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Distinct Profiles of Attention in Children Born Moderate-to-Late Preterm at 6 Years

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Abstract

Objective Attention difficulties are commonly reported by caregivers in school-aged children born moderate-to-late preterm (MLPT; 32–36 weeks' gestation). We aimed to assess distinct aspects of attentional functioning (i.e. orienting, alerting and executive attention, processing speed and behavioral components) in children born MLPT and full term (FT), profiles of attentional functioning, and associated risk factors such as preterm birth. **Methods** Participants were 170 (87 MLPT and 83 FT) children, evaluated on cognitive and behavioral attention aspects at 6 years of age. We used a variable-centered approach to compare attentional functioning of children born MLPT and FT at group level, and a person-centered approach to identify profiles of attentional functioning. Neonatal and demographic characteristics of these profiles were compared. **Results** The variable-centered approach showed that at group level children born MLPT had poorer orienting attention and processing speed, and behavioral attention than children born FT. The person-centered approach revealed four profiles: (a) normal attentional functioning, (b) overall poorer attention, (c) poorer cognitive attention, and (d) behavioral attention problems. Children born MLPT were overrepresented in each of the suboptimal attention profiles, and were more dispersed across profiles than children born FT. **Conclusions** Children born MLPT are at increased risk of difficulties in some attention aspects, but at group level differences with children born FT are small. However, children born MLPT show considerable variation in the nature of attention difficulties and are twice as likely to show a suboptimal attention profile, indicating a cumulation of poorer attention scores.

Key words: attention; moderate-to-late preterm; patterns; prematurity; profiles; school-age.

Introduction

Worldwide roughly 13 million babies are born moderate-to-late preterm (MLPT) at 32–36 weeks' gestation (Blencowe et al., 2012) every year. These children are at increased risk of poorer developmental outcomes (De Jong, Verhoeven, & Van Baar, 2012). One of the most consistent concerns is that at school-age children born MLPT have greater difficulties in attentional functioning compared to children born full term (FT; 37–40 weeks' gestation; Cserjesi et al., 2012; Talge et al., 2010; Van Baar, Vermaas, Knots, De Kleine, & Soons, 2009). Attention skills are essential for acquiring new skills and knowledge (Bahrick, Todd, & Soska, 2018), and problems in attention negatively impact academic (Jaekel, Wolke, & Bartmann, 2013; Mulder, Pitchford, & Marlow, 2010; Rose, Feldman, & Jankowski, 2011) and social competence (Andrade, Brodeur, Waschbusch, Stewart, & McGee, 2009). To allow for tailored treatment or prevention of further problems, early assessment and recognition of specific attention difficulties is needed, especially for children at risk such as children born preterm.

Attention is conceptualized as a multidimensional construct, involving various distinct skills. Posner and Petersen (1990) and Mirsky (1991) proposed the two most widely used neuropsychological models of attention. Posner and Petersen distinguished three attentional networks. The *orienting* network manages the orientation of attention toward or from a certain stimulus. The *alerting* network attends to achieving and maintaining a focused state. The *executive* network regulates more complex forms of attention, such as goal-directed and planned attention (Petersen & Posner, 2012; Posner & Petersen, 1990). Mirsky's original model also consisted of three factors of attention, comparable to the three networks of Posner and Petersen's model. *Selective attention* reflects the ability to focus on relevant information in the environment (i.e. the orienting network). *Sustained attention* refers to the ability to achieve and maintain attention for a considerable interval of time (i.e. the alerting network). *Shifting attention* is defined as the ability to move attention from one stimulus or activity to another, and is part of the executive network (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Mirsky & Duncan, 2001). Mirsky (1996) later extended his model and added that *stability*, i.e. the ability to respond fast and consistently, is essential for attentional functioning. Stability can be measured with variability of reaction times (Mirsky, 1996), which is commonly referred to as *processing speed*. In addition to these cognitive attention skills, problems can also be presented behaviorally, e.g. low concentration, high distractibility, and trouble completing daily tasks. In sum, various distinct cognitive and behavioral aspects reflect attentional functioning, and thus deficits in attention may be specific with different implications for functioning.

