Cognitive Development 64 (2022) 101247

Contents lists available at ScienceDirect

Cognitive Development

journal homepage: www.elsevier.com/locate/cogdev

Maternal care and general cognitive functioning in moderate and late preterm-born children

Lexuri Fernández de Gamarra-Oca [a], Natalia Ojeda [a,*,1], Begoña Loureiro [b],
Andrea Sierra-Ibarbia [a], M. Acebo García-Guerrero [a], Javier Peña [a],
Naroa Ibarretxe-Bilbao [a], Leire Zubiaurre-Elorza [a]

[a] *Department of Psychology, Faculty of Health Sciences, University of Deusto, Bilbao, Bizkaia, Spain*
[b] *Division of Neonatology, Biocruces Health Research Institute, University Hospital Cruces, Barakaldo, Bizkaia, Spain*

ARTICLE INFO

Keywords:
Cognitive functioning
Preterm birth
Early life environmental factors
Maternal care
Childhood

ABSTRACT

Aim: To establish the neuropsychological profile in moderate and late preterm (MLPT) samples during childhood, and to assess the potential role of early life environmental factors in cognitive outcomes.
Methods: One hundred-and-six children took part in this study, including 42 moderate preterm (M_{age}=11.57 years; Md_{age}: 12; SD_{age}=1.77), 33 late preterm (M_{age}=12.21 years; Md_{age}: 12; SD_{age}=0.78) and 31 full-term children (M_{age}=11.42 years; Md_{age}: 12; SD_{age}=1.84). All participants underwent an environmental, emotional-behavioural, life satisfaction, functionality, resilience, and cognitive assessment.
Results: Significant differences were found in several cognitive domains among groups. Further, the maternal care measure moderated the relationship between the degree of maturity/immaturity at birth and general cognitive functioning score ($F_{(4,1014101)}= 3.72$, $p = 0.007$, $R^2 = 0.13$).
Conclusions: The findings showed different neuropsychological profiles during childhood, with the moderate preterm sample reporting poorer general cognitive functioning. Additionally, the appropriate level of maternal care measure used in this study seems to have had a protective effect on cognitive development.

Prematurity is described as a chronic condition (Raju et al., 2017) which can have adverse long-term neurodevelopmental consequences even for infants born at 32–36 weeks of gestation. Moderate (32–34 weeks' gestational age (GA)) and late (35–36 weeks' GA) preterm (MLPT) neonates are born during a sensitive period for brain development (Walsh et al., 2014), with a commensurate higher risk of neonatal morbidity requiring admission to a neonatal unit when compared to those born at term (Boyle et al., 2015). These subgroups account for more than 80 % of preterm deliveries (Shapiro-Mendoza & Lackritz, 2012), and some may present academic difficulties in a variety of higher- and lower-order subskills (McBryde et al., 2020).

During infancy, lower scores in cognitive performance are commonly displayed in preterm-born infants compared to their full-term peers, which seem to appear early in life and increase over time (Yaari et al., 2018). However, low-risk preterm samples have been far less explored, as have the cognitive differences that may exist between moderate and late preterm newborns. The double burden of

---

[*] Correspondence to: Department of Psychology, Faculty of Health Sciences, University of Deusto, Avda de las Universidades 24, 48007 Bilbao, Biscay, Spain.

E-mail address: nojeda@deusto.es (N. Ojeda).

[1] ORCID: 0000-0002-0952-0649

https://doi.org/10.1016/j.cogdev.2022.101247
Received 18 January 2022; Received in revised form 29 August 2022; Accepted 5 September 2022

preterm birth and related factors (i.e., neonatal and environmental factors) are thought to have a strong impact on cognitive functioning across adulthood (Fernández de Gamarra-Oca et al., 2021). Nevertheless, the extent to which these factors may affect early cognition in the MLPT population during childhood still needs to be addressed more thoroughly. While biological factors have a modest effect on cognition at the early stages, they seem to lose their effect over time in low-risk preterm children (Pérez-Pereira et al., 2020). In contrast, environmental factors have been shown to be increasingly important during infancy after preterm delivery (Ross & Perlman, 2019); the quality of the home environment, parenting behaviors and socioeconomic factors appear to challenge the relationship between prematurity and cognitive delays (McMahon et al., 2022; Pérez-Pereira et al., 2020; Wong & Edwards, 2013). Nonetheless, studies carried out to date have largely concentrated on the early years of life, without assessing this potential environmental impact in later years.

As there is wide heterogeneity in the way prematurity shapes the brain (Dimitrova et al., 2020), there may be different factors that influence cognitive functioning during childhood after preterm delivery. This study aims to determine the neuropsychological profiles of MLPT children, given the lack of research on the differences between both preterm samples, as most of the existing studies have focused on extremely and very preterm birth. Furthermore, in view of the biological risk factor of prematurity, contextual factors may put children at an even higher risk of worse functioning (Bills et al., 2021). This study therefore retrospectively assesses the potential role that early life environmental factors play in the cognitive outcomes of MLPT children.

1. Methods

1.1. Participants

A total of 106 children participated in this study, including 42 moderate preterm, 33 late preterm, and 31 full-term children (see Table 1). The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Deusto [ETK-22/17-18] and the Drug Research Ethics Committee of the Basque Country [CEIm-E, PI2018154]. All participants provided prior written informed assent and legal tutors' consent was required at the beginning of the study.

A sample of 75 MLPT children born between 2007 and 2011 was recruited by the neonatology department from the Cruces University Hospital (Bilbao, Spain), which was supplemented by chain-referral sampling from two Spanish autonomous regions (Basque Country and Aragon) (see Fig. 1). More specifically, the neonatologist identified 168 potential participants, of whom 56 agreed to take part in the study. Additionally, 32 children were recruited after the research project was publicized; however, 13 of these were excluded (i.e., 10 children had a GA of less than 32 weeks, and three children had intraventricular hemorrhage). Participant inclusion criteria were as follows: (1) absence of brain pathology identified by neonatal cranial ultrasound; (2) lack of substantial neonatal morbidity (i.e., congenital, neurological, cardiac, or digestive malformations, necrotizing enterocolitis, or septic shock); and (3) aged 6–15 at evaluation. In addition, a full-term group of 31 participants was recruited by chain-referral sampling. Inclusion criteria for this group were: (1) GA $>$ 37 weeks; and (2) aged 6–15 at evaluation. The exclusion criteria for the three groups (i.e., moderate preterm, late preterm and full-term children) were a history of acquired brain injury, cerebral palsy or any other neurological impairment, congenital malformations, or chromosomal abnormalities.

