Delayed school entry and academic performance: A natural experiment

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Abstract
Aim. Recent reports suggest that delayed school entry (DSE) may be beneficial for children with developmental delays. However, studies of the effects of DSE are inconclusive. This study investigated the effects of DSE versus age-appropriate entry (ASE) on children's academic achievement and attention in middle childhood.
Method. 999 children (492 females, 507 males; 472 born preterm) were studied as part of a prospective population-based longitudinal study in Germany. Using a natural experimental design, propensity score matching was applied to create two matched groups who differed only in terms of DSE vs. ASE. Teacher ratings of achievement in mathematics, reading, writing, and attention were obtained in Year 1, and standardized tests were administered at age 8 years.
Results. There was no evidence of a difference in the odds of DSE vs. ASE children being rated as above average by teachers in Year 1. In contrast, DSE children's standardised mean test scores were lower than ASE children's mean scores in all domains (mathematics: *B*=-0.28[-0.51,-0.06)], reading: *B*=-0.39[-0.65,-0.14], writing: *B*=-0.90[-1.07,-0.74], and attention: *B*=-0.58[-0.79,-0.36]).
Interpretation. DSE did not affect teacher rated academic performance. However, missing one year of learning opportunities was associated with poorer average performance in standardized tests at 8 years of age. Future research is needed to determine the long-term effect of DSE on academic achievement.

Short title: Impact of delayed school entry on achievement

What this paper adds
- Delayed school entry has no effect on Year 1 teacher ratings of academic performance
- Delayed school entry is associated with poorer performance in standardized tests of reading, writing, mathematics and attention at age 8 years
- Future research needs to determine longer-term effects of delayed school entry

A child's initial entry into formal schooling marks an important developmental transition. Compulsory school entry age is determined according to a child's birth date relative to a country-specific cut-off date which indicates the start of the academic year. Research has shown that, within the same academic year, the youngest children have lower academic achievement compared with the oldest children in class.[1-3] In countries such as Germany, paediatricians assess children's school readiness and may recommend that children who fail such tests should enter school a year later. Preterm children may be born up to four months before their due date and may have to enter school less mature than their peers.[4] Thus, the issue of delayed school entry (DSE) is particularly pertinent for these children and their parents often enquire whether they can delay entry into school as they believe it would benefit their child to enter school a year later.

Delaying school entry may be beneficial because teachers may not be able to provide differential support for the less mature children in class,[5] and thus they may not receive developmentally appropriate teaching if they start school at the age-appropriate time. DSE may therefore prevent psychological pressure and negative feedback for those who delay school entry due to developmental immaturity. Indeed, positive effects of DSE on primary school achievement have been reported.[6; 7] Conversely, DSE may disadvantage children as it denies them the opportunity to receive the early intellectual input they may need to catch up with their peers. Accordingly, DSE has also been shown to negatively affect school performance.[8]

However, previous studies are characterised by inadequate power and selection bias because, compared with children who entered school age-appropriately (ASE), DSE children more often had special educational needs (SEN) or behavioural problems and were more often summer born boys and from disadvantaged backgrounds.[9; 7] Consequently, it remains unclear if DSE has any positive or negative long-term effects on academic achievement.[7; 10] Given that randomised controlled trials are not feasible, applying propensity score matching (PSM) to observational data within a natural setting provides a method for reducing selection bias.[11] PSM can be used to select two comparable groups of children who are similar in baseline characteristics but different in their treatment, i.e. whether they are DSE or ASE. Using PSM, the aim of this study was to investigate the effect of DSE on children's academic performance. The specific research questions were:

1. Does DSE affect children's mathematics, reading, writing, and attention as rated by teachers at the end of Year 1?
2. Does DSE affect children's performance in standardized mathematics, reading, writing, and attention tests at 8 years of age?
3. Are differences between ASE and DSE children's performance explained by the length of formal schooling received at the time of assessment?

In addition, given the study's particular relevance for preterm children, we repeated analyses on a matched sub-sample of children born preterm.

Method

PARTICIPANTS

Data were collected as part of the prospective Bavarian Longitudinal Study (BLS)[12], a whole-population study of children born in 1985/1986 within a geographically defined area of Southern Bavaria (Germany) who required admission to a children's hospital within the first 10 days of life (*n*=7505; 10.6% of all live births). Additionally, 916 healthy term-born control infants were identified at birth from the same hospitals in Bavaria. Of the initial 8421 children, 1316 survivors stratified by sex, socio-economic status, and degree of neonatal risk were assessed at 6 and 8 years of age.[13; 12] Of these, 118 children were excluded: these were born >41 weeks of gestation, entered school one year early[1], or were enrolled directly in special school (i.e. teacher ratings would not be comparable). In addition, n=199 children had incomplete information on baseline characteristics and could not be included in PSM.[11] Descriptive characteristics of the 999 children included and 317 excluded in the present study are shown in Appendix Table A1.

PROCEDURE

Parents were approached within 48 hours of the infant's hospital admission and were included in the study once they had given written consent for their child to participate. Ethical approval was obtained from the University of Munich Children's Hospital Ethics committee. Study follow-up assessments were scheduled at 5, 20, 56 months, and 6 years of age in order to assess children's pre-school neurological and cognitive abilities. For the present report, two sets of formal assessments were used as dependent variables. (1) At 8 years of age (irrespective of school year), children's mathematics, reading, writing, and attention regulation abilities were assessed using standardised tests by psychologists who were blind to group membership. (2) At the end of school Year 1, when ASE children were aged 6-7 years and DSE children aged 7-8 years, teacher ratings of mathematics, reading, writing, and attention were obtained.

MEASURES

Delayed school entry. In 1990-1993, Bavarian policy required that all children were assessed by a community paediatrician 3-12 months before their chronological-age school entry date to determine their school readiness. All children who turned 6 years before 30th June would ordinarily start school the following September. Assessments lasted 30-60 minutes and covered key developmental domains. Paediatric recommendation for DSE was based on the results of these assessments. Schools, in conjunction with parents, made the final decision regarding DSE. Parents could not request DSE if their child passed the test.

