhm B, Lagercrantz H, Forssberg H, Smedler A-C. Cognitive outcome varies in adolescents born preterm, depending on gestational age, intrauterine growth and neonatal complications. Acta Paediatr. 2015;104(3):292-299.
18. Cheong JLY, Anderson PJ, Burnett AC, et al. Changing neurodevelopment at 8 years in children born extremely preterm since the 1990s. Pediatrics. 2017;139(6):e20164086
19. Hutchinson EA, Luca CRD, Doyle LW, Roberts G, Anderson PJ, Group for the VICS. School-age outcomes of extremely preterm or extremely low birth weight children. Pediatrics. 2013;131(4):e1053-e1061.
20. Johnson S, Marlow N. Preterm birth and childhood psychiatric disorders. Pediatr Res. 2011;69(8):11-18.
21. Fitzallen GC, Taylor HG, Bora S. What do we know about the preterm behavioral phenotype? A narrative review. Front Psychiatry. 2020;11:154.
22. Burnett A, Youssef G, Anderson P, Duff J, Doyle L, Cheong J. Exploring the "Preterm behavioral phenotype" in children born extremely preterm. J Dev Behav Pediatr. 2019;40(3):200-207.
23. Pennington BF, Ozonoff S. Executive functions and developmental psychopathology. J Child Psychol Psychiatry. 1996;37(1):51-87.
24. Wascher CAF, Kulahci IG, Langley EJG, Shaw RC. How does cognition shape social relationships? Philos Trans R Soc B Biol Sci. 2018;373(1756):20170293.
25. Johnson S, Hennessy E, Smith R, Trikic R, Wolke D, Marlow N. Academic attainment and special educational needs in extremely preterm children at 11 years of age: the EPICure study. Arch Dis Child Fetal Neonatal Ed. 2009;94(4):F283-F289.
26. Simms V, Cragg L, Gilmore C, Marlow N, Johnson S. Mathematics difficulties in children born very preterm: current research and future directions. Arch Dis Child Fetal Neonatal Ed. 2013;98(5):F457-F463.
27. Taylor HG. Neurodevelopmental origins of social competence in very preterm children. Semin Fetal Neonatal Med. 2020;25(3):101108.
28. Hale JB, Fiorello CA, Kavanagh JA, Hoeppner JB, Gaither RA. WISC-III predictors of academic achievement for children with learning disabilities: are global and factor scores comparable? School Psychol Quarter. 2001;16:31-55.
29. DuPaul GJ, Volpe RJ, Jitendra AK, Lutz JG, Lorah KS, Gruber R. Elementary school students with AD/HD: predictors of academic achievement. J Schl Psychol. 2004;42(4):285-301.
30. Daley D, Birchwood J. ADHD and academic performance: why does ADHD impact on academic performance and what can be done to support ADHD children in the classroom? Child Care Health Dev. 2010;36(4):455-464.
31. Johnson S, Hollis C, Kochhar P, Hennessy E, Wolke D, Marlow N. Psychiatric disorders in extremely preterm children: longitudinal finding at age 11 years in the EPICure study. J Am Acad Child Adolesc Psychiatry. 2010;49(5):453.e1-463.e1.
32. Bolk J, Farooqi A, Hafström M, Åden U, Serenius F. Developmental coordination disorder and its association with developmental comorbidities at 6.5 years in apparently healthy children born extremely preterm. JAMA Pediatr. 2018;172(8):765-774.

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