1.2. Neuropsychological assessment

Analogical reasoning was evaluated using the matrix reasoning subtest from the Wechsler Intelligence Scale for Children (WISC-V) (Kaufman et al., 2015), whereas *receptive language* was measured by the Peabody Picture Vocabulary Test III (PPVT-III) (Dunn & Dunn, 1981). Verbal fluency was also assessed by the completion of *phonetic* (P, M, R) and *semantic fluency* tasks (category of animals), with a minute being given for each trial (Lezak et al., 2004). The Rey Auditory Verbal Learning Test (RAVLT) was used to assess *memory performance*. The measurements obtained from this test included: learning, delayed recall, and delayed recognition (Baron, 2018). *Working memory* was assessed by the use of the WISC-V (Kaufman et al., 2015); using digit span (forward, backward, and increasing) and picture span subscales. *Cognitive flexibility* was measured using the Children's Color Trails Test (CCTT) part B (Williams et al.,

Table 1
Neonatal and Sociodemographic Data.

	Moderate preterm n = 42 mean ± SD	Late preterm n = 33 mean ± SD	Full-term n = 31 mean ± SD	Statistics (*p*)
Neonatal data				
GA. wks	33.07 ± 0.81	35.42 ± 0.50	39.29 ± 1.04	**H= 94.289 (<0.001)***
[range]	[32–34]	[35,36]	[37–41]	
BW. g	1874.63 ± 336.14	2133.86 ± 463.11	3160.14 ± 351.44	**H= 62.520 (<0.001)***
Sociodemographic data				
Gender. male/female	23/19	17/16	12/19	X^2 = 1.955 (0.38)
Age. yrs [range]	11.78 ± 1.50 [7–14]	11.42 ± 1.84 [10–14]	11.42 ± 1.84 [8–14]	H= 2.329 (0.31)
Handedness right-handed/left-handed	36/6	31/2	30/1	X^2 = 3.172 (0.21)

Note: SD: standard deviation; GA: gestational age; wks: weeks; BW: birth weight; g: grams; yrs: years; H: Kruskal-Wallis test; and X^2: Chi-square test.
*Statistically significant differences between Moderate preterm<Late preterm, Moderate preterm<Full-term and Late preterm<Full-term.

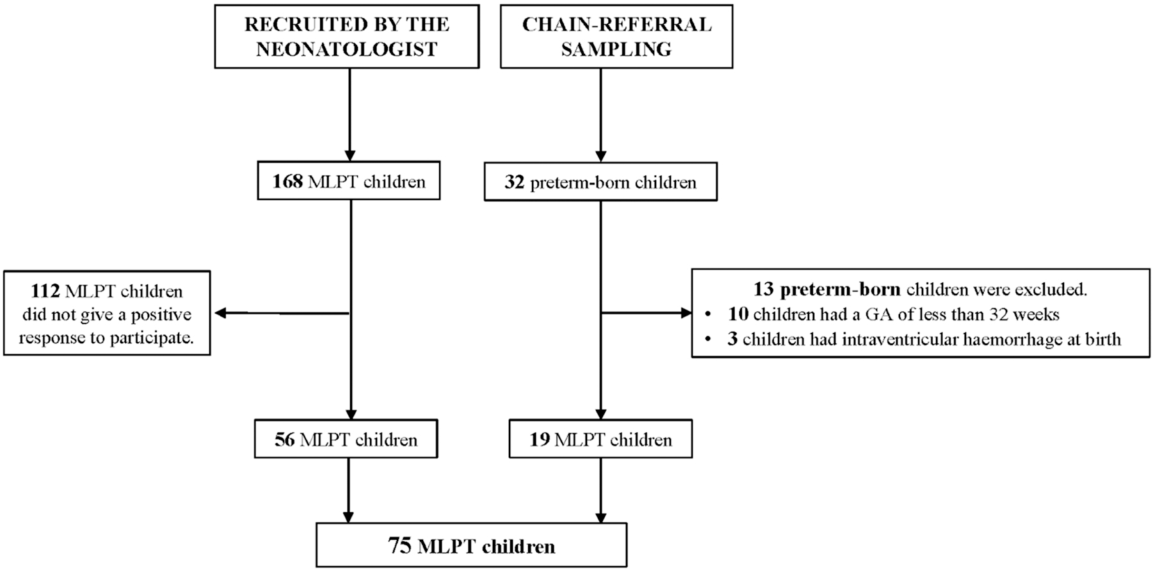

Fig. 1. Flow chart for MLPT children from June 2019 to June 2021, Note: GA: gestational age; and MLPT: moderate and late preterm.

1995), the Modified Wisconsin Card Classification Test (M-WCST) (Schretlen, 2010), and the PC measure from the Stroop Test (Stroop, 1992). Lastly, *processing speed* was assessed by means of the Stroop Test (P and C measures) (Stroop, 1992) and CCTT part A (Williams et al., 1995).

1.3. Emotional-behavioral assessment

The Child Behavior Checklist (CBCL) is a widely used questionnaire used to screen for *emotional-behavioral problems* (Achenbach & Edelbrock, 1983). It measures eight behavioral problem scales that are combined to form broadband scales of both internalizing problems (i.e., anxious/depressed, withdrawn-depressed, and somatic complaints scores) and externalizing problems (i.e., rule-breaking and aggressive behavior). Scores for social, thought, and attention problems obtained from this questionnaire were also taken into account.

The abridged 48-item version of the Conners' Parent Rating Scale (CPRS) (Goyette et al., 1978) provided a picture of children's *emotions and behavior* based on five subscales: conduct problems, learning problems, psychosomatic and impulsive-hyperactive issues, and anxiety.

1.4. Early life environmental factors

Parental care and overprotection measures were obtained using the Parental Bonding Instrument (Parker et al., 1979) to assess the participants' parents' independent behavior toward them. *Familial socioeconomic status (SES)* was measured by means of the Hollingshead Index (Hollingshead, 1975), which considered data from the occupation and education domains from the parent who had signed the informed consent. Lastly, the Adverse Childhood Experiences International Questionnaire (ACE-IQ) (World Health Organization, 2018) was used to assess the *adverse childhood experiences (ACEs)* and the ensuing health consequences.

1.5. Life satisfaction, functionality and resilience

The Satisfaction with Life Scale-Child (SWLS-C) was used to measure the participants' judgements of *satisfaction with their life* (Gadermann et al., 2010), while the WHODAS 2.0 parent's report tool was employed to establish standardized *disability levels and profiles* (Üstün et al., 2010). *Resilience* was assessed by using the 2-item Connor-Davidson Resilience scale (CD-RISC2), with higher scores reflecting greater resilience (Vaishnavi et al., 2007).

All neuropsychological assessments during childhood were conducted at DeustoPsych of the University of Deusto and at the Association of Preterm Infants of Aragon (ARAPREM).

1.6. Statistical analysis

Normal distribution of data was assessed using the Kolmogorov-Smirnov test (K-S). Any missing values (with the exception of cognitive variables) were imputed using the expectation maximization algorithm (5.62 % of the used data). All tests were standardize in order to create a composite score (Cronbach's alpha=0.89), henceforth referred to as the general cognitive functioning score. The

PPVT-III receptive language total scores, M-WCST category and perseverative error scores, RAVLT learning, delayed recall and delayed recognition measures, WISC-V matrices, digit span and picture span, phonetic and semantic fluencies, Stroop Test P, C, PC and interference measures, and CCTT part A and B were used to calculate it.