Baseline characteristics. Twelve variables were included in PSM. These were measured between birth and 56 months of age, before the DSE decision was made, and were selected as potential confounders of the association between DSE and academic achievement (see Appendix Table A2 for details).

Teacher ratings of mathematics, reading, writing, and attention at the end of school Year 1. Teacher ratings of children's performance in mathematics, reading, writing and attention were obtained from written reports of primary school teachers' assessments when children had completed their first year of schooling and coded into a binary variable (0=average or below average, 1=above average). These reports describe a child's achievement during Year 1 in comparison to what is expected from an average child in their age group. Psychologists achieved excellent inter-rater reliability on these codings (100% agreement in a subsample of 50 reports).

Standardised assessment of *mathematics, reading, writing, and attention regulation at 8 years of age.* To assess intuitive mathematical competencies, individual children were administered a mathematics test.[13; 14] Tasks were presented to children in book form with 29

[1] In Germany, parents can ask to have their child tested for early school entry.

items assessing estimation, reasoning, and visual-spatial problem solving. Item responses were scored for accuracy and summarised into a total score (range: 5-24, *M*=13.25, *SD*=3.45). Reading was assessed using the validated Zürich Reading Test[15] and a pseudo-word reading test.[13; 16] Both scores were highly correlated (*r*=0.69) and combined into one Reading Test Score (range: 1-235, *M*=33.49, *SD*=29.62). Orthographic abilities (writing and spelling) were assessed with a structured diagnostic test (DRT-2; range: 0-24, *M*=11.19, *SD*=5.64).[17] Children's attention regulation during a standardized test situation was evaluated with the *Task Orientation* sub-scale (range: 11-60, *M*=44.72, *SD*=5.36) of the Tester's Rating of Child Behaviour (TRCB).[18] Assessments were scheduled to take place when children were 8 years, 5 months old; however, DSE children on average had their assessments slightly later than ASE children (mean difference: 0.77 months; *95% CI*:0.21-1.33) and had completed fewer months of schooling when assessments were administered (mean difference: 7.65 months; *95% CI*:6.84-8.46). Test scores were z-standardised according to the total sample included in this study. See Appendix Table A3 for more details on dependent variables.

Preschool numeric and phonetic knowledge. Assessments were made to objectively measure children's knowledge before they started elementary school at 6 years. Standardized numeric and phonetic tests comprised 10 and 34 items, respectively,[12; 13] and two total accuracy scores were computed.

Length of schooling. The number of completed months of schooling when standardised tests were administered was calculated.

STATISTICAL ANALYSIS

Propensity score matching. Propensity scores were estimated with a logistic regression of DSE when compared to ASE on baseline characteristics. When cases were matched, the difference in baseline characteristics between DSE and ASE children disappeared.[11] Thus, PSM resulted in an unbiased estimate of the association of DSE/ASE with academic achievement.[19] We used the Radius algorithm whereby each DSE child was "paired" with one or more ASE children who had similar propensity scores.[19] Children were excluded from the matched sample if no participants shared similar values. Analysis used the matched sample incorporated weights that reflected the ratio of DSE and ASE children sharing similar PSM values.[19] The weighting on the matched sample accounts for the fact that an individual DSE child may have been matched to more than one ASE child in the matching process, i.e. matching with replacement. For example, if 1 DSE child was matched to only 1 ASE child, this ASE child received a weight of 1. If 1 DSE child was matched to 4 ASE children, each ASE child received a weight of ¼ in the analysis. The overall matching balance was measured using pseudo R^2, where a value close to 0 indicates the probability that DSE/ASE would be independent of all baseline variables. Standardised bias was used to evaluate the balance in individual variables (>5%=meaningful imbalance). PSM was implemented using the psmatch2 and pstest STATA packages.

Ordinary least squares linear/logistic regressions. Analyses predicting academic achievement were conducted using (1) the final PSM sample, (2) the whole sample, and (3) a subgroup of the PSM sample comprising only preterm children. The effect of DSE on academic achievement was estimated with logistic (above average Year 1 teacher ratings) and linear (standardised test scores at 8 years) regressions. The effects of preschool knowledge were then taken into account in adjusted models. Bootstrapping (1000 replications) and matching weights were used to account for changes in the sample distribution introduced by PSM.[19]

It was not possible to control for length of schooling in these regression models as it reflects the decision for DSE/ASE. DSE children had completed, on average, eight fewer months of schooling when standardized assessments were administered. We calculated the effect of months of schooling on each standardized assessment within the ASE group only and used this predictive function to predict DSE children's performance if they would have received the same amount of schooling (i.e. eight additional months) as ASE children at the time of assessment (proxy estimates).

Results

Propensity score matching. The matched total PSM sample included 959 children (99 DSE, 860 ASE) with similar propensity scores. Table 1 shows baseline characteristics for the unmatched and matched PSM sample. Before matching, there were moderate to large differences on all 12 baseline covariates between DSE and ASE children. After matching, none of these variables remained statistically different and bias for all 12 covariates was <5% in the matched sample, indicating that a good balance was obtained for all variables. A good overall matching quality was also indicated by Pseudo R^2=0.12.

-Table 1 here-

The matched PSM subsample included 472 preterm children (see Appendix Table A4).

Does delayed school entry affect teacher ratings of children's mathematics, reading, writing, and attention at the end of Year 1? Table 2 shows that there was no evidence of a difference in the odds of DSE compared with ASE children being rated as performing above average in mathematics, reading, writing, and attention by teachers in Year 1. Regression results were robust across the final overall PSM sample, the logistic regression sample, and the PSM subsample of preterm children. Controlling for children's preschool numeric and phonetic knowledge did not change these findings. Better preschool numeric knowledge was consistently associated with higher odds of being rated as performing above average in mathematics, reading, and writing when compared to lower preschool numeric knowledge.