Children born preterm show difficulties in attention, and to understand if specific aspects of attention may be impaired it is important to distinguish these different aspects. Several studies assessed multiple attention aspects in school-aged (6–12 years) children born very preterm (VPT; <30 weeks' gestation), but results are inconsistent. Some found that children born VPT show poorer functioning in all aspects of attention assessed (selective attention, sustained attention, and shifting/executive attention) compared to children born FT (Anderson et al., 2011; Murray et al., 2014). Others reported difficulties only in specific aspects of attention (Bayless & Stevenson, 2007; Lean, Melzer, Bora, Watts, & Woodward 2017; Mulder, Pitchford, & Marlow, 2011) At school-age, children born VPT also exhibit slower processing speed (Anderson & Doyle, 2003; Mulder et al., 2011; Murray et al, 2014; Rose & Feldman, 1996) and higher rates of behavioral attention problems than children born FT (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009). While these studies have focused on children born VPT, much less is known about attentional functioning in children born MLPT.

In a meta-analysis, Mulder, Pitchford, Hagger, and Marlow (2009) reported poorer selective and sustained attention skills in children born preterm (<37 weeks' gestation) compared to children born FT. Differences in performance were more subtle yet still apparent for children born at later gestation. We previously compared several aspects of attentional functioning at group-level in our sample of children born MLPT. As early as 18 months of age children born MLPT showed poorer orienting (i.e. selective attention) and alerting (i.e. sustained) attention on an eye-tracking task, without any differences in executive and behavioral attention (De Jong, Verhoeven, & Van Baar, 2015). At 6 years of age more attention behavior problems and poorer processing speed were found compared to children born FT (Bogičević, Verhoeven, & Van Baar, 2019). Our previous findings indicate that children born MLPT show more difficulties in some aspects of attention compared to children born FT.

Abovementioned studies used variable-centered approaches which are generally suitable to detect differences in attentional functioning between preterm and FT children at group level, showing a general risk of prematurity relative to FT birth. Children born preterm can, however, exhibit different patterns of functioning due to heterogeneity in neonatal and demographic factors (Poehlmann-Tynan et al., 2015). Some children may perform poorer across all attention aspects, some might only show specific attention difficulties, while other children will exhibit average attentional functioning. Considering that a variable-centered approach is not aimed at examining patterns across a set of measures, differences in patterns of attentional functioning in children born preterm may not become apparent when comparing them to children born FT at group level. A person-centered approach acknowledges such heterogeneity by considering subgroups of individuals with similar patterns of performance across several outcomes and can help detect different profiles of attentional functioning. Previous studies that implemented person-centered approaches indeed showed the added value of examining profiles of developmental outcomes—other than attentional functioning—in children born preterm, as these children showed more heterogeneity in their profiles than their peers born FT (Burnett et al., 2019; Lean, et al., 2020). Moreover, classifying children according to these profiles not only enables us to examine co-occurrence of attention difficulties but also offers new perspectives to investigate risk factors associated with attentional functioning. In addition to preterm birth, other biological and social factors such as lower gestational age, lower birth weight, male gender, and low parental education have been related to poorer attentional functioning (Eryigit-Madzwamuse & Wolke, 2015; McGrath et al., 2005) and may be predictive for specific profiles of attention. Applying a variable- and a person-centered approach simultaneously could aid improved understanding of the level and pattern of attention difficulties in children born MLPT.

This study aimed to assess differences between children born MLPT and FT in several aspects of attention at group level by applying a variable-centered approach. Based on prior research in our own and other MLPT samples, we expected that children born MLPT would perform poorer on orienting, alerting, and behavioral attention, and processing speed, but not on executive and shifting attention compared to children born FT. Using a person-centered approach, we aimed to identify profiles of attentional functioning in the total sample of children born MLPT and FT and to evaluate if these profiles are associated with neonatal and demographic characteristics, such as MLPT birth. Based on prior research using person-centered approaches, we expected that children born MLPT would show more variability across profiles of attentional functioning. Finally, we hypothesized that lower gestational age, lower birth weight, male gender, and lower parental education would be associated with profiles of poorer attentional functioning.

Methods

Participants and Procedure

Children born MLPT and FT born between March 2010 and April 2011 were recruited at 10 months of age from nine hospitals around Utrecht, the Netherlands, as part of the STAP (Study on Attention of Preterm children) Project. Exclusion criteria were dysmaturity, multiple births, admission to a tertiary Neonatal Intensive Care Unit, severe congenital malformations, antenatal substance abuse, and chronic antenatal use of psychiatric drugs by the mother. Participants in the current study were 87 children born MLPT and 83 children born FT. Neonatal and demographic characteristics of the participating children are presented in Table I.

