Mathematics difficulties in extremely preterm children:

Evidence of a specific deficit in basic mathematics processing.

Running title: Mathematics difficulties in EP children

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Abstract

Background Extremely preterm (EP, <26 weeks gestation) children have been observed to have poor academic achievement in comparison to their term-born peers, especially in mathematics. This study investigated potential underlying causes of this difficulty.

Methods. 219 extremely preterm participants were compared with 153 term-born control children at 11 years old. All children were assessed by a psychologist on a battery of standardised cognitive tests and a number estimation test assessing children's numerical representations.

Results. EP children underperformed in all tests in comparison to the term controls (the majority of p's<.001). Different underlying relationships between performance on the number estimation test and mathematical achievement were found in extremely preterm compared to control children. That is, even after controlling for cognitive ability, a relationship between number representations and mathematical performance persisted for EP children only (EP: $r= .346$, $n= 186$, $p< .001$; Control: $r= .095$, $n=146$, $p= .256$).

Conclusion. Interventions for EP children may target improving children's numerical representations in order to subsequently remediate their mathematical skills.

Despite sustained increases in survival rates for children born extremely preterm (EP; <26 weeks gestation)[1] , the prevalence of severe neurodevelopmental impairments has remained relatively static and cognitive deficits continue to be the most prevalent disability[2].In addition to global cognitive impairments present in up to 45% of survivors[3], specific neuropsychological difficulties include deficits in attention[4], executive function[5,6] , working memory[7], processing speed[8] and visuo-spatial skills[9]. These are evident even in the preschool years[10,11] and contribute to the poor educational outcomes observed in this population[3,12]. EP children also have specific difficulties in processing simultaneously, rather than sequentially, presented information[13].

Although there is considerable individual variation in outcomes, as a group EP children have poorer academic attainment than term-born peers across all school subjects[9,14] and up to two-thirds have some special educational needs (SEN)[3]. One of the most consistent findings is that EP children have specific difficulties with mathematics that impact markedly upon their attainment at school[13,15]. When comparing EP children to term born peers the most substantial deficits are consistently in mathematics. In contrast to reading, performance, group differences in mathematics performance remain after controlling for neurosensory impairments or general cognitive ability[3,16].

As yet, little is known about the specific nature of mathematics difficulties in preterm populations and there is a paucity of studies investigating the underlying mechanisms that may account for these deficits[17]. Emerging research with typically developing children has revealed that both domain-general and domain-specific skills play a critical role in individual differences in mathematical attainment[18].Domain-general skills observed to be important predictors of attainment in mathematics include visuospatial skills, working memory, shifting and inhibitory control[19,20] and there is also evidence that language abilities perform an essential role[21].In addition, domain-specific skills such as retrieval speed of answers[22], use of efficient strategies[23] and procedural competency[24]also contribute to mathematical success. In particular, the accuracy and precision of internal numerical representations, typically assessed using measures of children's estimation skills or the ability to enumerate or discriminate between quantities, have been found to be predictive of achievement in mathematics[25].

Investigating EP children's numerical representations and mathematical processing in detail is thus an important first step in understanding their mathematical difficulties and in developing targeted interventions for this group. This study aimed to (1) investigate the association between numerical representations and attainment in mathematics and (2) identify domain-general and domain-specific processes that may underlie poor mathematical attainment in EP children.

Results

Effect of EP birth on standardised and experimental tests

Control children completed all of the tasks, except for one child who did not complete the Mathematics Estimation Test (MET) due to time constraints. Three EP children were unable to complete the Wechsler Individual Achievement Test-Reading (WIAT-RS), two did not complete the developmental neuropsychology test (NEPSY-II) Attention/Executive Functioning sub-task and one did not complete the MET. Table 1 shows descriptive statistics for all standardised and experimental tasks.