-Table 2 here-

Does delayed school entry affect children's performance in standardized mathematics, reading, writing, and attention tests at 8 years of age? In contrast to the outcomes for Year 1, there was evidence that DSE predicted significantly lower mean scores in all four standardised tests (mathematics, reading, writing, and attention regulation) and across all PSM and OLS models at age 8 years (Table 2, also see Appendix Figure A1) with one exception: preterm children's intuitive mathematics mean scores were not affected by DSE after controlling for children's preschool knowledge and sex. Preschool numeric knowledge consistently predicted better average performance across all four domains.

-Table 3 here-

Are differences in performance between children with age-appropriate and delayed school entry explained by the length of schooling? We calculated the effect of eight additional months of schooling within the ASE group and used this predictive function to test if DSE children would have reached a similar level of performance if they had received the same amount of schooling as ASE children at the time of assessment. Figure 1 shows DSE children's observed standardised test results at 8 years of age (dots) and predicted mean test results (lines) if DSE children had received, on average, eight additional months of schooling.

Although not shown in the figure, predictions were based on the observed effect of eight months of schooling on ASE children's scores. These results suggest that even if DSE children had received the same amount of schooling as ASE children, the majority would show worse mean performance than ASE children (i.e. dots are below the line). Similar findings were obtained on the PSM subsample of preterm children (Appendix Figure A2).

- Figure 1 here -

Discussion

This study found that there was no significant difference in the odds of ASE vs. DSE children being rated as performing above average in mathematics, reading, writing and attention by their teachers at the end of Year 1. In contrast, DSE children's standardised mean test scores of mathematics, reading, writing and attention at 8 years of age were lower than ASE children's mean scores. To our knowledge this is the first study that assessed the effect of DSE in a large sample after minimising selection bias and accounting for confounding effects of preschool knowledge.

The issue of DSE has received considerable interest.[9; 7; 8; 20] Parents who wish to delay their child's school entry may do so because their child has developmental problems. If these are due to developmental immaturity then starting school a year later may give their child additional time to mature.[9] However, these problems may often indicate developmental impairments or SEN which could be better addressed with early intervention rather than DSE. Our results suggest that DSE has no effect on academic achievement but may delay formal instruction and the provision of special educational support during a key developmental period.

The findings presented here are based on both assessments according to age (standardized tests) and according to grade level (teacher ratings). In primary school, age has a large impact on performance as older children outperform younger children within a class.[21] Thus neither age-level nor grade-level assessments alone provide unbiased outcome measures. Our results indicate that despite DSE children being older, they did not outperform the younger ASE children on teacher ratings. Similarly, DSE did not lead to any performance advantage in standardized tests. DSE children had completed, on average, eight fewer months of schooling than ASE children when standardized assessments were administered at age 8 years and it was not possible to control for length of schooling in regression models as it reflects the decision for DSE/ASE. We however estimated the effect of eight months of schooling on mean test scores within the ASE group and used the regression line to estimate the impact of longer schooling within the DSE group. Still, more DSE children would have lower mean test scores than ASE children. Overall, delayed school entry may thus not provide any advantage for achievement at school. However, this analysis needs to be interpreted cautiously.

These findings are particularly applicable to preterm children who are born up to four months before their due date and may enter school less mature compared with their peers.[4] Preterm children were over-represented in the DSE group and our analyses on a matched subsample of preterm children confirmed the total sample results. Although there was only one significant DSE x preterm birth interaction on attention regulation but not on academic performance this analysis is important for several reasons: Prematurity is associated with increased need for special educational support[22; 23] and specific impairments may only become apparent during primary school because of the larger demands on cognitive and socio-emotional abilities.[24; 25] Parents of preterm children often enquire whether they can delay entry into school as they believe it would benefit their child. This may arise from an expectation that preterm children will developmentally catch-up with their peers over time. Accordingly, it has recently been suggested that DSE may particularly benefit preterm children.[26] However, parents and professionals should be aware that DSE may not promote preterm children's academic performance. Teachers are essential resources in encouraging learning and providing formal instruction. Raising education professionals' awareness of the potential problems faced by preterm children may aid in ensuring they receive the specific help they need to thrive in school. In some situations, delaying children's school entry may seem an appealing solution – but our results suggest that DSE children increase heterogeneity in class[8] and make it more difficult for teachers to address individuals' needs. Thus decisions to delay school entry should be taken with due caution as there may be disadvantages arising from missing one year of learning opportunities or not receiving special educational support during the critical primary years.[9; 8]

Strengths and limitations. The longitudinal data reported here were collected in a large whole-population sample of children born across the full spectrum of gestational ages. Assessors were blind to DSE vs. ASE group membership but teachers were not and thus their ratings could have been biased. While this is a general problem of all studies that include teacher ratings, these assessments are highly reliable as teachers based their judgement on knowing the child for a whole school year. The application of PSM provided precise effect estimates of DSE on academic performance while taking into account a comprehensive number of confounding variables. In this way, we carefully matched both groups on variables previously shown to be relevant for predicting school progress and controlled for preschool numeric and phonetic knowledge. Most birth cohort studies (e.g. all British cohort studies) schedule assessments according to age. Thus, both DSE and ASE children were assessed with standardised tests at the same age (8 years), rather than according to length of school experience. However we also included an assessment according to grade level using teacher reports at the end of Year 1, the first year of schooling for all children in the study. This assessment is thus based on the length of academic experience and not age. Thus we were able to assess the effects of DSE according to both age (standardized tests) and grade level (teacher assessments). We believe that this combination of grade-level and age-level assessments allows us to be confident in our conclusion that DSE did not enhance school achievement compared to ASE. Although there may be additional confounding factors not assessed there was no indication that DSE could be beneficial for academic progress and regression models confirmed these findings. In Germany, decisions to delay children's school entry are based on community paediatric assessments and not on parents' requests; thus our data are comparable with international studies on retaining (school decision to delay entry) but less with studies on 'redshirting' (parent decision to delay school entry).

Conclusion. DSE has no advantage for the likelihood of positive teacher ratings of academic achievement taken at the same point in Year 1 or on children's mean scores in standardized tests of mathematics, reading, writing and attention at 8 years of age. Effectively, DSE may mean that children miss out on learning opportunities during the critical early years. Future research is needed to determine the long-term impact of DSE on academic performance and attainment at the end of formal schooling.