The Kruskal-Wallis test was used to analyze differences in non-normally distributed data such as neonatal data (GA and BW), age at evaluation, familial SES, ACEs, emotional-behavioral problems, life satisfaction, functionality, and resilience. The Chi-squared test was employed to assess differences in two qualitative sociodemographic characteristics (i.e., sex and handedness), and univariate analyses of variance were run to compare maternal and paternal care and overprotection measures' scores between the three groups. All early life environmental, emotional-behavioral, life satisfaction, functionality, and resilience data are reported in Table 2. Lastly, a multivariate analysis of covariance was used to compare different cognitive test scores and the general cognitive functioning composite score using age and familial SES as covariates (see Table 3). Bonferroni's post-hoc test was employed to assess differences between groups, and a Bonferroni corrected p-value ($p = 0.05/18 = 0.003$) was used in assessing significance in different cognitive tests. Partial eta squared was used to measure the effect sizes of the cognitive comparisons. To interpret this value, around.01 is a small size effect,.06 is medium, and higher than.14 is large (Cohen, 2013).

Finally, the moderating effect of early life environmental factors (i.e., maternal and paternal care, maternal and paternal overprotection, and ACEs) were independently analyzed in the relationship between the degree of maturity/immaturity at birth and general cognitive functioning score. To assess the moderation effect, five moderation analyses (see Fig. 2) were executed using the macro PROCESS 3.5 script for SPSS (released on 1 May 2020) (Hayes, 2017). Outlier analysis assessed rupture of linearity, normality, multicollinearity, and homoscedasticity, and was conducted before carrying out the moderation analyses; Mahalanobis and Cook's distances as well as Leverage parameters were used to detect possible outliers. A scatterplot and histogram check showed no sign of any outliers in the study sample. A Johnson-Neyman output was generated to determine the points at which early life environmental factors had a significant conditional effect on the degree of maturity/immaturity at birth in the prediction of the general cognitive functioning score. For all preceding raw data analyses, IBM SPSS version 26.0 (SPSS Inc., Chicago, USA) was used. Significance level was set at 0.05.

2. Results

As expected, there were significant differences in the neonatal data of the three groups (GA and BW). Greater immaturity levels were found in both preterm groups. There were no statistically significant differences in sex, age, or handedness between groups, as reported in Table 1.

Emotional-behavioral problems showed no significant differences in the present study sample (see Table 2). According to

Table 2
Early Life Environmental, Emotional-Behavioural, Life Satisfaction, Functionality and Resilience Data.

	Moderate preterm n = 42 mean ± SD	Late preterm n = 33 mean ± SD	Full-term n = 31 mean ± SD	Statistics (p)
Early Life Environmental Factors				
Maternal care measure	28.00 ± 5.18	29.49 ± 3.86	29.97 ± 3.53	F=1.890 (0.16)
Paternal care measure	26.90 ± 4.57	28.61 ± 5.88	29.20 ± 4.08	F=2.528 (0.08)
Maternal overprotection measure	15.24 ± 4.57	14.51 ± 5.88	14.96 ± 4.08	F=0.170 (0.84)
Paternal overprotection measure	14.27 ± 4.57	13.88 ± 5.88	13.94 ± 4.08	F=0.076 (0.93)
ACEs	0.36 ± 0.66	0.27 ± 0.52	0.39 ± 0.88	H=0.137 (0.93)
Familial SES	44.10 ± 14.05	36.33 ± 14.56	43.89 ± 11.93	**H=6.252 (0.04)***
Emotional-Behavioural Assessment				
Child Behaviour Checklist (CBCL)				
Internalizing problems	8.66 ± 6.10	8.82 ± 7.25	9.84 ± 8.60	H=0.027 (0.99)
Externalizing problems	8.78 ± 8.02	8.04 ± 6.30	7.56 ± 4.62	H=0.226 (0.89)
Attention problems	4.83 ± 4.23	4.67 ± 4.39	3.40 ± 3.42	H=1.833 (0.40)
Thought problems	0.73 ± 0.99	1.01 ± 1.43	0.74 ± 0.81	H=0.186 (0.91)
Social problems	2.17 ± 2.13	2.02 ± 2.64	1.63 ± 1.61	H=1.343 (0.51)
Conners Parent Rating Scale-48 items (CPRS)				
Conduct problems	4.60 ± 3.91	4.25 ± 4.22	3.53 ± 2.48	H=0.841 (0.66)
Learning problems	4.63 ± 3.16	3.03 ± 2.26	3.25 ± 2.34	H=4.273 (0.12)
Psychosomatic complaints	2.34 ± 1.66	1.53 ± 1.39	2.16 ± 1.95	H=5.318 (0.07)
Impulsivity-Hyperactivity	3.86 ± 2.84	3.63 ± 2.65	3.65 ± 2.02	H=0.128 (0.94)
Anxiety	1.77 ± 1.47	1.67 ± 1.31	1.93 ± 1.33	H=0.951 (0.62)
Life satisfaction, Functionality and Resilience				
SWLS	20.05 ± 3.41	18.94 ± 3.78	17.71 ± 3.66	**H=7.109 (0.03)**$^{¥}$
WHODAS	48.31 ± 13.05	46.23 ± 13.29	45.36 ± 10.50	H=3.296 (0.19)
Resilience	6.00 ± 1.35	5.91 ± 1.44	5.71 ± 1.39	H=1.418 (0.49)

Note: SD: standard deviation; H: Kruskal-Wallis test; F: Snedecor's F distribution; ACEs: adverse childhood experiences; SES: socioeconomic status; SWLS: satisfaction with life scale; and WHODAS: WHO Disability Assessment Schedule.
*Statistically significant differences between Late preterm<Moderate preterm. $^{¥}$Statistically significant differences between Full-term<Moderate preterm.

Table 3
Cognitive Tests Differences and General Cognitive Functioning Score among Three Groups.