As expected, EP children underperformed on all measures in comparison to term-born children. There were large effect sizes for between group differences in accuracy on all measures, except for three of the four MET subcomponents (length, dots and distance) wherein small to medium effect sizes were observed. Not only were control children significantly more accurate on all subcomponents of the MET, but they also made significantly fewer erroneous responses to the dot and number line questions (Table 1). Group differences in the magnitude of error for the number line and dots subcomponent also showed large effect sizes. There were no significant sex differences in the control group on any measure. Sex differences were observed for the EP group for Mental Processing Composite (MPC) scores (Male: M= 85.4, SD=12.2, Female: M=89.3, SD= 13.6; t(196)=-2.1, p=.04), Kaufman Assessment Battery for Children (K-ABC) Simultaneous (Male: M= 84.8, SD=12.5, Female: M=88.8, SD=13.6; t(196)=-2.1, p=0.03), Sensorimotor (Male: M= 81.7, SD=15.1, Female: M=86.5, SD= 13.1; t(193)=-2.4, p=.02) and Attention/Executive Function (Male: M= 80.2, SD=17.2, Female: M=90.4, SD= 18.4; t(195)=-3.9, p<.001), with females having higher scores than males. There were no significant differences in any test scores between EP children born at 22-24w vs. 25w.

Associations between mathematics attainment and domain-specific and domain-general measures

Bivariate correlations between all measures for control and EP children are shown in Table 2. There were significant correlations between Wechsler Individual Achievement Test-Mathematics (WIAT-MS) and all domain-general and domain-specific measures for both control and EP children. However, for the MET sub-component scores, for control children the only significant correlation was between WIAT-MS and number line scores. In contrast, for EP children, significant correlations were observed between WIAT-MS and number line, dot and length sub-components. Fisher r-to-z transformations revealed that all correlations between WIAT-MS scores and other measures were significantly stronger for EP than control children (z range: -2.61 to -4.75, all $p<.05$). The most substantial differences in correlations between EP and control children were for WIAT-MS and MET scores ($z=-4.75$, $p=.003$) and WIAT-MS and Number Line sub-component scores ($z= -4.58$, $p<.001$) with significantly stronger associations found for EP children.

Partial correlations were conducted to control for MPC (Table 2). For control children, the only correlations with WIAT-MS scores that remained significant were with WIAT-RS and NEPSY Visuospatial scores. For EP children correlations between WIAT-MS scores and the other main measures remained significant ($p<.05$). For the domain-specific skills the correlation with WIAT-MS and both MET total score and number line MET sub-component remained significant. After adjustment for MPC, the correlation between MET and WIAT-MS was no longer significant for control children ($p= .250$), but this correlation remained so for EP children ($r= .346$, $n= 186$, $p< .001$) (Figure 1).

Predicting attainment in mathematics

Hierarchical step-wise multivariable linear regression was conducted to evaluate the contribution of domain-general (K-ABC Simultaneous, K-ABC Sequential, , WIAT-RS, NEPSY Sensorimotor, NEPSY Visuospatial and NEPSY Attention and Executive Function) and domain-specific (MET) measures to attainment in mathematics (WIAT-MS). This analysis was completed separately for control and EP children to establish differences in the strength of the contribution of the measures within each group (Table 3). Regression analysis indicated that K-ABC Simultaneous, K-ABC Sequential, WIAT-RS and NEPSY Visuospatial scores significantly contributed to both EP and control children's attainment in mathematics, explaining a substantial amount of the variance in WIAT-MS scores (Control= 48%, EP= 72%). Simultaneous processing was a stronger predictor of WIAT-MS than sequential processing for EP children; the reverse was true for control children (EP Simultaneous: B= .30, p=.001, 95% CI= .12 to .48; EP Sequential: B= .19, p=.02, 95% CI= .03 to .35; Control Simultaneous: B= .20, p=.02, 95% CI= .03 to .38; Control Sequential: B= .24, p=.01, 95% CI= .05 to .43). MET scores only contributed significantly to EP children's WIAT-MS, explaining an extra 2% of the variance for this group of children (EP MET: B= 1.59, p=.001, 95% CI= .66 to 2.52; Control MET: B= .29, p>.05, 95% CI= -.69 to 1.27).

