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Cognitive outcomes in children and adolescents born very preterm: A meta-analysis

Christopher R. Brydges[a,b], PhD, Jasmin K. Landes[a], BPsych (Hons), Corinne L. Reid[a,e], PhD, Catherine Campbell[c], PhD, Noel French[c,d], MB ChB, Mike Anderson[a], DPhil

Affiliations: [a] School of Psychology & Exercise Science, Murdoch University, Perth, Western Australia, Australia; [b] School of Psychological Science, University of Western Australia, Perth, Western Australia, Australia; [c] Neonatal Clinical Care Unit, King Edward Memorial Hospital, Perth, Western Australia, Australia; [d] State Child Development Centre, West Perth, Western Australia, Australia; and [e] School of Health in Social Sciences, The University of Edinburgh, United Kingdom.

Address correspondence to: Christopher Brydges, School of Psychological Science, University of Western Australia, 35 Stirling Highway, Perth, WA, 6009, Australia; [christopherbrydges@gmail.com], +61 (8) 6488 1404.

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Abstract

Aim: To estimate the association between very preterm birth (gestation ≤ 32 weeks) and intelligence, executive functioning, and processing speed throughout childhood and adolescence, and to examine the effects of gestational age, birthweight, and age at assessment.

Method: Studies were included if children were born at fewer than 32 weeks gestation, aged 4-17 years, had an age-matched full-term control group, and if the studies used standardised measures, were published in an English language peer-reviewed journal, and placed no restrictions on participants based on task performance.

Results: We evaluated 6,163 children born very preterm and 5,471 term-born controls from 60 studies. Very preterm children scored 0.82 *SD*s (95% CI = 0.74 - 0.90, $p < .001$) lower on intelligence tests, 0.51 *SD*s (95% CI = 0.44 - 0.58, $p < .001$) lower on measures of executive functioning, and 0.49 *SD*s (95% CI = 0.39 - 0.60, $p < .001$) lower on measures of processing speed than term-born controls. Gestational age and birthweight were associated with study effect size in intelligence and executive functioning of younger children only. Age at assessment was not associated with study effect size.

Interpretation: Children born very preterm have medium to large deficits in these cognitive domains.

Keywords: Preterm birth; Executive functioning; Processing speed; Intelligence; Meta-analysis.

What this paper adds:

- This meta-analysis is centred on very preterm birth and three cognitive domains
- The three critical cognitive domains are intelligence, executive functioning and processing speed
- It is an updated meta-analysis in the field
- It is the first to examine all the cognitive domains listed

Cognitive outcomes in children born very preterm: A meta-analysis

Children born very preterm (less than 32 weeks gestation) have increased risks of cognitive problems, as well as academic underachievement and behavioural problems. [1,2,3] We conducted a quantitative meta-analysis to integrate previous research on problems in three critical cognitive domains: intelligence, executive function (EF), and processing speed. Intelligence usually refers to individual differences in overall cognitive ability, though is often examined in terms of a person's ability to solve novel problems independent of previously acquired knowledge. [4] Executive functioning is an umbrella term used to describe cognitive processes that are specifically associated with goal-directed behaviour, including inhibition, working memory, and task switching. [5] Processing speed refers to the speed at which individuals can perform cognitive tasks. [6] Large bodies of evidence have found intelligence, EF, and processing speed deficits in children born very preterm, [1,2,3,7] likely due to underlying neurological disruptions to a large frontoparietal network. [8]

With an increase in the number of prematurely born children in the last 20 years that are live-born at steadily decreasing gestational age [9] and a decrease in neonatal morbidity over the same time period [10], the long-term developmental sequelae of preterm birth at earlier gestational age are a growing public health concern. A major issue in paediatric research is whether such decreases in gestational age (GA) and/or birthweight (BW) moderate the development of neurocognitive deficits. That is, whether children born extremely preterm (fewer than 28 weeks GA) perform significantly worse on cognitive measures than, for example, children born at 32 weeks GA. Aarnoudse-Moens et al[1] reported no significant correlations between EF domains and GA or BW, suggesting that broadly, children born preterm may perform worse than children born full-term without any indication of differences within the preterm population. Conversely, Kerr-Wilson et al[3] reported an 11.94 point reduction in IQ as a result of preterm birth, and found a significant association between GA and IQ, whereby IQ steadily declined with decreases in GA. This highlights that children born at an increasingly early gestational age are at increasing risk of developing neurocognitive problems. A second issue is whether such neurocognitive problems occur as a deficit or a developmental delay. [11] That is, whether children born very/extremely preterm experience a delay in comparison to typical developmental trajectories, but eventually catch up, or whether they remain at an impaired level. Given that differences in intelligence are due to both individual and developmental differences, [12] comparing differences in cognition between children born very preterm and their term-born peers throughout childhood and adolescence may shed further light on atypical cognitive development in this most-at-risk group among the broader population of preterm born children.

This meta-analysis was conducted to update the meta-analyses conducted by Bhutta et al[2] and Aarnoudse-Moens et al[1], and to integrate the findings of more recent research in the field. Additionally, the current meta-analysis is the first, to the authors' knowledge, to examine all these cognitive domains. Bhutta et al[2] examined cognitive studies as a whole, and Aarnoudse-Moens et al[1] split EFs into verbal fluency, working memory, and cognitive flexibility, but did not examine intelligence or processing speed. Although Kerr-Wilson et al[3] recently examined the association between preterm birth and intelligence, no meta-analysis has examined these three cognitive domains simultaneously. Indeed, processing speed appears to have been overlooked entirely. As such, there were two aims of this study: first, to investigate the outcome of children born very preterm in terms of intelligence, EF, and processing speed as compared to their term born peers; and second, to determine whether variation in our estimates of the association between very preterm birth status and cognitive outcomes can be explained by differences in GA, BW, and age across studies.

Method

Selection of Studies

The guidelines published by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) group were followed in the design and reporting of this meta-analysis. [13] A systematic search of abstracts and titles of peer-reviewed articles was conducted using PsycInfo, Web of Science, and PubMed databases including papers up to July 2017. Search terms included either “low birth weight” OR premature* OR preterm, AND child*, AND at least one of the following terms: neurocogn* OR “processing speed” OR “speed of processing” OR executive function* OR intelligence OR IQ. Reference lists of identified relevant articles were searched for other appropriate articles.

Inclusion Criteria

Studies were included in this meta-analysis if they met the following criteria: (1) the very preterm children were born at fewer than 32 weeks GA; (2) had a mean age between 4 and 17 years; (3) reported an age-matched full-term control group; (4) used standardised measures of EF/processing speed/intelligence; (5) were published in an English language peer-reviewed journal, and; (6) no restrictions were placed on participants based on task performance (e.g. excluding participants with an IQ < 70). Studies were excluded if they did not meet all of these inclusion criteria. Studies that exclusively examined low birth weight children were excluded because of the possibility that small-for-gestational age more mature children may be included. If data from the same cohort was published more than once, only the most recent publication was included in the meta-analysis, unless different measures were used, in which case each study was included. Figure 1 shows the PRISMA[13] flow diagram for studies included in the final analysis, and Tables I, II, and III provide details on the studies included that examine intelligence, EF, and processing speed, [7,14-72] respectively. Additionally, Figures 2-4 show forest plots of the studies included in each of the analyses.