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Table 1. Means and prevalence of baseline covariates of children with delayed versus age-appropriate school entry before and after propensity score matching; descriptive outcome variable information of matched groups				
n (%) or mean		DSE (unmatched=104; matched=99)	ASE (unmatched=895; matched=860)	Standardised bias (%)
Child sex (n (%) female)	Unmatched	40 (38.5)	452 (50.5)	-24.3
	Matched	38 (38.3)	315 (36.6)	3.6
SES at birth (n (%))				
Low	Unmatched	30 (28.8)	295 (33.0)	-[a]
	Matched	28 (28.2)	267 (31.1)	-[a]
Middle	Unmatched	48 (46.2)	319 (35.6)	21.7
	Matched	46 (46.5)	382 (44.5)	4.0
High	Unmatched	26 (25.0)	281 (31.4)	-14.2
	Matched	25 (25.3)	210 (24.4)	1.9
Neonatal index (n (%))[27]				
1. quartile	Unmatched	26 (25.0)	294 (32.9)	-[a]
	Matched	26 (26.3)	221 (25.7)	-[a]
2. quartile	Unmatched	21 (20.2)	259(28.9)	-20.4
	Matched	21 (21.2)	187 (21.7)	-1.1
3. quartile	Unmatched	14 (13.5)	179 (20.0)	-17.5
	Matched	13 (13.1)	120 (13.9)	-2.0
4. quartile	Unmatched	42 (41.3)	163 (18.2)	52.1
	Matched	39 (39.4)	333 (38.7)	1.6
Birth weight (g)	Unmatched	2158.2	2738.5	-62.4
	Matched	2182.1	2204.1	-2.4
SGA (n (%))	Unmatched	35 (33.7)	212 (23.7)	22.1
	Matched	34 (34.3)	288 (33.5)	1.8
GA (weeks)	Unmatched	34.4	37.0	-62.8
	Matched	34.6	34.6	-1.5
Parent-infant relationship problems (n (%))	Unmatched	55 (52.9)	284 (31.7)	43.7
	Matched	50 (50.5)	442 (51.4)	-1.9
IQ (20 months)	Unmatched	98.3	105.3	-68.5
	Matched	99.7	99.8	-0.8
AWST-language test (56 months)	Unmatched	89.0	98.6	-58.1
	Matched	89.9	89.8	0.6
Attention span (56 months)	Unmatched	2.7	3.1	-58.4
	Matched	2.7	2.7	2.5
Visual–Motor Integration (56 months)	Unmatched	5.8	6.9	-47.5
	Matched	5.9	5.9	0.4
Behaviour regulation (56 months, n (%))[27]				
1. quartile	Unmatched	44 (42.4)	251 (28.0)	-[a]
	Matched	41 (41.4)	373 (43.4)	-[a]
2. quartile	Unmatched	20 (19.2)	169 (18.9)	0.9
	Matched	19 (19.2)	157 (18.3)	2.4
3. quartile	Unmatched	30 (28.8)	325 (36.3)	-15.9
	Matched	29 (29.3)	243 (28.3)	2.1
4. quartile	Unmatched	10 (9.6)	150 (16.8)	-21.2

	Matched	10 (10.1)	86 (10.0)	0.9
Outcome variables				
Teacher ratings at the end of year 1 (% above average)				
	Mathematics	42(62.7%)	487 (58.9%)	
	Reading	42 (61.8%)	483 (58.4%)	
	Writing	34 (60.7%)	434 (62.5%)	
	Attention	33 (58.9%)	404 (60.6%)	
Standardised test mean scores at age 8 years (SD)				
	Mathematics	-0.6 (1.2)	0.1 (1.0)	
	Reading	-0.6 (1.4)	0.1 (0.8)	
	Writing	-1.1 (0.8)	0.1 (0.9)	
	Attention	-0.8 (1.2)	0.1 (0.9)	

Please note: DSE=delayed school entry, ASE=age-appropriate school entry. Numbers are reported as means if not stated otherwise. [a] STATA default-standardised bias was not computed on the reference group of nominal variables.

Table 2. Association of delayed school entry with above average teacher ratings at the end of year 1 (odds ratio *Exp(B)* (95% *CI*))

	Unadjusted PSM models (n=959)	Fully adjusted PSM models (n=959)	Logistic regression models (n=1198)[a]	Fully adjusted PSM models only including preterm children (n=343)[a,b]
		Mathematics		
Delayed entry[c]	1.59 (0.92, 2.73)	1.61 (0.90, 2.86)	1.49 (0.77, 2.89)	1.62 (0.60, 4.39)
Preschool numeric knowledge		1.28 (1.19, 1.37)	1.19 (1.11, 1.28)	1.19 (1.07, 1.31)
Preschool phonetic knowledge		0.94 (0.89, 1.00)	0.92 (0.85, 1.00)	0.89 (0.80, 1.00)
		Reading		
Delayed entry[c]	1.59 (0.97, 2.62)	1.48 (0.88, 2.51)	1.34 (0.73, 2.47)	1.40 (0.53, 3.68)
Preschool numeric knowledge		1.24 (1.16, 1.31)	1.14 (1.06, 1.21)	1.17 (1.06, 1.29)
Preschool phonetic knowledge		1.06 (1.01, 1.12)	0.99 (0.93, 1.05)	1.00 (0.90, 1.10)
		Writing		
Delayed entry[c]	1. 32 (0.75, 2.34)	1.30 (0.73, 2.33)	1.12 (0.58, 2.16)	2.28 (0.69, 7.51)
Preschool numeric knowledge		1.18 (1.11, 1.26)	1.08 (1.00, 1.16)	1.15 (1.03, 1.27)
Preschool phonetic knowledge		0.98 (0.92, 1.04)	1.00 (0.93, 1.06)	0.92 (0.82, 1.03)
		Attention		
Delayed entry[c]	1.20 (0.66, 2.16)	1.04 (0.57, 1.88)	1.06 (0.56, 2.01)	0.48 (0.16, 1.43)
Preschool numeric knowledge		1.10 (1.03, 1.17)	1.01 (0.95, 1.07)	1.00 (0.90, 1.10)
Preschool phonetic knowledge		1.06 (1.00, 1.13)	1.01 (0.95, 1.08)	0.96 (0.86, 1.07)

Please note: PSM=propensity score matching. All estimates were run with 1000 bootstrap replications.