At 6 years of age children underwent neuropsychological assessment in two visits, administered by trained examiners who were blind to birth status. Children born MLPT were invited at corrected age to exclude subtle maturational effects. Mothers and teachers completed questionnaires. The Utrecht Medical Center Ethics Committee approved the study and both parents provided written informed consent.

Table I *Neonatal and Demographic Characteristics of the FT and MLPT Groups*

	FT ($n = 83$)	MLPT ($n = 87$)
Corrected age in years		
Mean (SD)	6.07 (0.06)	6.05 (0.05)
Range	6.0–6.2	6.0–6.3
Gestational age		
Mean (SD)	39.54 (0.94)	34.67 (1.36)***
32 weeks (%)		10%
33 weeks (%)		11%
34 weeks (%)		18%
35 weeks (%)		24%
36 weeks (%)		37%
37 weeks (%)	4%	
38 weeks (%)	12%	
39 weeks (%)	32%	
40 weeks (%)	40%	
41 weeks (%)	12%	
Birth weight in grams		
Mean (SD)	3,604 (450)	2,523 (492)***
Range	2,795–5,330	1,420–3,635
Days in hospital		
Mean (SD)	0.40 (1.06)	11.86 (10.14)***
Range	0–6	1–42
Need for oxygen (%)	0%	26%***
Phototherapy (%)	0%	35%***
Hypoglycemia (%)	0%	5%*
Gender (% boys)	45%	58%
Ethnic origin (% Dutch)	96%	95%
Maternal education (%)		
Low	2%	8%
Medium	10%	35%*
High	88%	57%*

Note. *$p < .05$, ***$p < .001$; Maternal education: Low = no education, elementary school, special education or lower general secondary education; Medium = secondary education or vocational education; High = college, university or higher.

Measures

Cognitive Assessment

A battery of neuropsychological tasks was administered to assess multiple distinct cognitive aspects of attention. Two standardized subtests (Coding and Symbol Search) from the Wechsler Preschool and Primary Scale of Intelligence (WPPSI-III-NL; Hendriksen & Hurks, 2010) were used to assess *Processing Speed IQ* (*PSQ*). Scores were based on Dutch norms with means of 100 and SDs of 15 with good reliability and validity (Hendriksen & Hurks, 2010).

We also administered the novel Cognitive Task Application (Rommelse, Hartman, Brinkman, Slaats-Willemse, De Zeeuw, & Luman, 2018); a child-friendly computerized task with a total duration of 30–35 min. We used four measures of processing speed and attention skills: *reaction time*, *variability in reaction time*, *inattention*, and *sustained attention*.

Table II *Measures and Loadings on Components of Attentional Functioning*

	PCA aspects of attention		
	Orienting attention and processing speed	Alerting attention	Behavioral attention problems
Measure			
COTAPP reaction time	**.82**	.05	−.05
COTAPP variability in reaction time	**.74**	−.20	−.11
COTAPP inattention	**.74**	.34	.06
NEPSY auditory attention	**−.64**	.14	.11
TEA-Ch score!	**−.51**	.17	−.14
WPPSI PSQ	**−.47**	.13	−.19
TEA-Ch sky search	−.01	**.82**	.02
COTAPP sustained attention	0.10	**−.58**	.08
TRF/6-18 inattention	−.05	.06	**.88**
CBCL/6-18 attention problems	.01	−.09	**.83**
Variance accounted for per component	31.07%	14.43%	10.17%

Note. Relevant loadings (≤−.40 or ≥.40) are printed in bold.

Reaction time was measured by the mean reaction time across all tasks in which children were required to respond fast and accurately. *Variability in reaction time* represents the (in)stability of these reaction times, measured by the intra-individual coefficient of variance. *Inattention* was measured by the amount of extremely slow responses across all tasks, defined as responses slower than the child's median reaction time + 3 SDs. *Sustained attention* was assessed by calculating the difference in reaction times of identical tasks at the start and the end of the assessment. Standardized z-scores, with lower scores indicating better performance, were based on Dutch norms, with moderate to good reliability (split-half: $r = .59–.95$; test–retest: $r = .37–.85$) and validity (Rommelse et al., 2018).