Statistical Analyses

All analyses were conducted in R 3.3.0 [73], using the metafor [74] package for analyses and ggplot2 [75] package to create forest plots. For studies that reported results for subgroups of very preterm children or controls, a weighted group mean and *SD* was calculated by multiplying each subgroup mean and *SD*, respectively, by its sample size, adding the subtotals, and dividing the obtained sum by the total sample size, in line with Aarnoudse-Moens et al[1]. Otherwise, group means and *SD*s were extracted from each study and effect sizes and 95% confidence intervals (CIs) were calculated in terms of Hedge's *g*. Hedge's *g* is conceptually very similar to Cohen's *d*, and measures how many standard deviations difference exists between two groups, and is calculated by dividing the between-group mean difference by the pooled and weighted standard deviation for those means. [76] Values of 0.20, 0.50, and 0.80 are considered to represent small, medium, and large effect sizes, respectively. When combining results across studies, the Hedges-Vevea[77] random-effects model was used due to potentially heterogeneous effect sizes arising from variations in GA, BW, and age at assessment between studies. Furthermore, it is recommended that the random-effects model is used in social sciences settings, [78] and also because it gives the same results as fixed-effects model if applied to homogeneous data. [79] Additionally, *Q*-test and I^2 statistics were conducted to examine the heterogeneity of effect sizes between studies. [80] The I^2 statistic has a range of 0-100%, where 25%, 50%, and 75% have been suggested to be indicative of low, medium and high levels of heterogeneity [81], respectively.

Meta-regression was conducted to determine whether variation in the estimates of the association between very preterm birth status and cognitive outcomes can be explained by differences in GA, BW, and age between studies. That is, whether variation in effect sizes between studies can be accounted for by GA, BW, and/or age. These three variables were treated as continuous variables and were entered in the meta-regression separately, in order to minimise any effects of multicollinearity between GA and BW. Additionally, in case the association between GA and neurodevelopmental outcomes is not linear, GA was also entered separately into the meta-regression as a categorical variable, with mean $GA \leq 28$ weeks as an extremely preterm group, and $28 < GA \leq 32$ weeks as a very preterm group. Studies that did not report GA and BW were excluded list-wise from these analyses.

It is well-known that publication bias is a major concern when conducting a meta-analysis, [78,82,83,84] as studies that report statistically significant results are seven times more likely to be published than studies reporting nonsignificant results. [85] As such, potential for publication bias was tested in two ways: first, Rosenthal's[86] fail-safe N (FSN) was calculated for each combined effect size. The FSN provides a measure of the number of studies that would be required to nullify the observed effect, and is generally considered robust if it is greater than $5k + 10$, where k is the number of studies in the meta-analysis. [86] Secondly, research has found that almost 80% of meta-analyses show a significant negative correlation between study sample size and study effect size, [87] again implying a systematic publication bias against nonsignificant findings and hence potentially overestimating population effect sizes. To examine this, Pearson's correlations between study effect size and study sample size were conducted (with a significant correlation suggesting publication bias), with a cut-off specified as statistical significance of $p < .05$.

We performed an assessment of study quality based on the same 10-point scale used by Bhutta et al. [2] The scoring was performed by the second author (JKL), and was based on the following parameters: population sample, study design, demographic data, socioeconomic data, neurological outcomes of prematurity, and matching of cases and controls. This score was treated as a continuous variable and were entered in the meta-regression separately with continuous GA, categorical GA, BW, and age at assessment.

Results

Intelligence

Based on the 44 studies (preterm *n* = 4,225; control *n* = 3,989) included in the analyses, children born very or extremely preterm performed significantly worse on measures of intelligence (Hedge's *g* = -0.82, 95% CI = -0.90 - -0.74, $p < .001$). This association was found to have medium to high heterogeneity ($Q = 115.81$, $df = 43$, $p < .001$; $I^2 = 62.87\%$), and the tests for publication bias did not indicate systematic bias: Rosenthal's[82] FSN was 17,346 ($p < .0001$, and greater than the cut-off of 230) and the correlation between study sample size and study effect size was nonsignificant ($r = -.12$, $p = .43$). A meta-regression found that age ($B = 0.01$, 95% CI = -0.01 - 0.04, $p = .34$), continuous GA ($B = 0.06$, 95% CI = -0.01 - 0.09, $p = .092$), categorical GA ($B = 0.13$, 95% CI = -0.08 – 0.33, $p = .21$), BW ($B = 0.0004$, 95% CI = -0.0000 - 0.0008, $p = .054$), and quality rating ($B = -0.01$, 95% CI = -0.07 - 0.05, $p = .63$) did not significantly account for variation in effect sizes between studies.

In the younger group (children aged 4-10 years), 29 studies were analysed (preterm *n* = 3,071; control *n* = 3,154). Preterm children were significantly worse on measures of intelligence (Hedge's *g* = -0.86, 95% CI = -0.99 – -0.73, $p < .001$). This association was found to have moderate to high levels of heterogeneity ($Q = 92.17$, $df = 28$, $p < .0001$; $I^2 = 69.62\%$). Rosenthal's[82] FSN was 9,226 ($p < .0001$, and greater than the cut-off of 155) and the correlation between study sample size and study effect size was not statistically significant ($r = .05$, $p = .79$). A meta-regression found that BW significantly accounted for variations in effect sizes for variation in effect sizes between studies within this group ($B = 0.0005$, 95% CI = 0.0001 - 0.0009, $p = .024$), but age ($B = 0.03$, 95% CI = -0.06 - 0.11, $p = .58$), continuous GA ($B = 0.07$, 95% CI = -0.02 - 0.15, $p = .11$), categorical GA ($B = .21$, 95% CI = -0.04 – 0.47, $p = .10$), quality rating did not ($B = -0.01$, 95% CI = -0.09 - 0.07, $p = .84$).

In the older group (aged 11-17 years), 15 studies were included in the analysis (preterm n = 1,154; control n = 835). Preterm children were significantly worse on measures of intelligence (Hedge's g = -0.76, 95% CI = -0.91 – -0.60, $p < .001$). This association was found to have low levels of heterogeneity (Q = 17.31, df = 14, p = .24; I^2 = 19.12%). Rosenthal's[82] FSN was 1,258 ($p < .0001$, and greater than the cut-off of 85), however, the correlation between study sample size and study effect size was statistically significant (r = .53, p = .043). A meta-regression found age (B = 0.02, 95% CI = -0.08 - 0.08, p = .97), continuous GA (B = 0.02, 95% CI = -0.13 – 0.17, p = .77), categorical GA (B = -0.05, 95% CI = -0.41 – 0.31, p = .79), BW (B = 0.0002, 95% CI = -0.0012 - 0.0016, p = .77), and quality rating (B = -0.01, 95% CI = -0.10 - 0.07, p = .73) did not significantly account for variation in effect sizes between studies within this group.

Executive functioning

Based on the 87 measures extracted from 34 studies (preterm n = 3,701; control n = 2,921) included in the analyses, preterm children were significantly worse on measures of EFs (Hedge's g = -0.51, 95% CI = -0.58 – -0.44, $p < .0001$). This association was found to have high levels of heterogeneity (Q = 355.86, df = 86, $p < .0001$; I^2 = 75.83%). Rosenthal's[82] FSN was 26,987 ($p < .0001$, and greater than the cut-off of 445) and the correlation between study sample size and study effect size was not statistically significant (r = .12, p = .27). A meta-regression found that continuous GA (B = 0.08, 95% CI = 0.03 - 0.14, p = .004) and BW (B = 0.0004, 95% CI = 0.0000 - 0.0008, p = .038) both significantly accounted for variation in effect sizes between studies, but categorical GA (B = 0.14, 95% CI = -0.02 – 0.30, p = .086), age (B = 0.00, 95% CI = -0.02 - 0.01, p = .68) and quality rating (B = -0.00, 95% CI = -0.05 - 0.04, p = .85) did not.