	Moderate preterm n = 42 mean ± SD	Late preterm n = 33 mean ± SD	Full-term n = 31 mean ± SD	*F-Snedecor Statistic (p)*	η_p^2
Matrices (WISC V)ǂ	19.17 ± 3.57	18.64 ± 3.73	20.13 ± 3.83	1.35 (0.27)	.03
PPVT-III	124.16 ± 18.93	127.55 ± 16.45	128.95 ± 21.72	0.89 (0.41)	.02
Phonetic Fluency	25.56 ± 8.12	23.36 ± 7.14	29.67 ± 10.12	4.63 (0.012)†	.08
Semantic Fluency	18.26 ± 4.44	18.57 ± 4.66	18.97 ± 4.40	0.23 (0.80)	.00
RAVLT Learning	43.83 ± 9.50	45.92 ± 6.53	45.55 ± 10.24	0.60 (0.55)	.01
RAVLT Delayed Recall	9.71 ± 2.88	10.03 ± 1.92	10.30 ± 2.51	0.50 (0.61)	.01
RAVLT Delayed Recognition	29.03 ± 1.31	29.45 ± 1.00	29.33 ± 0.98	1.38 (0.26)	.03
Digit Span (WISC V)	27.72 ± 5.19	28.00 ± 5.59	28.66 ± 5.22	0.32 (0.73)	.01
Picture Span (WISC V)	31.44 ± 7.56	31.43 ± 8.56	29.71 ± 8.23	0.54 (0.58)	.01
WMI (WISC V)	105.50 ± 14.28	106.19 ± 17.16	105.07 ± 15.34	0.40 (.96)	.00
M-WCST Categories	6.32 ± 0.86	6.21 ± 0.95	6.47 ± 0.77	0.74 (0.48)	.02
M-WCST Perseverative Errors	1.40 ± 1.85	1.13 ± 1.16	0.91 ± 0.88	1.15 (0.32)	.02
Stroop Test (P)	84.85 ± 17.49	84.64 ± 14.30	94.29 ± 15.75	3.79 (0.026)¥	.07
Stroop Test (C)	56.93 ± 11.54	53.14 ± 8.65	63.65 ± 14.39	**7.63 (<0.0001)¤**	**.13**
Stroop Test (PC)	34.73 ± 9.26	33.43 ± 6.98	38.88 ± 10.01	3.77 (0.026)†	.07
Stroop Test (Interference)	0.36 ± 7.40	0.82 ± 4.76	1.15 ± 5.00	0.16 (0.85)	.00
CCTT Part A	24.11 ± 13.62	23.43 ± 8.89	20.08 ± 7.69	1.73 (0.18)	.03
CCTT Part B	46.01 ± 17.16	46.44 ± 9.07	37.71 ± 11.76	**6.07 (0.003)¤**	**.11**
Composite Score					
General Cognitive Functioning Score	-0.07 ± 0.65	-0.05 ± 0.43	0.22 ± 0.64	3.30 (0.041)¥	.06

Note: SD: standard deviation; F: Snedecor's F distribution; PPVT-III: Peabody picture vocabulary test-III; MWCST: Modified Wisconsin Card Sorting Test; RAVLT: Rey Auditory Verbal Learning Test; WISC V: Wechsler Intelligence Scale for Children V; WMI: working memory index; CCTT: Children's Color Trail Test; and η_p^2: partial eta squared.

ǂAvailable data for Matrices (WISC V): 41 moderate preterm, 33 late preterm and 31 full-term children.

The cognitive domains in bold are those that remained significant after Bonferroni correction was applied for multiple comparisons ($p = 0.003$).

¤Statistically significant differences between Moderate preterm<Full-term and Late preterm<Full-term. ¥Statistically significant differences between Moderate preterm<Full-term. †Statistically significant differences between Late preterm<Full-term.

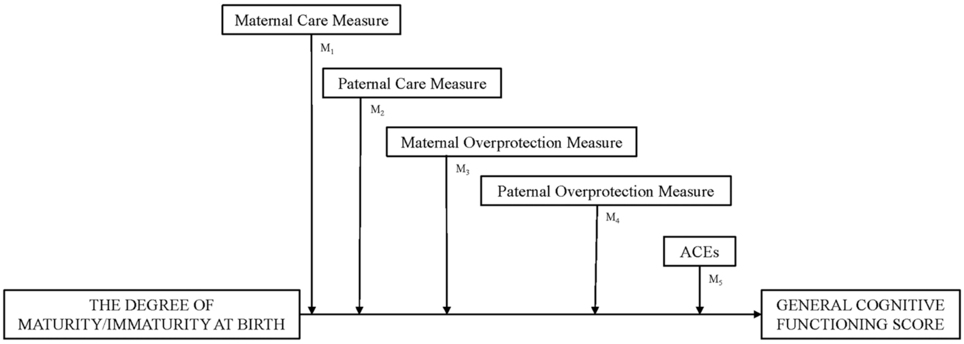

Fig. 2. Moderation Models between the Degree of Maturity/Immaturity at Birth and General Cognitive Functioning Score, Note: ACEs: adverse childhood experiences. M_1: the moderating effect of maternal care measure in the relation between the degree of maturity/immaturity at birth and general cognitive functioning; M_2: the moderating effect of paternal care measure in the relation between the degree of maturity/immaturity at birth and general cognitive functioning; M_3: the moderating effect of maternal overprotection measure in the relation between the degree of maturity/immaturity at birth and general cognitive functioning; M_4: the moderating effect of paternal overprotection measure in the relation between the degree of maturity/immaturity at birth and general cognitive functioning; and M_5: the moderating effect of ACEs in the relation between the degree of maturity/immaturity at birth and general cognitive functioning.

environmental factors, familial SES showed statistically significant differences between both preterm groups, with lower scores being obtained for those born at 35–36 weeks' GA. Satisfaction with life showed statistically significant differences between moderate preterm-born children and their full-term peers, and higher levels of satisfaction were reported by those born prematurely. Nevertheless, the analysis of the rest of environmental, functionality and resilience variables did not yield any statistically significant differences between the three groups.

Regarding the different cognitive tests, a number of statistically significant differences between the groups remained significant after a Bonferroni correction was applied for multiple comparisons ($p = 0.003$), as indicated in Table 3. Concretely, lower scores in cognitive flexibility (i.e., CCTT part B), and processing speed (i.e., C Stroop Test measure) were found in the MLPT group compared to full-term children. Moreover, poorer outcomes were observed in processing speed (i.e., P Stroop Test measure) in moderate preterm-born children compared to their full-term peers without surviving Bonferroni correction. Lastly, poorer performance in phonetic fluency, and cognitive flexibility (i.e., PC Stroop Test measure) was found in late preterm children in comparison to the full-term sample without surviving Bonferroni correction. All differences showed medium effect sizes, the largest of which were in the following cognitive domains: Stroop Test C (η_p^2=.13), and CCTT part B (η_p^2=.11). In addition, no significant differences were found between the groups in receptive language, semantic fluency, M-WCST cognitive flexibility, WISC-V analogical reasoning, digit span, picture span and working memory index, RAVLT verbal memory, and the Stroop Test interference measure. Finally, the general cognitive functioning score showed statistically significant differences, with a medium effect size (η_p^2=.06) between moderate preterm and full-term children, with the moderate preterm sample reporting lower values.