Discussion

The results of this study confirm those of previous investigations and demonstrate that, by the end of primary education, EP children have markedly poorer attainment in mathematics compared with children born at term. As expected, term-born control children outperformed EP children on all measures with large effect sizes for the majority of comparisons. The observed between-group discrepancies in performance are consistent with previous studies that have reported significant deficits in academic performance in EP children with the most substantial differences in standardised measures of attainment in mathematics compared with other school subjects[3,14,17].

This study also confirmed previous research that has shown that both literacy skills and visuospatial skills are important for success in mathematics in both EP and control groups as quantified in Table 3[22,24,25]. The relationship between these domain-general skills and mathematics attainment observed for both groups emphasises the importance of a wide set of neuropsychological skills in the development of mathematical ability. In contrast, we did not observe a significant contribution to WIAT-MS scores from sensorimotor or attention/executive skills for both the control and EP group. This may be a surprising in light of previous studies that have suggested the importance of attention, executive functions and motor skills for success in mathematics[22-24] and academic performance in general[26].

A contrasting relationship between scores on the K-ABC Sequential and Simultaneous scales was noted for EP and control children. EP children did not perform as well as control children on either of these scales; however EP children had greater difficulty with processing simultaneously presented information rather than sequentially presented information, a result replicating that of previous studies[13,14]. In fact, simultaneous, rather than sequential, processing score was a stronger predictor of WIAT-MS for the EP group, the reverse was true for control children. Therefore our results suggest that EP children may have a specific difficulty in integrating information, a skill that appears to be important for mathematical processing.

To our knowledge, this is the first study to investigate specific components of mathematic processing in EP children. Initially we observed significant correlations with WIAT-MS and MET scores for both control and EP children, indicating a relationship between attainment in mathematics and children's accuracy of numerical representations. This was expected and is consistent with previous studies of typically developing children that have demonstrated a relationship between numerical representations and mathematical ability[27].

However, we observed a different relationship between numerical representations and attainment in mathematics for EP and control children. Associations between the measures of attainment and numerical representations were significantly stronger for EP children. After controlling for overall cognitive ability (MPC), the relationship between WIAT-MS and MET scores remained significant for EP children only. This suggests that, in contrast to control children, EP children's attainment in mathematics was associated with their underlying accuracy of numerical representations and was not simply a component of their general cognitive ability. This was further exemplified in the results of the step-wise regression analyses in which MET scores contributed significantly to WIAT-MS scores above the other domain general measures only for EP children. This study therefore pinpoints that EP children have specific difficulty in numerical estimations – a basic mathematical skill - that contributed significantly to their overall mathematical performance. Thus we have demonstrated that mathematics learning difficulties in the EP population may not arise solely as part of the spectrum of domain-general cognitive impairments typically associated with preterm birth, but may involve additional deficits in specific components of mathematical processing which contribute significantly their underachievement in this area.

Solving mathematical tasks involves different brain areas and the collaboration of large neural networks. The 4CAPS model of complex cognitive neuroarchitecture proposes that when resource demands exceed the resource supply of the first centre, processing spills over to less-specialized centres that are now been recruited into the large-scale network[28].

Considering that EP children have greater general domain limitations, this spill-over is likely to occur sooner and requires the recruitment of specific skills, such as numerical representations. Thus, it appears consistent with the 4CAPS model, that recruiting more centres leads to costs such as bandwith limitations and more co-ordination, all which can be costly for overall performance.

Our finding of the importance of numerical representations for achievement in mathematics in the EP population may perhaps have been expected. A previous neuroimaging study has suggested that preterm children's poor magnitude representations may contribute to their overall difficulty in mathematics[29]. In addition, it is interesting to note that mathematical difficulties have been associated with poor internal representations of number in other populations of children with neurodevelopmental disorders, for example in children with William's Syndrome[30], Downs Syndrome[30] and Velio Cardial Facial Syndrome[31].

These results suggest that potential educational interventions aiming to improve mathematics attainment in EP children might be best targeted specifically to this population and may involve attempting to improve numerical representations. Indeed, interventions designed to increase children's accuracy of numerical representations have been shown to concurrently improve general mathematical performance[32]. However, given the significant association between attainment and other domain-general measures observed in this study, the potential of targeting improvement in these other skills, such as visuospatial skills that require simultaneous information processing, for improving outcomes in mathematics should also be considered. Perhaps EP children would benefit from a combined intervention focusing on both numerical representations and visuospatial skills, in contrast to interventions used with term-born children experiencing pure mathematical difficulties.