In the younger group, 58 measures were extracted from 23 studies (preterm $n = 2{,}306$; control $n = 2{,}167$). Preterm children were significantly worse on measures of EF (Hedge's $g = -0.51$, 95% CI = -0.60 – -0.42, $p < .001$). This association was found to have high levels of heterogeneity ($Q = 293.75$, $df = 57$, $p < .0001$; $I^2 = 80.60\%$). Rosenthal's[82] FSN was 11,283 ($p < .0001$, and greater than the cut-off of 300) and the correlation between study sample size and study effect size was not statistically significant ($r = .17$, $p = .19$). A meta-regression found that continuous GA ($B = 0.10$, 95% CI = 0.03 - 0.17, $p = .005$) significantly accounted for variation in effect sizes between studies within this group, but age ($B = -0.02$, 95% CI = -0.07 - 0.04, $p = .60$), continuous GA ($B = 0.02$, 95% CI = -0.13 – 0.17, $p = .77$), categorical GA ($B = 0.20$, 95% CI = -0.02 – 0.42, $p = .068$), BW ($B = 0.0004$, 95% CI = -0.0001 - 0.0010, $p = .098$), and quality rating ($B = 0.02$, 95% CI = -0.05 - 0.09, $p = .56$) did not.

In the older group, 29 measures were extracted from 11 studies (preterm $n = 1{,}402$; control $n = 755$). Preterm children were significantly worse on measures of EF (Hedge's $g = -0.52$, 95% CI = -0.62 – -0.42, $p < .001$). This association was found to have moderate levels of heterogeneity ($Q = 60.78$, $df = 28$, $p = .0003$; $I^2 = 53.93\%$). Rosenthal's[82] FSN was 3,341 ($p < .0001$, and greater than the cut-off of 155) and the correlation between study sample size and study effect size was not statistically significant ($r = .06$, $p = .75$). A meta-regression found that age at assessment ($B = -.02$, 95% CI = -0.10 - 0.06, $p = .68$), continuous GA ($B = 0.04$, 95% CI = -0.05 – 0.14, $p = .38$), categorical GA ($B = 0.05$, 95% CI = -0.16 – 0.26, $p = .64$), BW ($B = 0.0003$, 95% CI = -0.0003 - 0.0009, $p = .29$), and quality rating ($B = -0.03$, 95% CI = -0.08 - 0.03, $p = .29$) did not significantly account for variation in effect sizes between studies.

Processing Speed

Based on the 22 measures extracted from 17 studies (preterm n = 2,126; control n = 1,610) included in the analyses, preterm children were significantly worse on measures of processing speed (Hedge's g = -0.49, 95% CI = -0.60 – -0.39, $p < .001$). This association was found to have moderate levels of heterogeneity (Q = 41.70, df = 21, p = .005; I^2 = 49.64%), and the tests for publication bias did not indicate systematic bias: Rosenthal's[82] FSN was 1,440 ($p < .0001$, and greater than the cut-off of 120) and the correlation between study sample size and study effect size was not significant (r = .01, p = .95). The meta-regression found that age (B = 0.03, 95% CI = -0.02 - 0.07, p = .22), continuous GA (B = 0.05, 95% CI = -0.03 - 0.13, p = .23), categorical GA (B = 0.14, 95% CI = -0.06 – 0.34, p = .18), BW (B = 0.0000, 95% CI = -0.0002 - 0.0003, p = .65), and quality rating (B = -0.01, 95% CI = -0.08 - 0.06, p = .81) did not significantly account for variation in effect sizes between studies.

In the younger group, 18 measures were extracted from 14 studies (preterm n = 1,344; control n = 1,137). Preterm children were significantly worse on measures of processing speed (Hedge's g = -0.53, 95% CI = -0.65 – -0.41, $p < .001$). This association was found to have moderate levels of heterogeneity (Q = 35.63, df = 17, p = .005; I^2 = 52.29%). Rosenthal's[82] FSN was 1,207 ($p < .0001$, and greater than the cut-off of 100) and the correlation between study sample size and study effect size was not statistically significant (r = .12, p = .63). A meta-regression found that age (B = 0.01, 95% CI = -0.07 - 0.09, p = .82), continuous GA (B = 0.03, 95% CI = -0.07 – 0.14, p = .54), categorical GA (B = 0.11, 95% CI = -0.13 – 0.34, p = .38), BW (B = 0.0002, 95% CI = -0.0001 - 0.0004, p = .13), and quality rating (B = 0.04, 95% CI = -0.05 - 0.13, p = .39) did not significantly account for variation in effect sizes between studies within this group.

In the older group, four measures were extracted from three studies (preterm n = 174; control n = 104). Preterm children were significantly worse on measures of processing speed (Hedge's g = -0.30, 95% CI = -0.52 – -0.08, p = .007). This association was found to have low levels of heterogeneity (*Q* = 2.98, *df* = 3, *p* = .40; I^2 = 0%). Rosenthal's[82] FSN was 7 (*p* = .004; smaller than the cut-off of 30) and the correlation between study sample size and study effect size was not statistically significant (*r* = -.10, *p* = .90). Due to two measures (one study) not providing BW and the remaining two measures having identical quality rating scores, only GA and age at assessment were included as moderators in the meta-regression analysis. Age (*B* = -0.21, 95% CI = -0.61 – 0.19, *p* = .30), continuous GA (*B* = 0.06, 95% CI = -0.14 – 0.27, *p* = .52), and categorical GA (*B* = 0.21, 95% CI = -0.56 – 0.98, *p* = .59) did not significantly account for variation in effect sizes between studies. Given the very small number of processing speed measures in this age group, we recommend interpreting these results with caution.

Discussion

This meta-analysis aimed to determine the association between very preterm birth and cognition in childhood and adolescence. Sixty studies with a total of 6,163 very preterm and 5,471 typical control children reported a strong association between very premature birth and intelligence and medium associations with executive functioning and processing speed. Specifically, children born very preterm were found to be 0.82 *SD*s below their term-born peers in terms of intelligence, corresponding to 12.30 IQ points, consistent with Kerr-Wilson et al's[3] finding of an 11.94 point deficit (though there was some overlap in selected studies). With regards to EF and processing speed, children born very preterm were 0.51 and 0.49 *SD*s lower than term-born children, respectively, highlighting substantial cognitive impairments of very preterm children. It is possible that these impairments are a result of incomplete prenatal neural development. That is, the perinatal development of the brain is not complete before preterm birth, resulting in widespread disruptions in the frontoparietal network, [8] the integrity of which is associated with optimal EF, processing speed, and intelligence. [88]