Concerning moderation analyses (see Fig. 2), familial SES could not be analyzed, given the differences in this variable between both preterm groups; therefore, it was used as a covariate in the subsequent analyses. Maternal care was the only early life environmental factor that had a moderating effect, as indicated in Table 4, and 13 % of the variance was explained by the three factors (i.e., the degree of maturity/immaturity at birth, maternal care measure and the interaction of both) in the overall model ($F(_{4,101})= 3.72, p = 0.007$, $R^2 = 0.13$). More specifically, for every unit increase in the maternal care measure as a moderator variable there was also an enhancement in the general cognitive functioning score ($\beta = 0.06$, $t(_{101})= 2.10, p = 0.03$). Only the low care measure (i.e., low care measure=25.00) showed a significant relationship between the different degrees of care (see Figs. 3 & 4). Nevertheless, having either a medium or high level of maternal care (i.e., higher than 28.84) did not further uphold a significant relationship between the degree of maturity/immaturity at birth and cognition across childhood. Additionally, whereas the overall models of all other early life environmental factors (i.e., paternal care, maternal overprotection, paternal overprotection, and ACEs) were significant, the nonsignificant interaction between predictors indicated a lack of moderation effect (see Table 4).

3. Discussion

The MLPT children who participated in this study obtained similar scores in the emotional-behavioral, life satisfaction, functionality, and resilience variables when compared to their full-term peers. However, different neuropsychological profiles were identified, as moderate preterm-born children had poorer performance in general cognitive functioning. The risk of adverse educational outcomes after being born MLPT has been suggested to rise in primary school and to remain in later years (Flores et al., 2021). Children born preterm without major neurosensory damage have shown higher levels of learning impairment than the normative population across their final years of primary school (Bucci et al., 2020). Furthermore, according to our findings, disparities in maternal care moderated the effect of preterm birth on general cognitive functioning during childhood, markedly so in those with greater neonatal immaturity. In other words, high maternal care buffered the impact of greater immaturity levels (i.e., smaller GA) on cognition. Parental responsivity has been associated with enhanced cognition in preterm-born infants (Neel et al., 2018); in particular, regarding reduced expression of developmental psychopathology and executive dysfunction after being born with a very small GA (Vanes et al., 2021).

In general, our results are in line with previous studies that found that preterm children with low risk of having neurodevelopmental deficits achieve poorer cognitive scores than those born at term (Arhan et al., 2017), even in adulthood (Fernández de Gamarra-Oca et al., 2021). In a context of low medical and environmental risk, consistently with Hodel and colleagues (2017), MLPT infants displayed subtle alterations in cognitive skills. Specifically, poorer performance in cognitive flexibility, and processing speed was found in MLPT children. Similarly, Martínez-Nadal and Bosch (2021) also showed the presence of mild difficulties in executive functioning, short-term verbal memory, literacy skills, and attention during childhood in a late preterm sample. On the other hand, phonetic fluency was revealed to be distinguishing feature in the neuropsychological profiles of MLPT children in our study. Late preterm children reported poorer scores in phonetic fluency, on which they are likely to continue to perform poorly at later ages (Putnick et al., 2017).

Even though cognitive performance was within normal range, some differences were found in this study in general cognitive functioning between those with a smaller GA (i.e., moderate preterm group) and those born at term. In fact, our findings are in

Table 4
Moderation Analyses of Early Life Environmental Factors between the Degree of Maturity/Immaturity at Birth and General Cognitive Functioning Score.

Criterion variable	*R*	*R^2*	*β*	*t*	*p*	Predictors
General cognitive functioning score	0.36	0.13	-0.03	-2.01	**0.04**	Maternal care measure
	0.34	0.11	-0.02	-1.62	0.11	Paternal care measure
	0.30	0.09	0.003	0.19	0.85	Maternal overprotection measure
	0.31	0.10	-0.01	-0.93	0.35	Paternal overprotection measure
	0.32	0.10	0.06	0.65	0.51	ACEs

Note: t: Student's t-test; and ACEs: adverse childhood experiences.
From the general model *R and R^2*.
From the interaction model *β*, *t* and *p*.

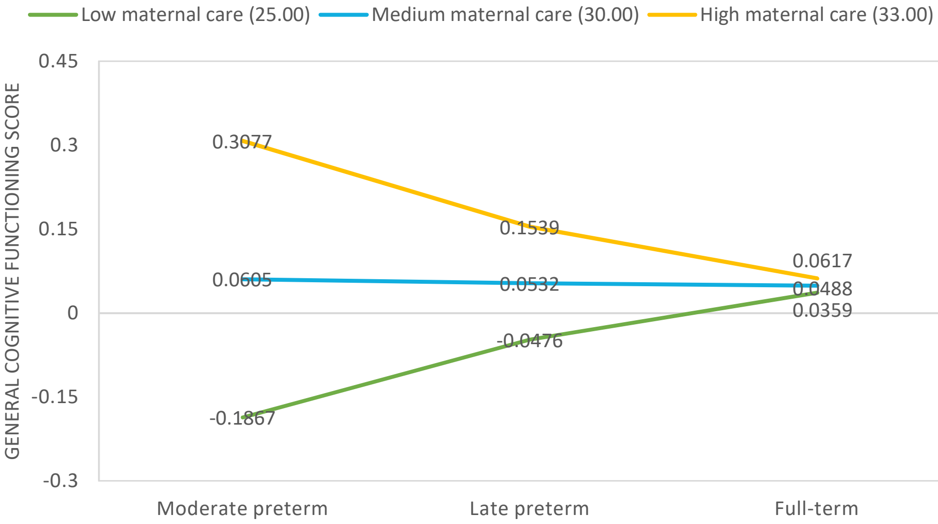

Fig. 3. Moderating Effect of Maternal Care Measure between the Degree of Maturity/Immaturity at Birth and General Cognitive Functioning Score, Note: Low maternal care (green line/bottom line) showed a significant relationship between the degree of maturity/immaturity at birth and cognition across childhood. Nevertheless, either having a medium (blue line/middle line) or high level (yellow line/top line) of maternal care did not further uphold a significant relationship between the degree of maturity/immaturity at birth and cognition across childhood.(For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