The strengths of this study may be attributed to its use of gold-standard contemporary measures of children's cognitive ability and academic attainment, the high level of inter-rater reliability achieved and the care taken to ensure psychologists were blind to the child's birth status. The EP children comprised a large, whole-population based sample drawn from children across the whole of the UK and Ireland who were assessed with a contemporaneous comparator group who achieved a distribution of scores on standardised tests that would be expected of the general population. This is the first time that numerical representations in relation to mathematics abilities has been reported in EP children; however the MET itself, although sensitive for detecting group differences, is a brief measure. On the other hand, it makes the MET highly usable in both research and school settings. Of course, numerical representations are a single component of a range of separable mathematical processes shown to underlie performance in curriculum-based tests. Thus, future studies should assess a wider range of processes and skills to further investigate the specific difficulties that EP children have with mathematics and the underlying processes associated with these problems.

The results of this study advance our understanding of the likely causes of EP children's difficulties in mathematics and have indicated that one contributing factor may be erroneous numerical representations. A further, more in-depth investigation of preterm children's understanding of mathematics would enable a clearer understanding of why these difficulties occur and what strategies may be effective in improving academic outcomes for these children.

Method

Participants

Children were recruited from the EPICure Study, a national study of outcome following EP birth (www.epicure.ac.uk). All babies born <26 weeks gestational age in the whole of the UK and Ireland from March through December 1995 and who were admitted for neonatal intensive care (n=811) were invited to participate in the EPICure study. Of surviving children at each time point, 283 (90%) were assessed at 2.5 years[33], 241 (78%) at 6 years[34] and 219 (71%) at 11 years of age[2].

Analyses for this report use data obtained from follow-up assessments at 11 years of age. At this age, 219 EP children were assessed with a comparison group of 153 children born at term and matched for age, sex and ethnic group where possible to an EP child in mainstream school. Controls were not selected for children in special schools. A detailed description of the full sample at 11 years is published previously[3]. Of these, 21 EP children were unable to complete the full battery of mathematics tests and were excluded from this study. Reasons for exclusion were as follows: functioning below the level of the test (14 children), blindness (2 children), attention difficulties (2 children), Autism (1 child), limited language (1 child) and poor motor skills (1 child). Nineteen of the excluded children were classified as having a serious disability. Participants thus comprised 195 EP children (mean age at assessment 131.1m; SD 4.5m; range: 121-145m; males: 43%) and 153 term-born control children (mean age at assessment 131.2m; SD: 6.6m; range: 117-147m; males: 42%). There were no significant differences in mean age at assessment (t(349)=0.3, p= .781) or sex (t(351)=0.1, p=0.8) between EP children and controls. Of EP children, 34.8% had a cognitive impairment (Intelligence quotient (IQ) score <-2SD of control reference data measured with the K-ABC MPC[35], and 4.5%, 5.6% and 1% had a motor, vision or hearing impairment. In contrast, 1.3% of term-controls had a cognitive impairment and none had visual, hearing or motor impairments.

Procedure

Parents and children received study information leaflets and parents provided informed consent for their child's participation at 11 years of age. Children were assessed individually by a psychologist in a quiet area in the child's school (92%), at their home (7%) or a hospital (1%). Psychologists had no prior knowledge of the child and were blind to study group allocation. The study was approved by the Southampton and South West Hampshire Research Ethics Committee.

Measures

One of three study psychologists administered the reading and mathematics scales of the Wechsler Individual Achievement Test-II (WIAT-II^{UK} [36]). This is the most contemporary standardised test of curriculum-based attainment from which standardised scores (mean 100; SD 15; range 40-160) were derived for attainment in reading and mathematics. WIAT-RS sub-scales assessed reading comprehension, word reading and pseudo-word decoding. WIAT-MS sub-scales comprised numerical operations (paper and pencil test of performance in simple operations such as addition or subtraction) and mathematical reasoning (orally presented test of ability to apply mathematics in everyday scenarios, e.g., telling the time, using money).