The Auditory Attention subtest from the NEPSY-II (Zijlstra, Kingma, Swaab, & Brouwer, 2010), aimed at assessing *auditory selective attention*, required children to listen to words on a 3-min audio recording and point to a colored circle when hearing the color name, while ignoring other color names and irrelevant words (maximum number of correct responses = 20). The subtest has good test–retest reliability ($r = .65$; Zijlstra et al., 2010).

Two subtests from the Test of Everyday Attention in Children (TEA-Ch; Manly, Roberston, Anderson, & Nimmo-Smith, 2004) were administered. Sky Search, aimed at assessing *visual selective attention*, required children to circle targets (pairs of identical space ships) while ignoring irrelevant targets (pairs of differing space ships) under time pressure (maximum number of correct targets found = 20). Score!, aimed at assessing *auditory sustained attention*, required children to count the number of tones on a 5.5-min audio recording (maximum number of correct trials = 10). These tasks show moderate test-retest reliability ($r = .57$ and .72, respectively; Manly et al., 2004).

Behavioral Assessment

We used the mother-reported subscale attention problems (10 items) of the Child Behavior Checklist (CBCL/6-18) and the teacher-reported inattention subscale (14 items) of the Teacher Report Form (TRF/6-18) to assess behavioral attention problems. Standardized T-scores (attention problem subscale) and percentiles (inattention subscale) were based on Dutch age and sex norms with good reliability and validity (Verhulst & Van der Ende, 2013). Higher scores indicate more attention problems. Attention problems were considered (borderline) clinical with T-scores ≤65 on the attention problem subscale and percentiles ≤93 on the inattention subscale.

Attention Aspects

To examine if these 10 measures covering a range of attention skills could be reduced to statistically represent distinct aspects of attention, a principal component analysis (PCA) was employed in SPSS Statistics 25.0. Sampling adequacy and sufficient correlations between measures for PCA were confirmed with the Kaiser–Meyer–Olkin statistic = .77 (>.50 is acceptable; Field, 2009) and Bartlett's test of sphericity χ^2 (45) = 322.42, p <.001, respectively. We extracted three components with Eigenvalues >1.0 accounting for a total variance of 55.67. Table II shows the loadings on the three statistically derived components. The loadings and nature of the measures suggested the following aspects of attention: (a) Orienting attention and processing speed; (b) Alerting attention, and (c) Behavioral attention. The first two aspects comprised cognitive measures, while the last aspect consisted of behavioral measures. PCA scores were computed into standardized z-scores, with lower scores indicating better performance, and these were used in further analyses.

Table III *Functioning in Attention Aspects for Children Born MLPT and FT*

Attention aspects	FT ($n = 83$), *M (SD)*	MLPT ($n = 87$), *M (SD)*	*p*-value	Effect size
Orienting attention and processing speed	−0.23 (0.94)	0.23 (1.01)	.02	.04
Alerting attention	−0.14 (1.06)	0.14 (0.92)	.32	.006
Behavioral attention problems	−0.20 (0.68)	0.19 (1.20)	.008	.04

Note. MANCOVA multivariate test: Wilk's $\Lambda = 3.74$, $F(3, 165) = 3.72$, $p = .01$, partial $\eta^2 = .06$. Effect size: partial η^2. Small = .01, moderate = .06, large = .14.

Table IV *Fit Statistics for Number of LPA Models (N = 170)*

Number of classes	BIC	Adjusted BIC	AIC	Entropy	VLMR *p*-value	Adjusted LMR *p*-value
1	1,475.12	1,456.13	1,456.31	NA	NA	NA
2	1,361.68	1,330.01	1,330.32	0.99	.03	.04
3	1,320.97	1,276.64	1,277.07	0.98	.06	.06
4	1,302.00	1,245.00	1,245.55	0.91	.046	.052
5	1,297.88	1,228.22	1,228.90	0.92	.33	.34

Note. AIC = Akaike information criterion; Adjusted LMR = adjusted Lo-Mendell-Rubin likelihood ratio test ; BIC = Bayesian information criterion; LPA = latent profile analysis; VLMR = Vuong-Lo-Mendell-Rubin likelihood ratio.

Statistical Analyses

Out of 170 children participating at 6 years, 26% had partial data of which 80% only missed questionnaire data. To maximize sample size, missing data for these 26% of the children were handled with the Expected-Maximization algorithm (Graham, 2009).