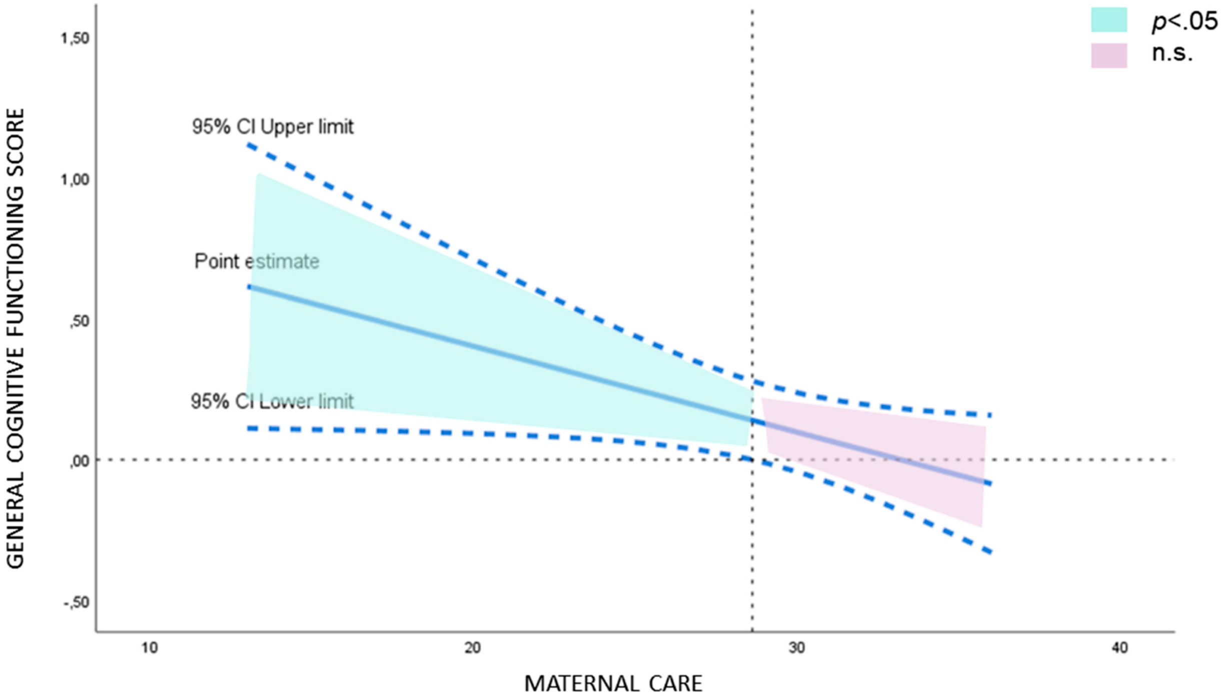

Fig. 4. Johnson-Neyman Moderation Analysis Plot.

agreement with the finding that prematurity in the absence of neonatal brain injury leads to poorer cognition, i.e., preterm birth to any degree affects cognition, resulting in altered neurodevelopment over time (Allotey et al., 2018).

According to Sansavini et al. (2011), preterm birth results in atypical developmental trajectories, which may vary depending on the complex interaction of biological and environmental factors. Long-term cognitive outcomes may be improved by means of factors that go beyond initial neonatal care (i.e., care-related risk factors) in the preterm-born population (Wolke, 2019). For instance, optimal school outcomes in preterm children have been related to greater parental education, child nurturing by both parents, and stability in family composition and geographic residence (Gross et al., 2001). Parent-child attachment has also been associated with brain development in typically developing children (Hidalgo et al., 2019); even in preterm samples (Treyvaud et al., 2021). Our findings suggest that maternal care moderated the effect of preterm birth on general cognitive functioning. That is, differences in maternal care during childhood might interfere with brain reorganization after prematurity and affect cognitive functioning during childhood, especially in moderate preterm-born children. Nevertheless, maternal responsivity to nonverbal cues and emotional harmony have been linked to verbal and performance intellectual quotients in both preterm-born and full-term children (Erickson et al., 2018).

The results in this study follow in the footsteps of a previous study that suggested that parents have an important role in shaping the long-term neurodevelopment of high-risk preterm newborns; however, the paternal care measure did not moderate this relationship. Likewise, this study found that a high maternal care measure prevented the impact of prematurity on general cognition during childhood. At the very least, positive parenting has been shown to have long-lasting advantages for preterm-born infants (Cheong et al., 2020). Nonmedical interventions (i.e., Family Nurture Intervention) designed to enhance mother-infant emotional connection have a beneficial impact on preterm-born neurobehavioral functioning at term equivalent age and 18 months (Welch & Myers, 2016). Hence, through these evidence-based interventions, cognition could also be improved. Lastly, our study's findings did not show overprotection measures and ACEs to be moderators of the relationship between the degree of maturity/immaturity at birth and cognition in low-risk preterm children.

4. Limitations

In contrast with previous studies that used heterogeneous preterm samples, this study succeed to reach comparable groups through their neonatal and sociodemographic data, thus fostering the generalizability of the results. However, differences in familial SES between both preterm groups compels us to treat the results from this study with caution. Another limitation was that there was no longitudinal follow-up from childhood onward in order to assert whether neurodevelopmental outcomes persisted, worsened, or improved over time. Moreover, the sample size was small, and familial SES was only obtained from the parent who completed the questionnaires. Despite no statistically significant differences being shown in which the late preterm group scored lower than moderate preterm-born children did, the mean scores in phonetic fluency and processing speed of late preterm children were lower than those of their preterm-born peers. Since late preterm children exhibited lower values in familial SES, adjustments for the differences have been done. However, caution would be required regarding the outcomes of late preterm birth effects. Furthermore, early life environmental factors were collected retrospectively as well as the theory of attachment on which this study is based has lately been considered to offer an increasingly complex picture of the principles that regulate mother-infant emotional behavior. Future studies should therefore contemplate alternative models such as emotional connection and calming cycle theories (Ludwig & Welch, 2019). Finally, the disparities concerning satisfaction with life were not further explored, although as reported by Gire et al. (2020), the child's overall intellectual ability has been found to be independent of quality of life in cases of extreme prematurity without major neurodevelopmental disability.

5. Conclusions

Our findings show that the participating MLPT children displayed poorer performance in a number of cognitive domains, which might potentially affect their long-lasting academic performance (de Jong et al., 2012). In our opinion, establishing different neuropsychological profiles among children born preterm according to their clinical conditions may support the development of specific intervention programs during childhood if deemed necessary. Moreover, considering preterm-born children's biological vulnerability, parenting quality may be even more significant for developmental consequences (Toscano et al., 2020). In fact, although mothers of preterm children are not less sensitive or responsive than mothers of full-term children (Bilgin & Wolke, 2015), the availability of appropriate resources, mainly for promoting a healthy maternal care, might lead to an improved preterm neuropsychological profile later in life. However, the neurobiological mechanism by which this moderating effect happens remains unknown. Therefore, MRI studies may be necessary to understand whether there are structural or functional alterations that could explain the current findings. More research is needed in MLPT samples to assert the clinical sway of the parent-child care on cognition, since family factors have been stronger predictors of school performance than perinatal complications (Gross et al., 2001).

Ethics approval statement

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of the University of Deusto [ETK-22/17–18] and the Drug Research Ethics Committee of the Basque Country [CEIm-E, PI2018154].

Funding statement

This research is funded by the Spanish Ministry of Science, Innovation and Universities [L. Zubiaurre-Elorza (PSI2017-83657-P)]; the Department of Education and Science of the Basque Government [N. Ojeda (IT946-16)]; and the Department of Education of the Basque Government [L. Fernández de Gamarra-Oca (PRE_2019_1_0105)].

Data Availability

The datasets generated and/or analysed during this study are available from the corresponding author upon reasonable request.