To assess domain-specific numerical representations, children completed the English version of the MET[37] previously used with very preterm and fullterm children in a German sample. This task was presented to children in book form and required oral or manual responses to 12 items assessing approximations of four sub-components of numerical estimations: length, number line, dot and distance (Table 4). Item responses were scored for accuracy and a total score (range 0-12) was summed in addition to summary scores for each of the four sub-components of the test. Error scores for the number line and dot tasks were also calculated by subtracting the correct answer from the child’s response in order to establish the magnitude of error on these tasks.

Two tests of domain-general abilities were administered. IQ was assessed using the K-ABC[35]. The K-ABC comprises eight age-appropriate subtests which generate two separate global scales: Sequential (3 subtests) and Simultaneous (5 subtests) Processing. These two global scales were also combined into a MPC (standardised mean 100; SD 15; range 40-160) score for global cognitive ability (IQ). Children also completed the NEPSY[38] a standardised developmental neuropsychological test battery. Standardised scores (mean 100; SD 15; range 50-150) for Sensorimotor, Visuospatial Processing and Attention and Executive Functioning were derived. Psychologists achieved excellent inter-rater reliability on all tests (agreement on >95% item scores) prior to commencing data collection.

Statistical Analyses

Data were double entered, verified and analysed using SPSS v18.0. Independent-samples t-tests were used to compare performance on all measures between EP and control children and Cohen's d was calculated to determine standardised effect sizes across tests. Effect sizes were defined as small (0.2-0.3), medium (0.3-0.5) or large (>0.5)[39]. Bivariate correlations (two-tailed) between all measures were conducted for EP and control children separately and partial correlations (two-tailed) were conducted controlling for MPC. Fischer r-to-z transformations were also calculated to assess the difference in magnitude between correlations for the EP and control group on the same measures. Separate hierarchical step-wise multivariable linear regressions were conducted for control and EP children to identify predictors of mathematics attainment. WIAT-MS was the dependent variable and independent variables were entered in the following order (domain general to domain specific): Step 1 K-ABC Simultaneous and Sequential Processing; Step 2 WIAT-RS; Step 3 NEPSY Sensorimotor, Visuospatial Processing and Attention and Executive Functioning; Step 4 MET.