[a] adjusted for all baseline characteristics used in selecting PSM sample

[b] additionally adjusted for child sex

[c] odds ratios indicate the predicted likelihood of DSE compared to ASE children being rated as performing above average

Table 3. Association of delayed school entry with children's standardised test scores at age 8 years (regression coefficient *B* (95% *CI*))				
	Unadjusted PSM models (n=959)	Fully adjusted PSM models (n=959)	OLS models (n=1198)[a]	Fully adjusted PSM models only including preterm children (n=343)[b]
		Mathematics		
Delayed entry[c]	-0.31 (-0.55, -0.07)	-0.28 (-0.51, -0.06)	-0.27 (-0.48, -0.07)	-0.30 (-0.65, 0.04)
Preschool numeric knowledge		0.12 (0.10, 0.14)	0.04 (0.02, 0.06)	0.14 (0.10, 0.17)
Preschool phonetic knowledge		-0.02 (-0.04, 0.00)	0.00 (-0.02, 0.01)	-0.04 (-0.07, 0)
		Reading		
Delayed entry[c]	-0.48 (-0.76, -0.19)	-0.39 (-0.65, -0.14)	-0.42 (-0.67, -0.18)	-0.62 (-1.01, -0.24)
Preschool numeric knowledge		0.13 (0.10, 0.16)	0.06 (0.03, 0.09)	0.12 (0.07, 0.17)
Preschool phonetic knowledge		0.03 (0.01, 0.05)	0.01 (0.00, 0.03)	0.02 (-0.01, 0.06)
		Writing		
Delayed entry[c]	-0.93 (-1.11, -0.74)	-0.90 (-1.07, -0.74)	-0.94 (-1.10, -0.77)	-0.98 (-1.17, -0.78)
Preschool numeric knowledge		0.12 (0.09, 0.14)	0.08 (0.06, 0.1)	0.11 (0.07, 0.14)
Preschool phonetic knowledge		0.03 (0.00, 0.05)	0.01 (-0.01, 0.04)	0.02 (-0.01, 0.05)
		Attention		
Delayed entry[c]	-0.64 (-0.89, -0.38)	-0.58 (-0.79, 0.36)	-0.57 (-0.77, -0.36)	-0.74 (-1.05, -0.43)
Preschool numeric knowledge		0.11 (0.09, 0.14)	0.03 (0.01, 0.06)	0.09 (0.05, 0.12)
Preschool phonetic knowledge		0.01 (-0.01, 0.03)	0.00 (-0.02, 0.02)	0.00 (-0.03, 0.03)

Please note: PSM=propensity score matching, OLS=ordinary least squares regression. The *B* coefficients express the effect size. All regression coefficients *B* where the 95% CI does not include 0 are statistically significant at the p<.05 level. All estimates were run with 1000 bootstrap replications.

[a] adjusted for all baseline characteristics used in selecting PSM sample

[b] additionally adjusted for child sex

[c] coefficients indicate DSE children's mean scores compared to ASE children's mean scores (baseline)