Additionally, effects of GA and BW were observed for EF, but not intelligence or processing speed. Furthermore, when the studies were split into subgroups of younger (4-10 years) and older children (11-17 years) effect sizes were very similar between groups, though moderator effects were found to be associated with study effect size in the younger children (BW was associated with intelligence study effect size, and continuous GA was associated with EF study effect size). These results are consistent with those reported by Bhutta et al[2], who found that mean cognitive test scores positively correlated with BW and GA in very preterm and/or very low birthweight children. However, Kerr-Wilson et al[3] reported a significant association between GA and IQ, rather than between BW and IQ. This is possibly due to the current meta-analysis only analysing studies that examined children born very preterm, whereas Kerr-Wilson et al[3] included studies with children who were born less than 37 weeks GA. There are two major implications of these findings: first, the results suggest that there may well be significant differences in cognitive ability within children born very preterm, especially in younger children. That is, cognitive impairments may increase in severity as GA and/or BW decrease. Whilst the meta-regression values are in the expected direction (i.e. younger GA and lower BW is associated with larger study effect size), the fact that a similar finding was not observed in the older children could potentially allude to developmental differences between children born very preterm and typically developing children beyond a simple deficit. Previous research has found that different EFs and intelligence develop rapidly throughout childhood but are indistinguishable in typically developing children until around the age of 10 years [89,90], implying that a general executive ability develops through early childhood, whilst specific EF and intelligence abilities only begin to mature from middle to late childhood. Hence, it is possible that the association between GA, BW and study effect size in young children is related to the development of this general executive/intellectual ability, whereas specific abilities (which begin to develop in older children) are unaffected by GA and BW. The second implication of these findings is related to the nonsignificant correlations between age at assessment and the effect sizes of each study, and the consistent effect sizes between the younger and older subgroups. The lack of association between cognitive impairment and age at assessment implies that children born very prematurely do not 'catch up' with their term-born peers through childhood and adolescence. That is, children born preterm suffer from a deficit in cognition, not a delay (see Doyle & Anderson[91] for a review of adult outcomes of extremely premature birth).

These cognitive deficits could also explain decreased academic achievement in children born prematurely. Previous research has found that these neurocognitive domains are associated with educational outcomes. Rose et al[92] reported a cascade of cognitive effects on academic achievement. Specifically, they found that preterm birth significantly predicted processing speed, which significantly predicted EFs, of which, working memory predicted mathematical and reading ability. Based on this cascade model, it may be possible to use cognitive training programs to improve processing speed in children born preterm [93], which may in turn improve performance in measures of EFs and academic performance.

Our meta-analysis has several limitations, resulting from methodological flaws and the heterogeneity of the included studies. First, it is possible that due to advances in medical research, a cohort effect may be evident in our selected studies. Specifically, research has found that mortality and neonatal morbidity rates have significantly decreased in recent years [10], and the children tested in older studies may not have received the same treatment as the children who participated in the most recent studies. As such, it may follow that cognitive outcomes have also improved in the same time period. Secondly, previous research has found that low socioeconomic status is associated with impaired cognitive development [94], increased risk of premature birth [95], and is predictive of IQ in adults born very preterm [96]. However, socioeconomic status was not included as a covariate in the current meta-analysis because there is a severe lack of consistency in terms of reporting socioeconomic variables across studies. Future research should consider including a standardised measure of socioeconomic status in an attempt for uniformity across studies. Third, although GA and BW are closely related and we excluded studies that exclusively investigated small for GA children, it is possible that some small for GA children were included in some studies, which could potentially introduce some bias into the results. Finally, the majority of studies included in the final analyses tested samples from predominantly high income countries (i.e., USA, UK, Australia, New Zealand, and Scandinavia), hence the results may only have limited generalisability due to state-of-the-art medical interventions in these developed countries potentially resulting in greater outcomes than treatments in developing countries.

The current study suggests promising avenues of future research. The development of child-friendly cognitive training programs may well prove to be a productive area of future research. Additionally, given that EF and processing speed are both predictive of intelligence in children, [12] it is possible that the deficits in EF and processing speed have an additive effect, which causes a greater deficit in intelligence than those observed in EF and processing speed. It would be of interest to test whether this is the case by conducting a mediation model, where EF and processing speed are tested as potential mediators of the association between preterm birth and intelligence, and would provide a window into the development of intelligence from an atypical perspective.

In conclusion, this meta-analysis has reported medium to large deficits in three major cognitive domains: EF, processing speed, and intelligence. Intelligence and EF deficits are associated with GA and/or BW, but not age at assessment, implying that (a) cognitive impairments do increase in severity as GA and/or BW decrease, and that (b) cognitive impairments in children born prematurely are deficits, rather than delays.

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Figure Captions

Figure 1. The PRISMA flow diagram of study selection. Taken from Moher et al. [13]

Figure 2. Forest plot of effect sizes obtained from studies the reporting on intelligence in children born very preterm.

Figure 3. Forest plot of effect sizes obtained from studies the reporting on executive functioning in children born very preterm.

Figure 4. Forest plot of effect sizes obtained from studies the reporting on processing speed in children born very preterm.

Tables

Table I. Studies Reporting on Intelligence in Children Born Very Preterm

Studies	Participants		GA, *M* (*SD*), weeks		BW, *M*, (*SD*), grams		Age, *M*, (*SD*), years		Type of test	Test Scores, *M* (*SD*)		Quality Rating
	VPT	Control	VPT	Control	VPT	Control	VPT	Control		VPT	Control	
Aarnoudse-Moens et al. (2009)[14]	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	WPPSI-R IQ	92.5 (17.5)	109.0 (19.2)	5
Aarnoudse-Moens et al. (2013)[15]	200	230	28.1 (1.4)	39.9 (1.2)	1013.0 (287.0)	3578.0 (482.0)	8.2 (2.5)	8.3 (2.3)	WISC-III/WPPSI-R IQ	93.3 (15.8)	105.0 (13.4)	5
Allin et al. (2008)[16]	94	44	N/A	N/A	N/A	N/A	15.5 (0.7)	15.0 (0.7)	WISC-R IQ	99.1 (16.8)	108.8 (13.2)	3
Anderson et al. (2011)[17]	189	173	26.5 (2.0)	39.3 (1.1)	833.0 (164.0)	3507.0 (453.0)	8.1 (0.4)	8.0 (0.4)	WISC-IV IQ	93.1 (16.1)	105.6 (12.4)	7
Anderson & Doyle (2003)[7]	275	223	26.7 (1.9)	39.3 (1.4)	884.0 (162.0)	3407.0 (443.0)	8.7 (0.3)	8.9 (0.4)	WISC-III IQ	95.5 (16.0)	104.9 (14.1)	7
Baron et al. (2012)[18]	84	183	26.2 (2.3)	39.0 (1.0)	777.6 (124.4)	3476.8 (113.7)	6.2 (0.2)	6.5 (0.3)	DAS-II	97.7 (12.5)	112.4 (10.1)	6
Bayless et al. (2008)[19]	69	70	28.8 (2.1)	N/A	1241.0 (361.9)	N/A	8.7 (1.3)	8.7 (1.7)	WISC-III IQ	98.4 (12.9)	105.6 (11.3)	4
Bayless & Stevenson (2007)[20]	40	41	28.4 (2.4)	N/A	1200.8 (368.3)	N/A	8.4	8.4	WISC-III IQ	98.4 (11.2)	107.1 (12.3)	4
Bowen et al. (2002)[21]	48	48	27.2 (2.0)	39.4 (1.3)	893.0 (133.0)	3464.0 (542.0)	8.2 (0.2)	8.2 (0.2)	Stanford-Binet-IV IQ	100.8 (9.2)	110.4 (12.3)	5
Breeman et al. (2015)[22]	260	229	30.6 (2.5)	39.7 (1.2)	1320.0 (287.9)	3360.0 (392.0)	8	8	Kaufman ABC IQ	90.3 (17.3)	102.0 (10.0)	7
Caldú et al. (2005)[23]	25	25	29.5 (2.5)	39.9 (1.4)	N/A	N/A	13.4 (1.9)	14.0 (2.5)	WISC-R/WAIS-III IQ	96.0 (16.8)	113.3 (12.2)	4
Cheong et al. (2013)[24]	148	132	25.8 (1.1)	39.3 (1.3)	897.0 (177.0)	3441.0 (457.0)	18	18	WASI-I IQ	95.7 (15.9)	107.6 (12.8)	7
Conrad et al. (2010)[25]	49	55	27.7 (2.0)	N/A	934.5 (198.4)	3640.0 (474.0)	12.1 (1.7)	10.9 (2.5)	WISC-IV IQ	96.0 (19.5)	110.4 (15.1)	5
de Kieviet et al. (2014)[26]	29	47	28.9 (1.7)	N/A	1187.0 (342.0)	N/A	8.6 (0.3)	8.7 (0.5)	WISC-III IQ	92.8 (18.4)	106.3 (14.8)	4
Dobson et al. (2016)[27]	84	90	27.0 (2.3)	40.0 (0.0)	829.0 (132.2)	3410.6 (473.3)	8	8	WISC-R IQ	93.4 (15.2)	106.4 (12.1)	4
Foulder-Hughes & Cooke (2003)[28]	280	210	29.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III IQ	89.4 (14.2)	100.5 (13.7)	4
Grunewaldt et al. (2014)[29]	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	WISC-III IQ	98.0 (19.6)	105.0 (20.5)	7