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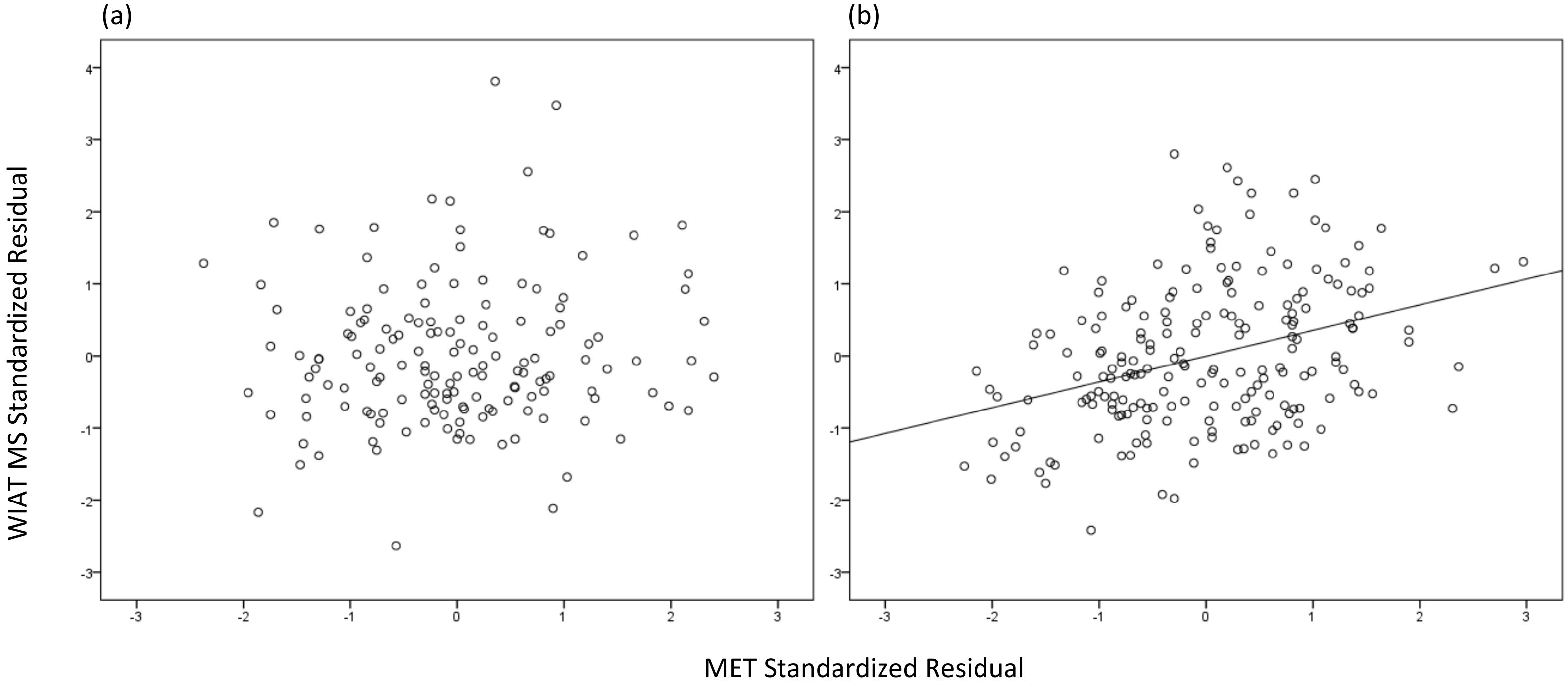
Figure legend text

Figure 1: The relationship between WIAT Mathematics and total MET score standardized residuals for (a) control group and (b) EP group (Regression line: R^2= .127)



(a)
(b)
WIAT MS Standardized Residual
MET Standardized Residual

Table 1: Descriptive statistics for term-born controls and EP children on standardised and experimental tests.

Test	Control (n=153) Mean (SD)	EP (n=195) Mean (SD)	Difference between control and EP children Mean difference (95% CI)	p	Effect size (Cohen's d)
K-ABC					
Simultaneous Score	104.9 (11.9)	87.0 (13.3)	-17.9 (-15.2 to -20.6)	<.001	1.4
Sequential Score	101.9 (11.5)	91.8 (13.1)	-10.1 (-7.5 to -12.7)	<.001	0.8
MPC Score	104.1 (11.06)	87.6 (13.1)	-16.5 (-13.9 to -19.1)	<.001	1.3
WIAT-II					
Reading	98.5 (15.0)	83.8 (17.0)	-14.7 (-11.6 to-17.9)	<.001	1.0
Mathematics	98.5 (11.6)	73.9 (19.4)	-24.6 (-20.8 to -28.3)	<.001	1.4
MET					
Summary score	6.6 (1.9)	4.5 (2.0)	-2.2 (-1.7 to -2.6)	<.001	1.1
Length	1.9 (0.7)	1.5 (0.8)	-0.3 (-0.1 to -0.4)	<.001	0.4
Number Line	3.2 (1.1)	1.9 (1.3)	-1.3 (-1.1 to -1.6)	<.001	1.1
Dots	1.0 (0.8)	0.6 (0.7)	-0.4 (-0.2 to -0.5)	<.001	0.5
Distance	0.6 (0.7)	0.4 (0.6)	-0.2 (-0.1 to -0.3)	.008	0.3
Mean Error Number Line	6.5 (6.1)	33.5 (64.1)	27.0 (16.6 to 37.3)	<.001	0.6
Mean Error Dots	11.0 (8.9)	18.7 (13.9)	7.7 (17.8 to 36.1)	<.001	0.7
NEPSY					
Sensorimotor skills	99.8 (11.6)	84.4 (13.9)	-15.4 (-12.6 to -18.2)	<.001	1.2
Visuo-spatial processing	107.5 (13.5)	86.2 (18.5)	-21.4 (-17.9 to-24.9)	<.001	1.3
Attention/Executive Function	104.2 (11.2)	86.0 (18.6)	-18.3 (-14.9 to -21.6)	<.001	1.2