A variable-centered approach was applied to examine group differences between children born MLPT and FT on three aspects of attention with a multivariate analysis of covariance (MANCOVA), adjusted for maternal education.

A person-centered approach was applied to identify distinct profiles of attentional functioning. We performed a latent profile analysis (LPA) across the total sample (children born MLPT and FT) using the three attention aspects as indicators in Mplus 8.2. LPA has sufficient power to detect at least three latent profiles in samples >100 participants (Dziak, Lanza, & Tan, 2014). A series of LPA models (1-profile to 5-profile models) was fitted, after which the best model was selected based on fit statistics, distribution of children across profiles, and interpretability. Fit statistics included: (a) the Bayesian Information Criterion (BIC), Adjusted Bayesian Information Criterion (Adj-BIC), Akaike Information Criterion (AIC), with lower values indicating better fit (Berlin, Williams, & Parra, 2014), (b) the Vuong–Lo–Mendell–Rubin (VLMR) and adjusted Lo-Mendell-Rubin (Adj-LMR) model comparison tests, with *p*-values indicating improved fit compared to a model with one less profile, and (c) entropy, with values ≥0.80 indicating good classification of individuals in subgroups (Berlin et al., 2014).

After selecting the best model, children were assigned to their most likely profile and profiles were compared regarding attention aspects and neonatal and demographic characteristics, using ANOVAs with Games–Howell *post hoc* tests (Field, 2009) and χ^2 tests with Fisher's exact *post hoc* tests (Shan & Gerstenberger, 2017) in SPSS Statistics 25.0. Effect sizes were calculated for ANOVAs with partial η^2 (small = .01, moderate = .06, large = .14) and for χ^2 tests with φ (small = .10, moderate = .30, large = .50).

Results

Variable-Centered Approach

MANCOVA results showed a significant multivariate test, indicating that there was an effect of MLPT birth on attentional functioning, after adjusting for maternal education (Table III). Children born MLPT showed poorer functioning on Orienting attention and processing speed ($F(1, 167) = 5.98$, $p = .02$) and Behavioral attention problems ($F(1, 167) = 7.13$, $p = .008$). Children born MLPT did not differ from children born FT in Alerting attention ($F(1, 167) = 0.96$, $p = .32$; Table III). Effect sizes were small to moderate (Table III).

Person-Centered Approach

Fit statistics for the series of LPA models are shown in Table IV. The likelihood ratio tests supported the 2- and 4-profile models, and information criterion values were lowest for the 4-profile model. The 2-profile model showed one profile containing the majority of children, which further split into meaningful profiles in following models. As the 4-profile model was supported by fit statistics, a meaningful distribution of children across profiles, and had good interpretability, this model was retained. High entropy supported use of profile assignment as an observed variable in further analyses (Berlin et al., 2014).

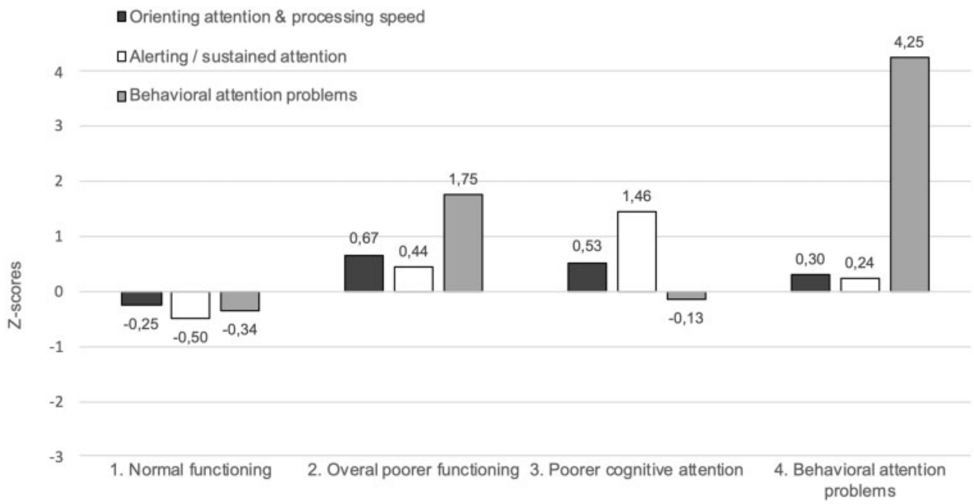

Figure 1. Functioning on attention aspects per profile.