Hagmann-von Arx et al. (2014)[30]	58	55	30.5 (1.2)	39.7 (1.6)	1302.0 (408.0)	3338.0 (441.0)	8.2 (1.3)	8.3 (1.3)	WISC-IV IQ	104.1 (14.1)	111.9 (13.8)	5
Hoff et al. (2004)[31]	194	72	27.5 (1.8)	40.1 (1.1)	924.6 (168.7)	3523.6 (510.6)	5.3 (0.1)	5.1 (0.1)	WPPSI-R IQ	95.7 (15.0)	108.1 (11.1)	7
Kesler et al. (2008)[32]	29	22	28.5 (2.1)	N/A	967.8 (147.8)	N/A	12.2 (0.4)	12.5 (1.0)	WISC-III IQ	88.9 (14.9)	103.7 (16.1)	4
Lax et al. (2013)[33]	25	32	27.4	N/A	N/A	N/A	8.7	8.4	WASI-II IQ	101.1 (6.9)	117.5 (7.1)	4
Lind et al.(2010)[34]	97	161	28.3 (2.7)	40.0 (1.1)	1054.0 (259.0)	3644.0 (446.0)	5.0 (0.2)	5.0 (0.2)	WPPSI-R IQ	100.0 (16.0)	111.7 (14.8)	6
Litt et al. (2012)[35]	181	115	26.4 (2.0)	N/A	815.0 (124.0)	3260.0 (524.0)	14.8	14.8	WASI-I IQ	87.1 (18.9)	96.4 (13.4)	7
Løhaugen et al. (2011)[36]	16	19	25.8 (1.8)	N/A	778.0 (118.0)	3924.0 (528.0)	14.1 (0.6)	14.3 (0.7)	WISC-III IQ	78.0 (13.0)	100.0 (12.0)	6
Mangin et al. (2017)[37]	107	113	27.8 (2.4)	39.5 (1.2)	1059.8 (315.3)	3583.6 (405.9)	12	12	WISC-IV IQ	96.59 (17.02)	106.65 (13.77)	4
Mulder et al. (2011)[38]	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	WISC-IV IQ	90.8 (12.6)	104.6 (9.4)	5
Mullen et al. (2011)[39]	44	41	28.3 (1.9)	N/A	994.0 (184.0)	N/A	16.4 (0.3)	16.3 (0.3)	WISC-III IQ	94.3 (14.3)	104.6 (16.3)	5
Murray et al. (2014)[40]	198	70	27.4 (1.9)	39.1 (1.3)	960.0 (222.0)	3322.0 (508.0)	7.5 (0.3)	7.7 (0.3)	WASI-II IQ	97.1 (13.8)	107.2 (12.8)	4
Northam et al. (2011)[41]	49	30	27.6 (2.4)	N/A	1088.6 (386.5)	N/A	16.1 (1.4)	15.8 (1.9)	WASI-I IQ	91.4 (16.0)	108.8 (17.2)	6
Peterson et al. (2000)[42]	25	39	28.7 (1.7)	39.4 (1.3)	997.4 (172.1)	3394.8 (589.8)	8.6 (0.4)	8.7 (0.8)	WISC-III IQ	93.2 (19.2)	116.7 (16.3)	6
Pikho et al. (2017)[43]	20	21	26.2 (1.1)	40.4 (0.8)	834 (162)	3640 (337)	6.5 (0.1)	6.5 (0.1	WISC-IV IQ	99 (11)	106 (10)	5
Potharst et al. (2011)[44]	104	95	28.7 (1.6)	39.9 (1.7)	1045.0 (254.0)	3436.0 (512.0)	5	N/A	WPPSI-III IQ	92.0 (17.0)	103.0 (11.0)	4
Rickards et al. (2001)[45]	120	41	29.3 (2.0)	39.9 (1.0)	1167.0 (215.0)	3417.0 (432.0)	14	N/A	WISC-III IQ	96.2 (15.5)	105.0 (13.3)	6
Saigal et al. (2000)[46]	150	124	27.0 (2.4)	N/A	833.0 (126.0)	3395.0 (483.0)	14.0 (1.6)	14.4 (1.3)	WISC-R IQ	90.0 (18.0)	102.0 (13.0)	10
Schneider et al. (2017)[47]	38	44	29.7 (2.2)	38.1 (1.5)	N/A	N/A	12.92	12.92	WJ III COG GIA	93.8 (13.0)	99.3 (11.2)	1
Serenius et al. (2016)[48]	371	367	25.4 (1.07)	39.9 (1.13)	779 (170)	3617 (482)	6.5	6.5	WISC-IV IQ	83.4 (14.8)	1003. (11.7)	8
Simms et al. (2012)[49]	115	77	28.6 (2.0)	N/A	1213.2 (365.4)	N/A	9.7 (0.7)	9.5 (0.7)	Raven's Coloured Progressive Matrices	97.8 (19.4)	104.9 (20.8)	4
Skranes et al. (2014)[50]	49	58	29.1 (2.7)	39.6 (1.1)	1195.0 (239.0)	3707.0 (486.0)	14.2 (0.3)	14.2 (0.3)	WISC-III IQ	79.0 (23.0)	96.0 (17.0)	5
Sølsnes et al. (2016)[51]	36	103	29.0 (2.9)	N/A	1019 (361)	3661 (485)	7.8 (1.7)	8.3 (1.0)	WPSSI-III/WISC-IV IQ	99 (9.9)	108 (13.6)	6
Stjernqvist & Svenningsen (1999)[52]	58	61	27.1 (1.0)	40.1 (1.4)	1042.0 (242.0)	3648.0 (533.0)	10.5 (0.6)	10.6 (0.6)	WISC-III IQ	89.8 (15.1)	106.5 (15.0)	6
Taylor et al. (2000)[53]	115	49	27.5 (2.8)	N/A	908.4 (299.3)	N/A	11.0 (1.2)	11.2 (1.2)	WISC-III IQ	83.5 (20.3)	99.1 (18.1)	8