Note: K-ABC MPC= Kaufman ABC Mental Processing Composite Score. Range of scores: K-ABC MPC (Control= 68 -143; EP= 47-123), WIAT-II MS (Control= 68-131; EP= 40-117), WIAT-II RS (Control= 67- 125, EP= 41-122), MET summary score (Control= 3-11; EP=0-9), NEPSY Sensorimotor skills (Control= 66-132; EP= 49- 120), NEPSY Visuospatial processing (Control= 68-139; EP= 49-124), NEPSY Attention/Executive Function(Control= 74-135; EP= 49-124).

Table 2: First-order and partial correlations (after controlling for MPC score) between WIAT-II Maths and other domain-general and domain –specific measures variables for control and EP groups

Control Bivariate Correlations		K-ABC MPC	WIAT-II Maths	WIAT-II Reading	NEPSY Visuospatial	NEPSY Sensorimotor	NEPSY Attention/EF	MET Total score	MET Length	MET Line	MET Dot	MET Distance
K-ABC	Simultaneous (n=153)	.891**	.417**	.297**	.401**	.184*	.320**	.268**	.193*	.266**	.010	.105
	Sequential (n=153)	.709**	.492**	.506**	.252**	.289**	.297**	.243**	.127	.304**	.122	-.049
	MPC (n=153)		.541**	.461**	.415**	.271**	.379**	.312**	.207*	.338**	.066	.052
WIAT-II	Mathematics (n=153)			.610**	.420**	.266*	.265*	.242*	.114	.277*	.144	-.038
	Reading (n=153)				.345**	.343**	.246**	.199	.086	.221*	.099	-.017
NEPSY	Visuospatial (n=153)					.308**	.289**	.231*	.197*	.156	.072	.111
	Sensorimotor (n=153)						.221*	.151	-.065	.191*	.097	.065
	Attention/EF (n=153)							.082	-.014	.123	.093	.011
MET	Total score (n=152)								.549**	.735**	.469**	.537**
	Length (n=150)									.209*	-.054	.219*
	Number Line (n=149)										.129	.151
	Dot (n=149)											.024

Control Partial Correlations		WIAT-II Reading	NEPSY Visuospatial	NEPSY Sensorimotor	NEPSY Attention/EF	MET Total score	MET Length	MET Line	MET Dot	MET Distance
WIAT-II	Mathematics (n=146)	.484**	.260*	.152	.077	.095	.005	.123	.134	-.080
	Reading (n=146)		.194*	.263*	.099	.062	-.012	.079	.076	-.045
NEPSY	Visuospatial (n=146)			.217*	.171*	.118	.126	.022	.050	.098
	Sensorimotor (n=146)				.165*	.068	-.126	.115	.079	.056
	Attention/EF (n=146)					-.006	-.098	-.003	.097	-.022
MET	Total score (n=146)						.520**	.704**	.469**	.555**
	Length (n=146)							.150	-.075	.216*
	Number Line (n=146)								.107	.145
	Dot (n=146)									.029