Acknowledgements

We would like to especially thank the families and the children who participated, as well as ARAPREM for enabling us to carry out this study.

Patient consent statement

All participants provided prior written assent and their legal guardians' informed consent was obtained before each subject's participation.

Conflict of interest disclosure

No conflicting financial interests exist.

References

Achenbach, T. M., & Edelbrock, C. S. (1983). *Manual for the child behavior checklist and revised child behavior profile* (p. 230). Burlington: University of Vermont, Department of Psychiatry.

Allotey, J., Zamora, J., Cheong-See, F., Kalidindi, M., Arroyo-Manzano, D., Asztalos, E., & Thangaratinam, S. (2018). Cognitive, motor, behavioural and academic performances of children born preterm: A meta-analysis and systematic review involving 64 061 children. *BJOG: An International Journal of Obstetrics & Gynaecology, 125*(1), 16–25. https://doi.org/10.1111/1471-0528.14832

Arhan, E., Gücüyener, K., Soysal, Ş., Şalvarlı, Ş., Gürses, M. A., Serdaroğlu, A., & Atalay, Y. (2017). Regional brain volume reduction and cognitive outcomes in preterm children at low risk at 9 years of age. *Child's Nervous System, 33*(8), 1317–1326. https://doi.org/10.1007/s00381-017-3421-2

Baron, I. S. (2018). Neuropsychological evaluation of the child: Domains. *Methods, & case studies*. Oxford University Press.

Bilgin, A., & Wolke, D. (2015). Maternal sensitivity in parenting preterm children: a meta-analysis. *Pediatrics, 136*(1), e177–e193. https://doi.org/10.1542/peds.2014-3570

Bills, S. E., Johnston, J. D., Shi, D., & Bradshaw, J. (2021). Social-environmental moderators of neurodevelopmental outcomes in youth born preterm: A systematic review. *Child Neuropsychology, 27*(3), 351–370. https://doi.org/10.1080/09297049.2020.1861229

Boyle, E. M., Johnson, S., Manktelow, B., Seaton, S. E., Draper, E. S., Smith, L. K., & Field, D. J. (2015). Neonatal outcomes and delivery of care for infants born late preterm or moderately preterm: A prospective population-based study. *Archives of Disease in Childhood-Fetal and Neonatal Edition, 100*(6), F479–F485. https://doi.org/10.1136/archdischild-2014-307347

Bucci, S., Bevilacqua, F., De Marchis, C., Coletti, M. F., Gentile, S., & Dall'Oglio, A. M. (2020). Learning abilities in a population of italian healthy preterm children at the end of primary school. *International Journal of Environmental Research and Public Health, 17*(20), 7599. https://doi.org/10.3390/ijerph17207599

Cheong, J. L., Burnett, A. C., Treyvaud, K., & Spittle, A. J. (2020). Early environment and long-term outcomes of preterm infants. *Journal of Neural Transmission, 127*(1), 1–8. https://doi.org/10.1007/s00702-019-02121-w

Cohen, J., 2013. Statistical power analysis for the behavioral sciences. Academic press.

de Jong, M., Verhoeven, M., & van Baar, A. L. (2012). School outcome, cognitive functioning, and behaviour problems in moderate and late preterm children and adults: A review. *Seminars in Fetal and Neonatal Medicine, 17*(3), 163–169. https://doi.org/10.1016/j.siny.2012.02.003

Dimitrova, R., Pietsch, M., Christiaens, D., Ciarrusta, J., Wolfers, T., Batalle, D., & O'Muircheartaigh, J. (2020). Heterogeneity in brain microstructural development following preterm birth. *Cerebral Cortex, 30*(9), 4800–4810. https://doi.org/10.1093/cercor/bhaa069

Dunn, L. M., & Dunn, L. M. (1981). Manual for the peabody picture vocabulary test-revised. Circle pines. *MN*. American Guidance Service.

Erickson, S. J., Duvall, S. W., MacLean, P. C., Tonigan, J. S., Ohls, R. K., & Lowe, J. R. (2018). Mother-child interactive behaviors and cognition in preschoolers born preterm and full term. *Journal of Child and Family Studies, 27*(11), 3687–3700. https://doi.org/10.1007/s10826-018-1196-z

Fernández de Gamarra-Oca, L. F., Ojeda, N., Gómez-Gastiasoro, A., Peña, J., Ibarretxe-Bilbao, N., García-Guerrero, M. A., & Zubiaurre-Elorza, L. (2021). Long-term neurodevelopmental outcomes after moderate and late preterm birth: A systematic review. *The Journal of Pediatrics, 237*, 168–176. https://doi.org/10.1016/j.jpeds.2021.06.004

Flores, C. T., Gerstein, A., Phibbs, C. S., & Sanders, L. M. (2021). Short-term and long-term educational outcomes of infants born moderately and late preterm. *The Journal of Pediatrics, 232*, 31–37. https://doi.org/10.1016/j.jpeds.2020.12.070

Gadermann, A. M., Schonert-Reichl, K. A., & Zumbo, B. D. (2010). Investigating validity evidence of the satisfaction with life scale adapted for children. *Social Indicators Research, 96*(2), 229–247. https://doi.org/10.1007/s11205-009-9474-1

Gire, C., Tosello, B., Marret, S., Cambonie, G., Souksi-Medioni, I., Müller, J. B., & Resseguier, N. (2020). Specific cognitive correlates of the quality of life of extremely preterm school-aged children without major neurodevelopmental disability. *Pediatric Research, 88*(4), 642–652. https://doi.org/10.1038/s41390-020-0795-8

Goyette, C. H., Conners, C. K., & Ulrich, R. F. (1978). Normative data on revised Conners parent and teacher rating scales. *Journal of Abnormal Child Psychology, 6*(2), 221–236. https://doi.org/10.1007/bf00919127

Gross, S. J., Mettelman, B. B., Dye, T. D., & Slagle, T. A. (2001). Impact of family structure and stability on academic outcome in preterm children at 10 years of age. *The Journal of Pediatrics, 138*(2), 169–175. https://doi.org/10.1067/mpd.2001.111945

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford publications.

Hidalgo, A. P. C., Muetzel, R., Luijk, M. P., Bakermans-Kranenburg, M. J., El Marroun, H., Vernooij, M. W., & Tiemeier, H. (2019). Observed infant-parent attachment and brain morphology in middle childhood–A population-based study. *Developmental Cognitive Neuroscience, 40*, Article 100724. https://doi.org/10.1016/j.dcn.2019.100724

Hodel, A. S., Senich, K. L., Jokinen, C., Sasson, O., Morris, A. R., & Thomas, K. M. (2017). Early executive function differences in infants born moderate-to-late preterm. *Early Human Development, 113*, 23–30. https://doi.org/10.1016/j.earlhumdev.2017.07.007

Hollingshead, A.B., 1975. Four factor index of social status. (Unpublished Working Paper).