Taylor et al. (2004)[54]	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	WISC-III/WAIS-III IQ	86.9 (19.8)	97.9 (16.2)	8
van Baar et al. (2006)[55]	28	30	28.6 (1.7)	39.7 (1.0)	1291.0 (319.0)	3403.0 (414.0)	10	N/A	WISC-R IQ	94.0 (14.4)	104.0 (12.6)	9
van Hus et al. (2014)[56]	81	84	28.7 (1.5)	40.0 (1.7)	1078.7 (264.2)	3448.1 (511.9)	5	5	WPPSI-III IQ	92.1 (17.5)	103.4 (11.4)	5

Table II. Studies Reporting on Executive Functioning in Children Born Very Preterm

Studies	Participants		GA, *M* (*SD*), weeks		BW, *M*, (*SD*), grams		Age, *M*, (*SD*), years		Type of test	Test Scores, *M* (*SD*)		Quality Rating
	VPT	Control	VPT	Control	VPT	Control	VPT	Control		VPT	Control	
Aarnoudse-Moens et al. (2009)[14]	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	TEA-Ch Shape School Inhibition	21.3 (0.6)	22.5 (0.2)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	TEA-Ch Shape School Switching	18.8 (0.7)	22.2 (0.3)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	Go/Nogo	20.8 (0.6)	22.6 (0.4)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	Day-Night	13.2 (0.4)	14.4 (0.2)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	Verbal Fluency	11.9 (3.7)	14.9 (5.2)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	Backward Word Span	1.9 (0.7)	2.8 (0.9)	5
	50	50	28.0 (1.4)	N/A	1042.6 (31.8)	N/A	5.9 (0.4)	6.0 (0.6)	Object Classification Task for Children	7.3 (2.1)	8.8 (2.0)	5
Allin et al. (2008)[16]	94	44	N/A	N/A	N/A	N/A	15.5 (0.7)	15.0 (0.7)	COWAT letters	28.7 (9.0)	32.9 (8.9)	5
	94	44	N/A	N/A	N/A	N/A	15.5 (0.7)	15.0 (0.7)	COWAT animals	19.9 (5.3)	19.3 (4.6)	5
Anderson et al. (2011)[17]	189	173	26.5 (2.0)	39.3 (1.1)	833.0 (164.0)	3507.0 (453.0)	8.1 (0.4)	8.0 (0.4)	TEA-Ch Opposite Worlds	44.2 (29.9)	44.0 (40.7)	7
	189	173	26.5 (2.0)	39.3 (1.1)	833.0 (164.0)	3507.0 (453.0)	8.1 (0.4)	8.0 (0.4)	TEA-Ch Creature Counting	4.2 (2.2)	5.3 (2.7)	7
Anderson & Doyle (2004)[57]	298	223	26.7 (1.9)	39.3 (1.4)	884.0 (162.0)	3407.0 (443.0)	8.7 (0.3)	8.9 (0.4)	WISC-III Digit Span	8.5 (2.8)	9.5 (2.9)	7
	298	223	26.7 (1.9)	39.3 (1.4)	884.0 (162.0)	3407.0 (443.0)	8.7 (0.3)	8.9 (0.4)	Tower of London	10.9 (1.6)	11.2 (1.2)	7
Baron et al. (2012)[18]	84	183	26.2 (2.3)	39.0 (1.0)	777.6 (124.4)	3476.8 (113.7)	6.2 (0.2)	6.5 (0.3)	Hopkins board	97.7 (12.5)	112.4 (10.1)	6
Burnett et al. (2015)[58]	228	166	26.6 (2.0)	39.2 (1.4)	884.0 (161.0)	3401.0 (453.0)	17.0 (1.5)	17.3 (1.6)	WMTB-C backward digit span	3.8 (1.1)	4.3 (1.1)	7
	228	166	26.6 (2.0)	39.2 (1.4)	884.0 (161.0)	3401.0 (453.0)	17.0 (1.5)	17.3 (1.6)	Tower of London	11.2 (1.1)	11.6 (0.7)	7
Campbell et al. (2015)[59]	32	40	25.9 (1.7)	N/A	862.2 (211.2)	N/A	7.1 (0.2)	7.1 (0.4)	WISC-IV Working Memory Index	89.4 (10.3)	99.1 (11.1)	3
	32	40	25.9 (1.7)	N/A	862.2 (211.2)	N/A	7.1 (0.2)	7.1 (0.4)	TEA-Ch Creature Counting Timing	7.0 (1.5)	6.0 (1.7)	3

Clark & Woodward (2015)[60]	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	Detour Reaching Box	1.0 (1.3)	0.5 (0.7)	7
	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	Conners K-CPT	0.4 (0.2)	0.3 (0.2)	7
	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	Tower of Hanoi	3.1 (2.0)	3.9 (2.1)	7
	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	NEPSY Visual Search	20.6 (10.5)	25.6 (8.3)	7
	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	WISC-IV Backward Digit Span	11.6 (7.0)	13.5 (6.1)	7
	102	108	27.9 (2.3)	39.5 (1.2)	1071.1 (314.5)	3574.6 (409.8)	6	6	Corsi Blocks	6.4 (6.0)	9.7 (7.3)	7
Crotty et al. (2012)[61]	114	108	26.3 (2.3)	39.2 (1.0)	772.8 (131.3)	3500.2 (423.4)	6.5 (0.6)	6.6 (0.3)	WISC-IV Backward Digit Span	9.2 (3.3)	11.3 (2.6)	6
	114	108	26.3 (2.3)	39.2 (1.0)	772.8 (131.3)	3500.2 (423.4)	6.5 (0.6)	6.6 (0.3)	Corsi Blocks	36.4 (9.6)	43.9 (9.3)	6
de Kieviet et al. (2014)[26]	29	47	28.9 (1.7)	N/A	1187.0 (342.0)	N/A	8.6 (0.3)	8.7 (0.5)	Flanker task	160 (116)	97 (77)	4
Foulder-Hughes & Cooke (2003)[28]	280	210	29.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III Arithmetic	10.3 (3.2)	11.4 (2.8)	4
	280	210	30.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III Digit Span	8.6 (2.7)	10.0 (3.0)	4
	280	210	31.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III Mazes	7.4 (3.3)	9.1 (3.2)	4
Geldof et al. (2013)[62]	108	72	30.1 (2.3)	39.9 (1.3)	1264 (355)	3600 (539)	5.5 (0.1)	5.6 (0.3)	ANT Executive Network	1324 (24.8)	1353 (30.6)	5
Giordano et al. (2016)[63]	52	52	28.71 (2.02)	39 (1.38)	1172.91 (399.88)	3455.37 (502.56)	5.7	5.8	Go/Nogo	2.9 (2.5)	3.8 (3.5)	5
	52	52	28.71 (2.02)	39 (1.38)	1172.91 (399.88)	3455.37 (502.56)	5.7	5.8	Flexibility	1793.4 (788.2)	1352.6 (500.2)	5
Grunewaldt et al. (2014)[29]	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	WISC-III Working Memory Index	91.0 (17.1)	101.0 (14.7)	7
	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	Stroop	87.7 (22.5)	78.7 (29.0)	7
	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	Trail-Making Test B	126.4 (47.0)	108.2 (51.6)	7
	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	Tower of London	552.9 (175.0)	471.3 (182.3)	7
Hagmann-von Arx et al. (2014)[30]	58	55	30.5 (1.2)	39.7 (1.6)	1302.0 (408.0)	3338.0 (441.0)	8.2 (1.3)	8.3 (1.3)	WISC-IV Arithmetic	10.4 (2.7)	11.5 (2.1)	5
Lind et al.(2010)[34]	97	161	28.3 (2.7)	40.0 (1.1)	1054.0 (259.0)	3644.0 (446.0)	5.0 (0.2)	5.0 (0.2)	NEPSY Inhibition	8.3 (3.3)	9.9 (3.0)	6