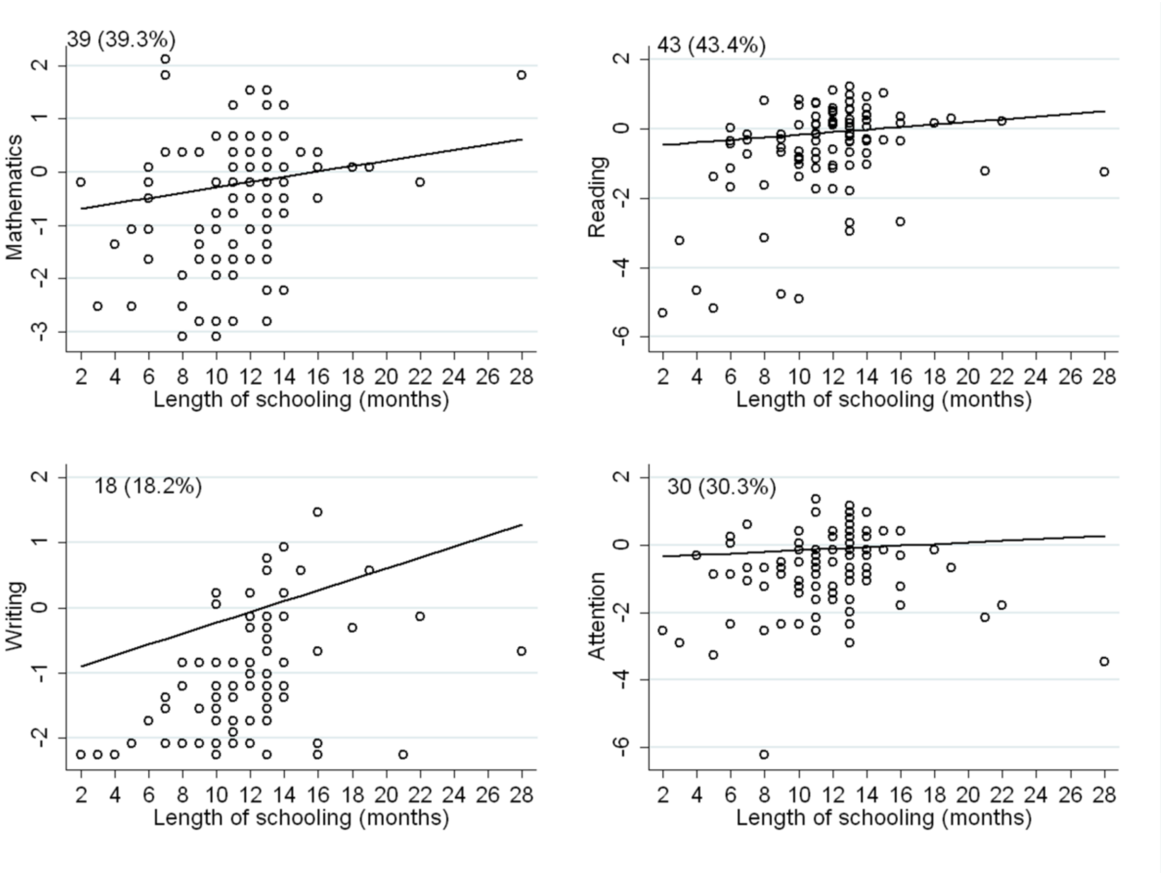


Figure 1. *Comparison of delayed school entry (DSE) children's (n=99) observed standardized test scores (dots) with their mean predicted scores (lines) given eight additional months of schooling. Predictions are proxy estimates based on the observed effect of eight months of schooling on appropriate school entry (ASE) children's scores. Please note: n (%): proportion of DSE children who would reach the same performance as ASE children if they had 8 more months of schooling at the time of assessment (i.e. DSE children's observed scores >= DSE children's predicted scores based on the same amount of schooling as ASE children at the time of assessment).*

Appendix Table A1: Characteristics of children included and excluded from analysis

n (%) or mean (SD)	Cases excluded (n=317)	Cases included (n=999)	Chi-square test/ T-test p value
Delayed school entry	19 (10.4%)	104 (10.4%)	0.991
Child sex (female)	154 (48.6%)	492 (49.2%)	0.836
SES at birth			
Upper	98 (30.9%)	326 (32.6%)	
Middle	119 (37.5%)	366 (36.6%)	0.850
Lower	100 (31.5%)	307 (30.7%)	
Neonatal optimality index (OPTI)			
1. quartile	48 (26.5%)	320 (32.1%)	
2. quartile	50 (27.6%)	280 (28.0%)	
3. quartile	34 (18.8%)	193 (19.3%)	0.214
4. quartile	49 (27.1%)	206 (20.6%)	
Birth weight (g)	2712.3 (1011.1)	2678.1 (919.3)	0.592
Gestational age (weeks)	36.9 (4.6)	36.7 (3.8)	0.402
Parent-infant relationship problems	67 (45.0%)	339 (33.9%)	0.009
IQ at 20m	96.4 (25.6)	97.4 (17.9)	0.620
Active Vocabulary Test (AWST) at 56 months	98.0 (17.7)	97.6 (15.9)	0.796
Visual–Motor Integration at 56 months	-0.3 (1.2)	-0.2 (1.0)	0.158
Behaviour regulation at 56 months			
1. quartile	21 (38.9%)	295 (29.5%)	
2. quartile	8 (14.8%)	189 (18.9%)	0.524
3. quartile	17 (31.5%)	355 (35.5%)	
4. quartile	8 (14.8%)	160 (16.0%)	
Attention span at 56 months	2.8 (0.8)	3.1 (0.7)	<0.001

Please see Table A2 for a detailed description of the baseline characteristics measures.

Appendix Table A2. Description of baseline characteristics included in propensity score matching		
Variable (point in time)	Description	Score / categories
Sex (birth)	• Documented in the birth records.	0=male, 1=female
Family socioeconomic status, SES (birth)	• Collected through structured parental interviews. • Family SES was computed as a weighted composite score derived from the occupation of the self-identified head of each family together with the highest educational qualification of both parents.[1]	0=low, 1=middle, 2=high
Neonatal optimality index (OPTI)	• Assessed infant neonatal complications (21 items, e.g. ventilation or intubation, severe anaemia, cerebral haemorrhage). • Higher scores indicate more problems.[2] • For the PSM scores were transformed into a categorical variable based on quartiles to minimise the misspecification of propensity score matching due to threshold effects.[3]	Quartiles
Birth weight (birth)	• Documented in the birth records.	Grams, ranging from 730g to 5050g
Gestational age (birth)	• Determined from maternal reports of the last menstrual period and serial ultrasounds during pregnancy.[4]	Weeks
Small for gestational age (SGA, derived from birth)	• Classified if children's birth weight was less than the gender-specific 10th percentile for gestational age. [5]	0=no, 1=SGA
Parent-infant relationship problems (5 months)	• Information collected from both a standard interview with parents and observations by study nurses. • Eight items including attachment-related parental concerns and current or anticipated relationship problems. • Items were dichotomised as 0 (no concern or problem) and 1 (problem) and were then summed into a score ranging from 0 (good relationship) to 8 (poor relationship). [5] • Transformed into a dichotomised variable due to an extremely left skewed distribution of the sum score.	0=good parent-infant relationship, 1=parent-infant relationship problems

IQ (20 months)	• The Griffiths Scales assessed the following dimensions: locomotor development, personal-social development, hearing and speech, hand and eye coordination and performance.[6] • A total developmental quotient across the five dimensions was computed based on the German norms.	Total score, ranging from 33 to 127
Active Vocabulary Test (AWST, 56 months)	• Active Vocabulary Test (AWST) assessed the expressive vocabulary of preschool children using 82 drawings.[6] • Children named the presented items.	Standardized score based on the BLS normative sample, ranging from 29.5 to 136.3
Attention span (56 months)	• Information from observations by study nurses on the child and parents on 11 items.[5]	Derived sum score, ranging from 0 (no problem) to 4 (several problems)
Visual-motor integration (56 months)	• Beery-Buktenica Developmental Test of Visual-Motor Integration. • Measured the integration of visual and motor abilities. • The child copied 15 drawings of geometric forms that had been arranged by increasing difficulty.[6]	Sum score of accuracy, ranging from 0 to 15