The 4-profile model (Figure 1) showed that most children ($n = 117$, 69%) functioned within the normal range in all three attention aspects (*Profile 1*, Normal functioning). *Profile 2* consisted of 13 (8%) children with poorer attentional functioning across all three aspects. Children in *Profile 2* performed poorer on Orienting attention and processing speed, and Alerting attention compared to children in *Profile 1* and had more Behavioral attention problems compared to children in *Profiles 1* and *3*. The 35 (20%) children classified in *Profile 3* performed poorer on all cognitive attention aspects, but not on the behavioral attention aspect. This profile was characterized by clearly poorer Alerting attention (z-score = 1.5) compared to all other profiles, and poorer Orienting attention and processing speed compared to *Profile 1*. Five children (3%) were assigned to *Profile 4*, characterized by prominent Behavioral attention problems (z-score = 4.3), which were substantially higher compared to all other profiles. Children in *Profile 4* also performed somewhat poorer on Alerting attention than children in *Profile 1*.

Mean performance on each attention aspect, and neonatal and demographic characteristics for the four profiles are shown in Table V. Pairwise comparisons are presented for continuous variables. Children in the profiles differed significantly in birth status ($\chi^2(3) = 9.72, p = .02$)). A *post hoc* test showed there were less children born MLPT than children born FT within *Profile 1* ($p = .004$), while children born MLPT were overrepresented in each of the profiles with suboptimal functioning (*Profiles 2*, *3*, and *4*). Accordingly, profiles differed in gestational age and birth weight, with moderate to large effect sizes. Additional *post hoc* tests could not discern which profiles differed regarding gestational age. Children in *Profile 3* had lower birth weight compared to *Profile 1* ($p = .03$). The profiles also differed in maternal education. *Profiles 1* and *4* had the largest proportion of children with high educated mothers, while *Profile 3* had the largest proportion of children with low educated mothers. Children in *Profile 2* had more mothers with medium education relative to other profiles.

The distribution of profiles in the children born FT showed they were mainly classified in *Profile 1* (66, 80%), followed by 13 (16%) in *Profile 3*, three (4%) in *Profile 2*, and one child (1%) in *Profile 4*. For children born MLPT the distribution of profiles followed the same order, but was more scattered: 51 (59%) children born MLPT were classified in *Profile 1*, 22 (25%) in *Profile 3*, ten (11%) in *Profile 2*, and four (5%) in *Profile 4*. The profiles with suboptimal functioning combined comprised 41% of children born MLPT compared to 20% of children born FT.

Discussion

In this study, we used two approaches to examine the association between MLPT birth and attentional functioning at age 6 years: a variable-centered and a person-centered approach. The variable-centered approach demonstrated that as a group children born MLPT performed poorer than children born FT in the Orienting attention and processing speed and Behavioral attention problems aspects but not in the Alerting attention aspect. The person-centered approach revealed a normal attentional functioning profile (*Profile 1*) and three distinct profiles of suboptimal attentional functioning across the total sample: *Profile 2*—Poorer overall attentional functioning, *Profile 3*—Poorer cognitive attentional functioning, and *Profile 4*—Behavioral attention problems. Children born MLPT were overrepresented in each of the suboptimal profiles of attentional functioning (*Profiles 2*, *3*, and *4*).

Table V *Descriptives and Characteristics Per Profile for the Full Sample (N = 170)*