Litt et al. (2012)[35]	181	115	26.4 (2.0)	N/A	815.0 (124.0)	3260.0 (524.0)	14.8	14.8	CANTAB Spatial Span	-0.7 (1.0)	0.0 (0.0)	7
Løhaugen et al. (2011)[36]	16	19	25.8 (1.8)	N/A	778.0 (118.0)	3924.0 (528.0)	14.1 (0.6)	14.3 (0.7)	WMS-III Digit Span Backwards	3.7 (0.7)	4.2 (0.9)	6
	16	19	25.8 (1.8)	N/A	778.0 (118.0)	3924.0 (528.0)	14.1 (0.6)	14.3 (0.7)	WMS-III Letter-Number Sequencing	7.4 (2.3)	8.4 (1.7)	6
	16	19	25.8 (1.8)	N/A	778.0 (118.0)	3924.0 (528.0)	14.1 (0.6)	14.3 (0.7)	WMS-III Spatial Span Backwards	4.6 (1.0)	5.6 (0.6)	6
Luu et al. (2011)[64]	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	D-KEFS Letters	8.7 (3.6)	10.8 (3.3)	8
	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	D-KEFS Category	9.7 (3.7)	11.3 (3.1)	8
	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	D-KEFS Inhibition	7.9 (3.8)	10.2 (2.6)	8
	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	D-KEFS Inhibition switching	8.4 (3.8)	10.3 (2.9)	8
	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	D-KEFS Tower	8.5 (3.1)	10.3 (2.2)	8
	337	102	28.0 (2.0)	N/A	961.0 (173.0)	N/A	16.1 (0.3)	16.2 (0.3)	WMS Spatial Span Backwards	8.8 (3.9)	11.0 (2.7)	8
Marlow et al. (2007)[65]	180	158	24.5 (0.7)	N/A	N/A	N/A	6.3	6.2	NEPSY Attention-Executive Domain	102.1 (11.0)	109.3 (8.3)	5
Mulder et al. (2011)[38]	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	TEA-Ch Walk Don't Walk	5.9 (3.2)	9.0 (3.7)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	TEA-Ch Opposite Worlds	7.0 (2.9)	10.0 (2.8)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	WISC-IV Backward Digit Span	9.1 (2.5)	11.1 (2.6)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	WISC-IV Letter-Number Sequencing	9.5 (2.6)	10.7 (1.8)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	NEPSY Verbal Fluency	10.7 (3.6)	12.3 (3.1)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	TEA-Ch Creature Counting	7.3 (3.4)	9.4 (3.1)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	NEPSY Tower	9.9 (2.5)	10.8 (2.3)	5
Murray et al. (2014)[40]	198	70	27.4 (1.9)	39.1 (1.3)	960.0 (222.0)	3322.0 (508.0)	7.5 (0.3)	7.7 (0.3)	TEA-Ch Creature Counting	3.3 (2.3)	4.6 (2.0)	4
Nosarti et al. (2008)[66]	207	104	29.1 (2.2)	40.1 (1.3)	1276.0 (353.8)	3358.4 (394.3)	15.2 (0.5)	15.0 (0.7)	FAS test	29.1 (8.6)	32.7 (8.5)	3
	207	104	29.1 (2.2)	40.1 (1.3)	1276.0 (353.8)	3358.4 (394.3)	15.2 (0.5)	15.0 (0.7)	Animals and Objects Trials	38.7 (11.2)	42.2 (11.6)	3
	207	104	29.1 (2.2)	40.1 (1.3)	1276.0 (353.8)	3358.4 (394.3)	15.2 (0.5)	15.0 (0.7)	Trail-Making Test B	83.9 (29.1)	73.2 (23.0)	3

Nosarti et al. (2006)[67]	8	14	27.8 (2.0)	N/A	1105.9 (163.4)	N/A	16.3 (1.1)	17.2 (1.1)	Go/Nogo	92.2. (7.5)	92.3 (13.5)	3
Pizzo et al. (2010)[68]	25	25	28.6 (2.8)	N/A	1125.6 (347.2)	N/A	5.8 (0.3)	5.1 (0.3)	Attentional Networks Task	62.0 (75.1)	121.6 (86.9)	5
Rickards et al. (2001)[45]	120	41	29.3 (2.0)	39.9 (1.0)	1167.0 (215.0)	3417.0 (432.0)	14	N/A	WISC-III Arithmetic	8.8 (3.3)	10.8 (3.2)	6
	120	41	29.3 (2.0)	39.9 (1.0)	1167.0 (215.0)	3417.0 (432.0)	14	N/A	WISC-III Digit Span	9.9 (3.6)	9.8 (3.6)	6
Simms et al. (2012)[49]	115	77	28.6 (2.0)	N/A	1213.2 (365.4)	N/A	9.7 (0.7)	9.5 (0.7)	Automate Working Memory Assessment	11.8 (3.5)	13.6 (3.8)	4
	115	77	28.6 (2.0)	N/A	1213.2 (365.4)	N/A	9.7 (0.7)	9.5 (0.7)	NEPSY Inhibition	8.3 (3.5)	9.6 (3.5)	4
Skranes et al. (2014)[50]	49	58	29.1 (2.7)	39.6 (1.1)	1195.0 (239.0)	3707.0 (486.0)	14.2 (0.3)	14.2 (0.3)	Wisconsin Card Sorting Test	18.8 (12.5)	11.5 (6.2)	5
	49	58	29.1 (2.7)	39.6 (1.1)	1195.0 (239.0)	3707.0 (486.0)	14.2 (0.3)	14.2 (0.3)	Knox Cube	12.0 (2.7)	13.8 (2.0)	5
	49	58	29.1 (2.7)	39.6 (1.1)	1195.0 (239.0)	3707.0 (486.0)	14.2 (0.3)	14.2 (0.3)	Trail-Making Test B	50.3 (25.0)	27.9 (13.6)	5
Stjernqvist & Svenningsen (1999)[52]	58	61	27.1 (1.0)	40.1 (1.4)	1042.0 (242.0)	3648.0 (533.0)	10.5 (0.6)	10.6 (0.6)	WISC-III Arithmetic	8.0 (2.7)	9.7 (2.8)	6
Taylor et al. (2000)[53]	115	49	27.5 (2.8)	N/A	908.4 (299.3)	N/A	11.0 (1.2)	11.2 (1.2)	Contingency Naming Test	0.5 (1.2)	0.0 (1.0)	8
Taylor et al. (2004)[54]	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	CANTAB IED Shift	41.6 (35.6)	34.2 (23.0)	8
	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	CANTAB Stockings of Cambridge	7.3 (2.0)	8.5 (1.9)	8
	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	CANTAB Spatial Working Memory	38.0 (23.5)	24.1 (16.0)	8
	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	CANTAB Rapid Visual Processing	17.0 (4.7)	18.9 (3.7)	8
	95	52	27.6 (2.8)	N/A	910.1 (299.2)	N/A	16.8 (1.2)	17.0 (1.3)	Contingency Naming Test	0.5 (0.3)	0.7 (0.3)	8
van Baar et al. (2006)[55]	28	30	28.6 (1.7)	39.7 (1.0)	1291.0 (319.0)	3403.0 (414.0)	10	N/A	WISC-R Mazes	10.0 (2.2)	11 (2.2)	9
	28	30	28.6 (1.7)	39.7 (1.0)	1291.0 (319.0)	3403.0 (414.0)	10	N/A	WISC-R Arithmetic	8.0 (2.7)	11 (2.2)	9
	28	30	28.6 (1.7)	39.7 (1.0)	1291.0 (319.0)	3403.0 (414.0)	10	N/A	WISC-R Digit Span	9.0 (2.7)	10.0 (3.2)	9
Wong et al. (2014)[69]	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	Woodcock-Johnson-III BIA	89.3 (18.4)	104.4 (18.4)	6
	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	NEPSY Shape School Inhibition	0.9 (0.3)	1.1 (0.3)	6