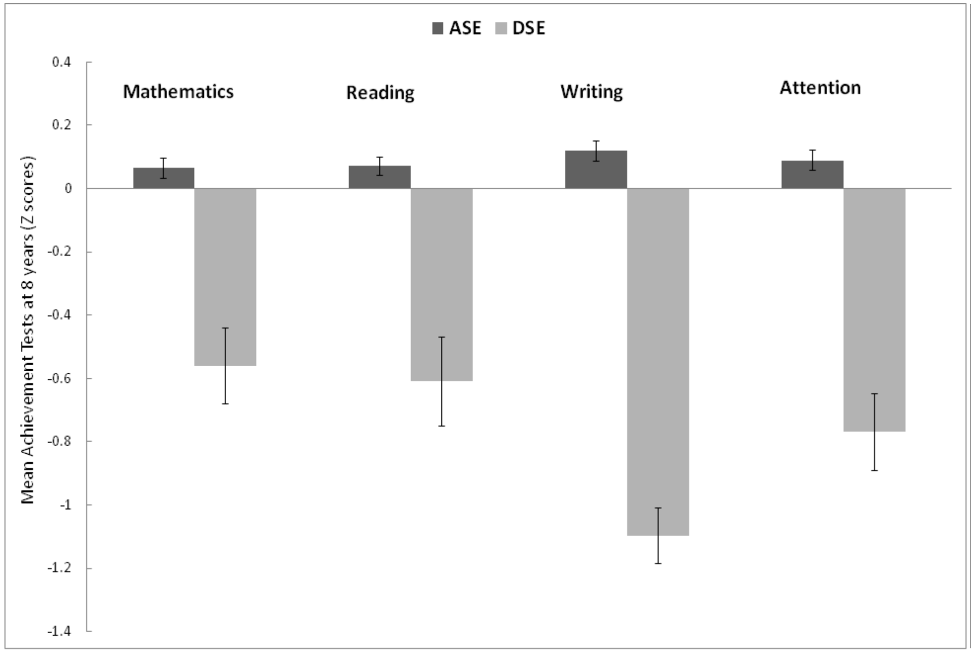
Appendix Table A3. Description of standardized tests used as dependent variables		
Test	Description	Score
Mathematics test[7,8]	• 29 items • Twelve estimation tasks measured children's accuracy in estimating numbers and comparing distances between numbers • Application of arithmetic abilities and procedural competence on real-world problems assessed with six reasoning tasks • Eleven mental rotation tasks testing visual-spatial problem solving	Combined raw total score range: 5-24, M=13.25, SD=3.45; z-standardised according to the total sample included in this study
Reading test score	• Zürich Reading Test[9] assessing children's word decoding skills via reading errors • Pseudo-word reading test[7,10] (Cronbach's α=.91)	Combined raw total score range: 1-235, M=33.49, SD=29.62; z-standardised according to the total sample included in this study
Structured diagnostic orthography test (DRT-2)[11]	• Assessment of writing and spelling abilities using simple words • Participants are required to fill in single words dictated by the experimenter into sentences depicted on the test materials • Differential diagnosis based on individual orthographic errors	Raw score range: 0-24, M=11.19, SD=5.64; z-standardised according to the total sample included in this study
Tester's Rating of Child Behaviour (TRCB)[12]	• Task Orientation index-scale • Psychologist-rated attention regulation during a standardized IQ test situation • Subscales included: 1. Attention, 2. Robustness and Endurance, 3. Demandingness (recoded), 4. Cooperativeness, 5. Compliance, 6. Difficulty (recoded) (Cronbach's α= .85; Inter-rater reliabilities (ICC) .63 to .97)	Raw score range: 11-60, M=44.72, SD=5.36; z-standardised according to the total sample included in this study

Appendix Table A4. Means and prevalence of baseline covariates of preterm children with delayed versus age-appropriate school entry before and after propensity score matching

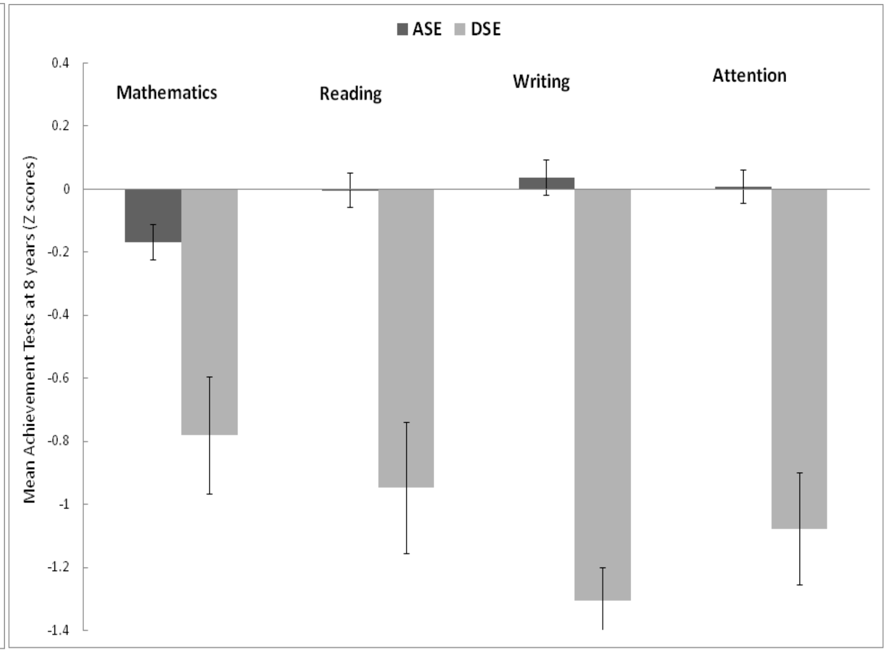
Proportion or mean		DSE (unmatched=78; matched=53)	ASE (unmatched=394; matched=287)	Standardised bias (%)
Child sex (proportion female)	Unmatched	0.34	0.48	-28.6
	Matched	0.35	0.28	14.5
SES at birth (proportion)				
Low	Unmatched	0.31	0.36	-
	Matched	0.32	0.35	-
Middle	Unmatched	0.45	0.32	26.9
	Matched	0.44	0.43	2.9
High	Unmatched	0.24	0.32	-16.4
	Matched	0.24	0.22	3.9
Parent-infant relationship problems (proportion)	Unmatched	0.60	0.37	48.5
	Matched	0.57	0.55	4.0
IQ (20 months)	Unmatched	94.31	103.07	-75.0
	Matched	96.57	96.96	-3.3
AWST-language test (56 months)	Unmatched	82.79	96.07	-77.8
	Matched	84.79	84.41	2.2
Attention span (56 months)	Unmatched	2.54	2.98	-60.7
	Matched	2.59	2.60	-0.5
Visual–Motor Integration (56 months)	Unmatched	5.29	6.39	-45.4
	Matched	5.5	5.66	-6.7
Behaviour regulation (56 months, proportion)				
1. quartile	Unmatched	0.41	0.31	-
	Matched	0.39	0.43	-
2. quartile	Unmatched	0.22	0.18	11.3
	Matched	0.22	0.21	3.1
3. quartile	Unmatched	0.28	0.38	-21.3
	Matched	0.30	0.26	7.7
4. quartile	Unmatched	0.09	0.13	-15.1
	Matched	0.09	0.10	-2.7
Gestational age (weeks)	Unmatched	30.66	32.77	-
	Matched	30.89	32.71	-
SGA (proportion)	Unmatched	44.87	32.49	-
	Matched	43.40	34.49	-
Birth weight (g)	Unmatched	1374.68	1829.27	-
	Matched	1440.38	1823.89	-
Neonatal optimality index (OPTI, proportion)				
1. quartile	Unmatched	2.56	3.56	-
	Matched	3.77	4.18	-
2. quartile	Unmatched	10.26	18.58	-
	Matched	13.21	19.16	-
	Unmatched	11.54	31.30	-