Note: *p<.05, **p <.001

EP Bivariate Correlations		K-ABC MPC	WIAT-II Maths	WIAT-II Reading	NEPSY Visuospatial	NEPSY Sensorimotor	NEPSY Attention/EF	MET Total score	MET Length	MET Line	MET Dot	MET Distance
K-ABC	**Simultaneous (n=198)**	.939**	.727**	.613**	.683**	.523**	.625**	.574**	.279**	.556**	.286**	.061
	Sequential (n=198)	.845**	.664**	.634**	.515**	.448**	.526**	.503**	.180*	.525**	.231**	.104
	MPC (n=198)		.733**	.684**	.678**	.541**	.641**	.597**	.260**	.598**	.288**	.084
WIAT-II	**Mathematics (n=198)**			.766**	.653**	.505**	.609**	.643**	.246**	.654**	.304**	.109
	Reading (n=195)				.538**	.398**	.542**	.550**	.121	.581**	.224*	.194*
NEPSY	**Visuospatial (n=198)**					.565**	.621**	.476*	.217*	.521**	.181*	.009
	Sensorimotor (n=195)						.530**	.407**	.171*	.403**	.14	.116
	Attention/EF (n=197)							.488**	.129	.477**	.322**	.077
MET	**Total score (n=197)**								.527**	.804**	.535**	.319**
	Length (n=196)									.210*	-.031	-.012
	Number Line (n=196)										.269**	.014
	Dot (n=196)											.063

EP Partial Correlations		WIAT-II Maths	WIAT-II Reading	NEPSY Visuospatial	NEPSY Sensorimotor	NEPSY Attention/EF	MET Total score	MET Length	MET Line	MET Dot	MET Distance
WIAT-II	**Mathematics (n=186)**		.504**	.260**	.156*	.220*	.346**	.067	.368**	.134	.068
	Reading (n=186)			.141	.080	.202*	.247*	-.070	.297**	.051	.205*
NEPSY	**Visuospatial (n=186)**				.318**	.315**	.099	.040	.180*	-.020	-.067
	Sensorimotor (n=186)					.268**	.108	.040	.117	-.028	.074
	Attention/EF (n=186)						.140	-.083	.138	.191*	.032
MET	**Total score (n=186)**							.474**	.695**	.474**	.334**
	Length (n=186)								.065	-.117	-.039
	Number Line (n=186)									.129	-.044
	Dot (n=186)										.030

Note: *p<.05, **p <.001

Table 3: Summary for Hierarchical Regressions Predicting WIAT MS for Control group and EP group

		Control			**EP**		
Model	**Predictor(s)**	R^2	ΔR^2	**B**	R^2	ΔR^2	**B**
1	**K-ABC Simultaneous**	.315**		.367**	.578**		.728**
	K-ABC Sequential			.524**			.523**
2	**K-ABC Simultaneous**	.458**	.143**	.279*	.683**	.105**	.505**
	K-ABC Sequential			.256*			.250*
	WIAT RS			.572**			.504**
3	**K-ABC Simultaneous**	.479**	.021	.212*	.700**	.017*	.357**
	K-ABC Sequential			.250*			.216*
	WIAT RS			.526**			.463**
	NEPSY- Attention/executive			.012			.050
	NEPSY- Sensorimotor			-.018			.053
	NEPSY- Visuospatial			.183*			.139*
4	**K-ABC Simultaneous**	.481**	.001	.204*	.718**	.018**	.297*
	K-ABC Sequential			.243*			.190*
	WIAT RS			.524**			.415**
	NEPSY- Attention/executive			.016			.036
	NEPSY- Sensorimotor			-.020			.038
	NEPSY- Visuospatial			.178*			.137*
	Total MET Score			.292			1.589*

Note: *p<.05, **p <.001

Table 4: Description and examples of Magnitude Estimation Test (MET) items[37].

Estimation subcomponent	Number of questions	Example question	Response
Length	3	Children were shown an image of three horizontal lines of different lengths. Children were asked: "Here are three lines. Which line is 5 cm long?"	Children were required to point to the correct line.
Number line	5	Children were shown a blank number line with the start and end number indicated and an X located on the line. Children were asked: "Here is '0' and here is '10'. Where do you think X is?"	Children were required to state the value of position X.
Dots	2	Children were shown a set of dots on a single page that varied in quantity. Children were asked: "Look at these spots! How many spots are on this page? Do you think there are 20, 40, 60 or 80 spots?"	Children were required to orally provide the correct quantity.
Distance	2	Children were shown a simple line-drawn map which included a treasure chest, other locations of interest and a 0.5cm line at the top of the page. Children were asked: "If every metre on this map is as long as this (points to the 0.5cm bar), how many metres are there between the tree and the treasure?"	Children were required to orally provide their approximation of the distance.