	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	Preschool Trials Test-Revised, Inhibition	3.6 (4.7)	6.1 (2.8)	6
	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	Nebraska Barnyard	4.9 (3.0)	6.4 (2.8)	6
	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	Go/Nogo	1.5 (1.1)	2.3 (1.1)	6
	111	110	26.0 (2.0)	N/A	818.0 (176.0)	3386.0 (446.0)	5.9 (0.3)	6.0 (0.3)	Continuous Performance Test	2.4 (1.3)	3.4 (1.3)	6
Woodward et al. (2012)[70]	106	109	27.9 (2.3)	39.5 (1.2)	1065.9 (312.6)	3574.6 (407.9)	6.0 (0.1)	6.0 (0.1)	Tower of Hanoi, Visual Search, Backward Digit Span, Corsi Blocks, Detour Reaching Box, Conners K-CPT - composite	9.3 (2.1)	10.7 (1.7)	7

Table III. Studies Reporting on Processing Speed in Children Born Very Preterm

Studies	Participants		GA, *M* (*SD*), weeks		BW, *M*, (*SD*), grams		Age, *M*, (*SD*), years		Type of test	Test Scores, *M* (*SD*)		Quality Rating
	VPT	Control	VPT	Control	VPT	Control	VPT	Control		VPT	Control	
Anderson & Doyle (2003)[7]	275	223	26.7 (1.9)	39.3 (1.4)	884.0 (162.0)	3407.0 (443.0)	8.7 (0.3)	8.9 (0.4)	WISC-III Processing Speed Index	98.8 (15.8)	105.4 (13.6)	7
Campbell et al. (2015)[59]	32	40	25.9 (1.7)	N/A	862.2 (211.2)	N/A	7.1 (0.2)	7.1 (0.4)	WISC-IV Processing Speed Index	92.9 (14.0)	102.3 (14.4)	3
Delane et al. (2016)[71]	44	36	26	40	870	N/A	7.29	7.28	Inspection Time	122.73 (71.80)	80.56 (27.35)	4
Delane et al. (2017)[72]	77	74	27	40	940	N/A	7.17	7.16	TEA-Ch Sky Search time	9.21 (3.24)	6.69 (1.77)	4
Foulder-Hughes & Cooke (2003)[28]	280	210	29.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III Coding	9.1 (3.7)	10.4 (3.6)	4
	280	210	29.8	N/A	1467.0 (424.0)	N/A	7.5 (0.4)	7.5 (0.5)	WISC-III Symbol Search	8.7 (3.2)	10.9 (3.3)	4
Giordano et al. (2016)[63]	52	52	28.71 (2.02)	39 (1.38)	1172.91 (399.88)	3455.37 (502.56)	5.7	5.8	WISC-IV Symbol Search	15.9 (9.2)	15.8 (7.7)	5
Grunewaldt et al. (2014)[29]	23	33	26.3 (1.9)	40.1 (0.9)	797.0 (145.0)	3609.0 (329.0)	10.2 (0.8)	10.5 (0.7)	WISC-III Processing Speed Index	97.0 (22.0)	103.0 (20.5)	7
Løhaugen et al. (2011)[36]	16	19	25.8 (1.8)	N/A	778.0 (118.0)	3924.0 (528.0)	14.1 (0.6)	14.3 (0.7)	WISC-III Processing Speed Index	90.0 (15.0)	98.0 (17.0)	6
Mulder et al. (2011)[38]	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	WISC-IV Processing Speed Index	93.8 (13.2)	102.2 (13.3)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	TEA-Ch Sky Search motor time/target	0.7 (1.5)	0.0 (1.0)	5
	56	22	27.6 (1.8)	N/A	N/A	N/A	9.8 (0.3)	9.8 (0.4)	TEA-Ch Same Worlds time	1.2 (1.7)	0.0 (1.0)	5
Murray et al. (2014)[40]	198	70	27.4 (1.9)	39.1 (1.3)	960.0 (222.0)	3322.0 (508.0)	7.5 (0.3)	7.7 (0.3)	TEA-Ch Identification task	2.9 (0.1)	2.9 (0.1)	4
	198	70	27.4 (1.9)	39.1 (1.3)	960.0 (222.0)	3322.0 (508.0)	7.5 (0.3)	7.7 (0.3)	TEA-Ch Detection task	2.7 (0.1)	2.7 (0.1)	4
Potharst et al. (2011)[44]	104	95	28.7 (1.6)	39.9 (1.7)	1045.0 (254.0)	3436.0 (512.0)	5	N/A	WPPSI-III Processing speed quotient	93.0 (19.0)	105.0 (14.0)	4
Rickards et al. (2001)[45]	120	41	29.3 (2.0)	39.9 (1.0)	1167.0 (215.0)	3417.0 (432.0)	14	N/A	WISC-III Coding	9.3 (3.6)	10.7 (3.0)	6

Schneider et al. (2017)[47]	38	44	29.7 (2.2)	38.1 (1.5)	N/A	N/A	12.92	12.92	Inspection Time	63.9 (18.1)	64.3 (15.0)	1
	38	44	29.7 (2.2)	38.1 (1.5)	N/A	N/A	12.92	12.92	Coding	43.8 (7.2)	44.9 (6.9)	1
Simms et al. (2012)[49]	115	77	28.6 (2.0)	N/A	1213.2 (365.4)	N/A	9.7 (0.7)	9.5 (0.7)	Rapid Automised Naming	30.5 (7.4)	33.6 (10.2)	4
Stjernqvist & Svenningsen (1999)[52]	58	61	27.1 (1.0)	40.1 (1.4)	1042.0 (242.0)	3648.0 (533.0)	10.5 (0.6)	10.6 (0.6)	WISC-III Coding	8.7 (2.7)	10.3 (3.4)	6
van Baar et al. (2006)[55]	28	30	28.6 (1.7)	39.7 (1.0)	1291.0 (319.0)	3403.0 (414.0)	10	N/A	WISC-R Substitution	9.0 (2.6)	10.0 (2.5)	9
van Hus et al. (2014)[56]	81	84	28.7 (1.5)	40.0 (1.7)	1078.7 (264.2)	3448.1 (511.9)	5	5	Amsterdam Neuropsychological Tests (baseline speed)	677.3 (191.8)	575.5 (108.7)	5