Profile	1. Normal functioning ($n = 117$) M (SD)	2. Overall poorer functioning ($n = 13$) M (SD)	3. Poorer cognitive attention ($n = 35$) M (SD)	4. Behavioral attention problems ($n = 5$) M (SD)	p-value	Effect size
Attention domains						
Orienting attention and processing speed	−0.25 (0.90)[a,b]	0.67 (0.68)[a]	0.53 (1.15)[b]	0.30 (0.74)	<.001	.14
Alerting attention	−0.50 (0.59)[a,b,c]	0.44 (0.84)[a,d]	1.46 (0.63)[b,d,f]	0.24 (0.28)[c,f]	<.001	.63
Behavioral attention problems	−0.34 (0.31)[a,c]	1.75 (0.57)[a,d,e]	−0.13 (0.45)[d,f]	4.25 (0.89)[c,e,f]	<.001	.85
Characteristics						
Birth status (% MLPT)	51 (44%)	10 (77%)	22 (63%)	4 (80%)	.02	.24
Gestational age (weeks)	37.50 (2.59)	35.08 (3.20)	36.46 (2.49)	35.60 (2.88)	.003	.08
Birth weight (grams)	3,169 (681)[b]	2,776 (1,138)	2,842 (573)[b]	2,518 (559)	.01	.06
Corrected age in years	6.07 (0.06)	6.05 (0.05)	6.05 (0.06)	6.09 (0.06)	.44	.02
Gender (% boys)	54 (46%)	11 (85%)	19 (54%)	3 (60%)	.06	.21
Maternal education (%)					.003	.34
Low	4 (4%)	0 (0%)	5 (14%)	0 (0%)		
Medium	19 (16%)	7 (54%)	11 (32%)	1 (20%)		
High	94 (80%)	6 (46%)	19 (54%)	4 (80%)		

Note. Pairwise comparison $p < .05$: Profile [a]1 versus 2; [b]1 versus 3; [c]1 versus 4; [d]2 versus 3; [e]2 versus 4; [f]3 versus 4. Effect size: partial η^2. Small = .01, moderate = .06, large = .14; φ. Small = .10, moderate = .30, large = .50.

Using a variable-centered approach we found that school-aged children born MLPT had poorer functioning in Orienting attention and processing speed and Behavioral attention problems, indicating poorer dynamic information processing and more behavioral distraction in daily tasks compared to children born FT, consistent with the relatively few studies in children born MLPT (Cserjesi et al., 2012; Mulder et al., 2009; Talge et al., 2010; Van Baar et al., 2009). Children born MLPT did not differ from children born FT in Alerting attention, suggesting that their more static and enduring attention skills were not affected. In short, as expected, the variable-centered approach showed that as a group children born MLPT are at increased risk of poorer functioning in some, but not all aspects of attention compared to children born FT. Our findings in the same sample at 18 months of age also demonstrated poorer orienting attention in children born MLPT compared to children born FT. At 6 years we did find poorer behavioral (as also reported in Bogičević et al., 2019) but not alerting attention, contrasting our previous findings at 18 months (De Jong et al., 2015). A possible explanation for the differences in findings may be that children born MLPT show diverging developmental patterns in specific attention aspects, illustrated by varying group differences across time. In their meta-analysis, Mulder et al. (2009) indeed found that across studies group differences in alerting attention between children born preterm and FT decreased after 6 years of age, which could indicate developmental delay with subsequent catch-up. Further research should be directed at longitudinal assessment of a range of attention aspects to examine whether children born preterm show such diverging developmental patterns of attention.

The person-centered approach revealed a profile of normal attentional functioning (*Profile* 1) and several distinct profiles of suboptimal attentional functioning. Children belonging to *Profile 2* showed overall poorer attentional functioning, with 85% of children showing parent- or teacher-rated (borderline) clinical behavioral attention problems. *Profile 3* was characterized by cognitive attention difficulties in the absence of behavioral attention problems; i.e. none of the children showed (borderline) clinical behavioral attention scores. Finally, *Profile 4* was marked by behavioral attention problems, with 60% of children displaying (borderline) clinical behavioral attention problems, without prominent difficulties in cognitive aspects of attention. Children classified in one of these suboptimal attention profiles (*Profiles* 2, 3, or 4) had greater neonatal risk, demonstrated by lower gestational age and birth weight, compared to children with normal attentional functioning. Children with cognitive attention difficulties (*Profile* 3) had more mothers with low education level compared to children with normal attentional functioning. In contrast with our expectations, no significant gender differences between attention profiles were found in our study. Mulder et al. (2009) concluded in their meta-analysis that the association between male gender and attentional functioning in preterm born children is inconsistent, emphasizing that the effect of gender on attention should be considered in further research with larger samples. Identification of these distinct profiles suggests that attention skills are not always equally affected and that there is variation in the type and pattern of attentional difficulties children may experience.