3. quartile	Matched	13.21	30.31	-
4. quartile	Unmatched	75.64	46.56	-
	Matched	69.81	46.34	-

Please note: Numbers are reported as means if not stated otherwise. [a] STATA default-standardised bias was not computed on the reference group of nominal variables.
PSM was based on baseline characteristics measured after birth (i.e, excluding gestational age, neonatal optimality, birth weight and small for gestational age). An imbalance in sex between groups remained after matching (35% DSE and 28% ASE preterm girls), thus regressions on the preterm subsample were additionally adjusted for child sex.

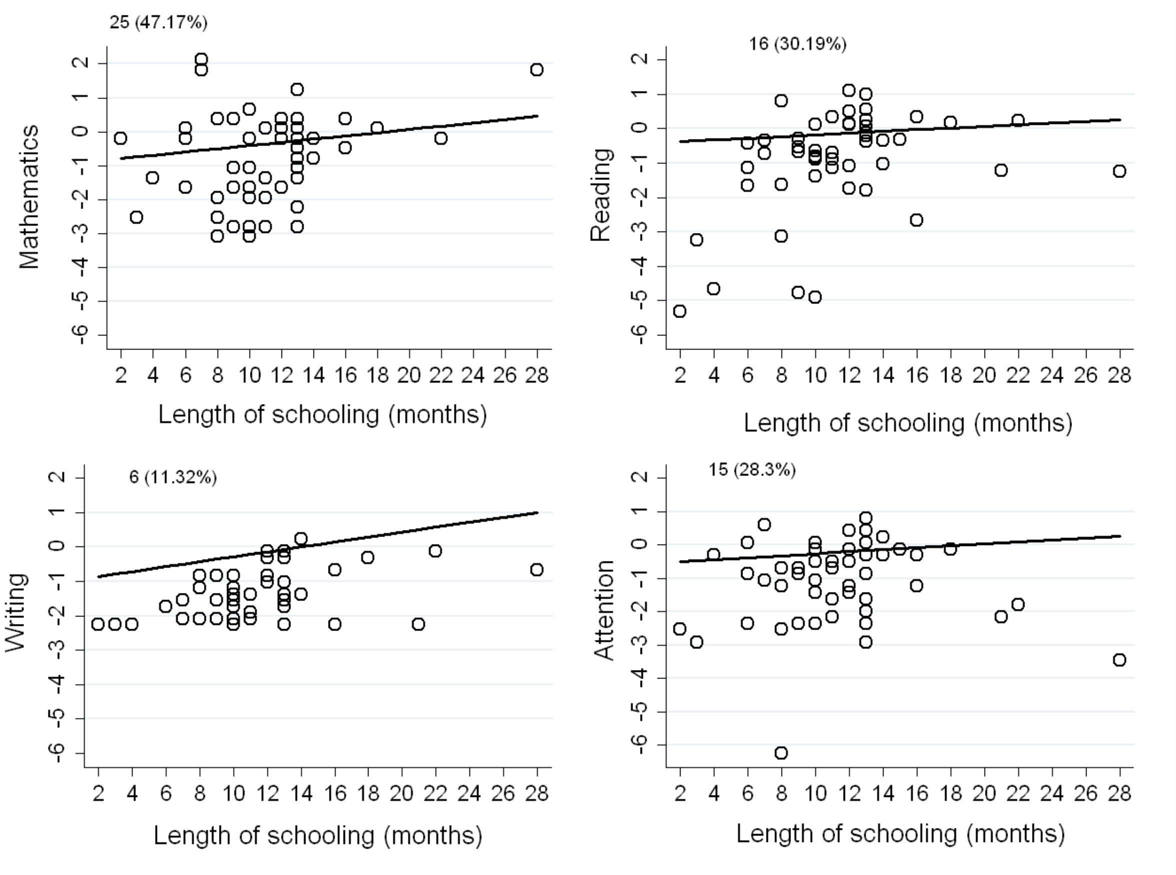


1a. PSM full sample (n=959)



1b. PSM preterm sample (n=343)

Appendix Figure A1. *Means of achievement tests at age 8 years with 95% confidence intervals according to appropriate (ASE) and delayed school entry (DSE) group status in the full propensity score matching (PSM) sample (1a) and in the PSM sample <u>only including preterm children</u> (1b)*



Appendix Figure A2. Comparison of delayed school entry (DSE) preterm children's (n=53) observed standardized test scores (dots) with their mean predicted scores (lines, proxy estimates) given eight additional months of schooling. Please note: *n* (%): proportion of DSE preterm children who would reach the same performance as ASE preterm children if they had 8 additional months of schooling at the time of assessment (DSE children's observed scores >= DSE children's predicted scores based on the same amount of schooling as ASE children at the time of assessment).

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