Kaufman, A. S., Raiford, S. E., & Coalson, D. L. (2015). *Intelligent testing with the WISC-V*. John Wiley & Sons.

Lezak, M. D., Howieson, D. B., Loring, D. W., & Fischer, J. S. (2004). *Neuropsychological assessment*. USA: Oxford University Press.

Ludwig, R. J., & Welch, M. G. (2019). Darwin's other dilemmas and the theoretical roots of emotional connection. *Frontiers in Psychology, 10*, 683. https://doi.org/10.3389/fpsyg.2019.00683

Martínez-Nadal, S., & Bosch, L. (2021). Cognitive and learning outcomes in late preterm infants at school age: A systematic review. *International Journal of Environmental Research and Public Health, 18*(1), 74. https://doi.org/10.3390/ijerph18010074

McBryde, M., Fitzallen, G. C., Liley, H. G., Taylor, H. G., & Bora, S. (2020). Academic outcomes of school-aged children born preterm: a systematic review and meta-analysis. *JAMA Network Open, 3*(4). https://doi.org/10.1001/jamanetworkopen.2020.2027

McMahon, G. E., Treyvaud, K., Spencer-Smith, M. M., Spittle, A. J., Lee, K. J., Doyle, L. W., & Anderson, P. J. (2022). Parenting and neurobehavioral outcomes in children born moderate-to-late preterm and at term. *The Journal of Pediatrics, 241*, 90–96. https://doi.org/10.1016/j.jpeds.2021.10.038

Neel, M. L. M., Stark, A. R., & Maitre, N. L. (2018). Parenting style impacts cognitive and behavioural outcomes of former preterm infants: A systematic review. *Child: Care Health and Development, 44*(4), 507–515. https://doi.org/10.1111/cch.12561

Parker, G., Tupling, H., & Brown, L. B. (1979). A parental bonding instrument. *British Journal of Medical Psychology, 52*(1), 1–10. https://doi.org/10.1111/j.2044-8341.1979.tb02487.x

Pérez-Pereira, M., Fernández, M. P., Gómez-Taibo, M. L., Martínez-López, Z., & Arce, C. (2020). A follow-up study of cognitive development in low risk preterm children. *International Journal of Environmental Research and Public Health, 17*(7), 2380. https://doi.org/10.3390/ijerph17072380

Putnick, D. L., Bornstein, M. H., Eryigit-Madzwamuse, S., & Wolke, D. (2017). Long-term stability of language performance in very preterm, moderate-late preterm, and term children. *The Journal of Pediatrics, 181*, 74–79. https://doi.org/10.1016/j.jpeds.2016.09.006

Raju, T. N. K., Buist, A. S., Blaisdell, C. J., Moxey-Mims, M., & Saigal, S. (2017). Adults born preterm: A review of general health and system-specific outcomes. *Acta Paediatrica, 106*(9), 1409–1437. https://doi.org/10.1111/apa.13880

Ross, G. S., & Perlman, J. M. (2019). Relationships of biological and environmental factors to cognition of preterm infants in the toddler and preschool periods. *Developmental Psychobiology, 61*(7), 1100–1106. https://doi.org/10.1002/dev.21855

Sansavini, A., Guarini, A., & Caselli, M. C. (2011). Preterm birth: Neuropsychological profiles and atypical developmental pathways. *Developmental Disabilities Research Reviews, 17*(2), 102–113. https://doi.org/10.1002/ddrr.1105

Schretlen, D.J., 2010. Modified Wisconsin Card Sorting Test®: M-WCST; Professional Manual. PAR.

Shapiro-Mendoza, C. K., & Lackritz, E. M. (2012). Epidemiology of late and moderate preterm birth. *Seminars in Fetal and Neonatal Medicine, 17*(3), 120–125. https://doi.org/10.1016/j.siny.2012.01.007

Stroop, J. R. (1992). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology: General, 121*(1), 15. https://doi.org/10.1037/0096-3445.121.1.15

Toscano, C., Soares, I., & Mesman, J. (2020). Controlling parenting behaviors in parents of children born preterm: A meta-analysis. *Journal of Developmental & Behavioral Pediatrics, 41*(3), 230–241. https://doi.org/10.1097/DBP.0000000000000762

Treyvaud, K., Thompson, D. K., Kelly, C. E., Loh, W. Y., Inder, T. E., Cheong, J. L., & Anderson, P. J. (2021). Early parenting is associated with the developing brains of children born very preterm. *The Clinical Neuropsychologist, 35*(5), 885–903. https://doi.org/10.1080/13854046.2020.1811895

Üstün, T. B., Kostanjsek, N., Chatterji, S., & Rehm, J. (2010). *Measuring health and disability: Manual for WHO disability assessment schedule WHODAS 2.0*. World Health Organization.

Vaishnavi, S., Connor, K., & Davidson, J. R. (2007). An abbreviated version of the Connor-Davidson Resilience Scale (CD-RISC), the CD-RISC2: Psychometric properties and applications in psychopharmacological trials. *Psychiatry Research, 152*(2–3), 293–297. https://doi.org/10.1016/j.psychres.2007.01.006

Vanes, L. D., Hadaya, L., Kanel, D., Falconer, S., Ball, G., Batalle, D., & Nosarti, C. (2021). Associations between neonatal brain structure, the home environment and childhood outcomes following very preterm birth. *Biological Psychiatry Global Open Science, 1*(2), 146–155. https://doi.org/10.1016/j.bpsgos.2021.05.002

Walsh, J. M., Doyle, L. W., Anderson, P. J., Lee, K. J., & Cheong, J. L. Y. (2014). Moderate and late preterm birth: Effect on brain size and maturation at term-equivalent age. *Radiology, 273*(1), 232–240. https://doi.org/10.1148/radiol.14132410

Welch, M. G., & Myers, M. M. (2016). Advances in family-based interventions in the neonatal ICU. *Current Opinion in Pediatrics, 28*(2), 163–169. https://doi.org/10.1097/MOP.0000000000000322

Williams, J., Rickert, V., Hogan, J., Zolten, A. J., Satz, P., D'Elia, L. F., & Light, R. (1995). Children's color trails. *Archives of Clinical Neuropsychology, 10*(3), 211–223.

Wolke, D. (2019). Is social inequality in cognitive outcomes increased by preterm birth–related complications? *JAMA Network Open, 2*(5). https://doi.org/10.1001/jamanetworkopen.2019.2902. e192902-e192902.

Wong, H. S., & 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. https://doi.org/10.1007/s10995-012-1183-8

World Health Organization , 2018. Adverse childhood experiences international questionnaire (ACE-IQ).

Yaari, M., Mankuta, D., Harel-Gadassi, A., Friedlander, E., Bar-Oz, B., Eventov-Friedman, S., & Yirmiya, N. (2018). Early developmental trajectories of preterm infants. *Research in Developmental Disabilities, 81*, 12–23. https://doi.org/10.1016/j.ridd.2017.10.018