Although roughly half of the children born MLPT seems resilient, twice as many children born MLPT showed one of the suboptimal attentional functioning profiles compared to children born FT (41% vs. 20%), indicating they are at increased risk of difficulties in one or several aspects of attention. Not one profile of attention difficulties was characteristic for children born MLPT. Instead, they were dispersed across differing profiles of attention difficulties, while most children born FT with a suboptimal attention profile showed a profile of cognitive attention difficulties (*Profile 3*). This variation in the type of attention difficulties within the MLPT group underlines the heterogeneity within the preterm population (Burnett et al., 2019; Lean et al., 2020), and may explain why some studies on children born preterm find poorer functioning across all attention aspects (Anderson et al., 2011; Murray et al., 2014), while others find difficulties only in some attention skills (Bayless & Stevenson, 2007; Lean et al., 2017; Mulder et al., 2011). In addition, most children with a suboptimal attention profile showed specific attentional difficulties—either in cognitive (*Profile* 3) or behavioral (*Profile* 4) aspects—rather than overall poorer attentional functioning. Hence, in clinical practice as well as in research, assessment of both cognitive and behavioral aspects of attention is essential to determine which specific difficulties an individual child may experience. While some children born MLPT require treatment across the whole range of attentional functioning, more often than not, interventions might need to be targeted at specific cognitive or behavioral attention aspects. For instance, such intervention programs could include training focused on maintaining attention for a considerable duration, or in case of behavioral attention problems, training in social competencies and reciprocal social interaction capacities.

Combining the variable- and person-centered approaches shows differentiated associations between MLPT birth and attentional functioning. Considering that group differences were relatively small, with small-to-moderate effect sizes, and were not found in all aspects of attention, the variable-centered approach alone would suggest that, although children born MLPT as a group perform below average, overall they are doing relatively well. The person-centered approach, however, shows that attention difficulties often co-occur across multiple aspects of attention and that children born MLPT are more likely to have a cumulation of attention difficulties than their peers born FT. Thus, attentional functioning of children born MLPT may not stand out when a single aspect of attention is evaluated, but co-occurring difficulties can become more apparent when multiple attention aspects are viewed in conjunction. Given that attention difficulties are related to adverse academic (e.g. Rose et al., 2011) and social outcomes (Andrade et al., 2009), problems across several attention skills could be expected to impact a child's later functioning more severely, emphasizing the value of person-centered approaches. Hence clinical practice should implement assessment of a range of attention aspects in case of suspected attention difficulties in children born preterm, and concurrently evaluate performance across these various aspects.

Other strengths of this study are the use of multi-method and multi-informant assessments of attention, and inclusion of a control group. Several limitations also need to be considered. The power to detect differences in neonatal and demographic characteristics between profiles with *post hoc* pairwise comparisons was quite weak due to the small number of children in some profiles (13 children in *Profile 2* and five children in *Profile 4*). For instance, the difference in birth weight was only significant for children with cognitive attention difficulties (*Profile* 3) compared to *Profile* 1, although birth weight was even lower for children in *Profiles* 2 and 4. While birth weight and gestational age are highly correlated, greater variance in birth weight in our study may explain why comparisons of attention profiles showed some significant differences in birth weight but not in gestational age. Nonetheless, our study showed that children born MLPT were more likely to be classified in both these profiles than children born FT. By including only low-risk children born MLPT (e.g. those without need for NICU admittance and a higher rate of children born at later gestational ages) the current study may have overestimated attentional outcomes of children born MLPT and potentially underestimated differences in some neonatal characteristics between profiles. In future studies investigation of associations with other factors, e.g. specific neonatal complications, early developmental functioning and contextual factors—such as parenting—may help to understand the variety of attention profiles children born preterm show. Another limitation is that our study design did not include measures of executive/shifting attention, potentially showing incomplete information on attentional profiles in children born MLPT and FT. Although our study is not exhaustive, it does contribute to existing literature regarding attentional functioning in children born preterm by evaluating cumulative attention difficulties and demonstrating variation in attentional functioning. Future research should therefore evaluate attentional profiles in larger samples that also include preterm populations at higher risk and follow these across different developmental stages.

Our study demonstrates that school-aged children born MLPT are at increased risk of suboptimal attentional functioning. Compared to peers born FT, children born MLPT perform poorer on some but not all aspects of attentional functioning and they are twice as likely to show a suboptimal attentional functioning profile, often with poorer performance in several aspects of attention. Finally, children born MLPT are heterogeneous in the type of attentional difficulties they experience, highlighting the importance of comprehensive assessment of attentional functioning and more personalized treatment approaches to improve their development.

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