

# Brain Functional Connectivity During Visual-Spatial Processing in Relation to Math Skills at Age 8 Years in Children Born Very Preterm

Phillips, H.<sup>(1,2,3)</sup>, Williams, L.J.<sup>(3)</sup>, McLean, M.A.<sup>(2,3)</sup>, Chau, C.M.Y.<sup>(2,3)</sup>, Bjornson, B.<sup>(2,3)</sup>, Synnes, A.<sup>(2,3)</sup>, Miller, S.<sup>(4,5)</sup>, Grunau, R.E.<sup>(2,3)</sup>

<sup>(1)</sup>Graduate Program in Neuroscience, University of British Columbia; <sup>(2)</sup>Department of Pediatrics, University of British Columbia; <sup>(3)</sup>BC Children's Hospital Research Institute; <sup>(4)</sup>Department of Neurology, The Hospital for Sick Children; <sup>(5)</sup>Department of Paediatrics, University of Toronto

## Introduction

- Math difficulties are prevalent in children born very preterm (24-32 weeks gestational age [GA]) compared to full-term<sup>1</sup>
- Visual-spatial processing is closely related to acquisition of early math skills<sup>2</sup>

## Aims

- To examine whether functional brain networks during visual-spatial processing (mental rotation) is related to arithmetic skills

## Participants

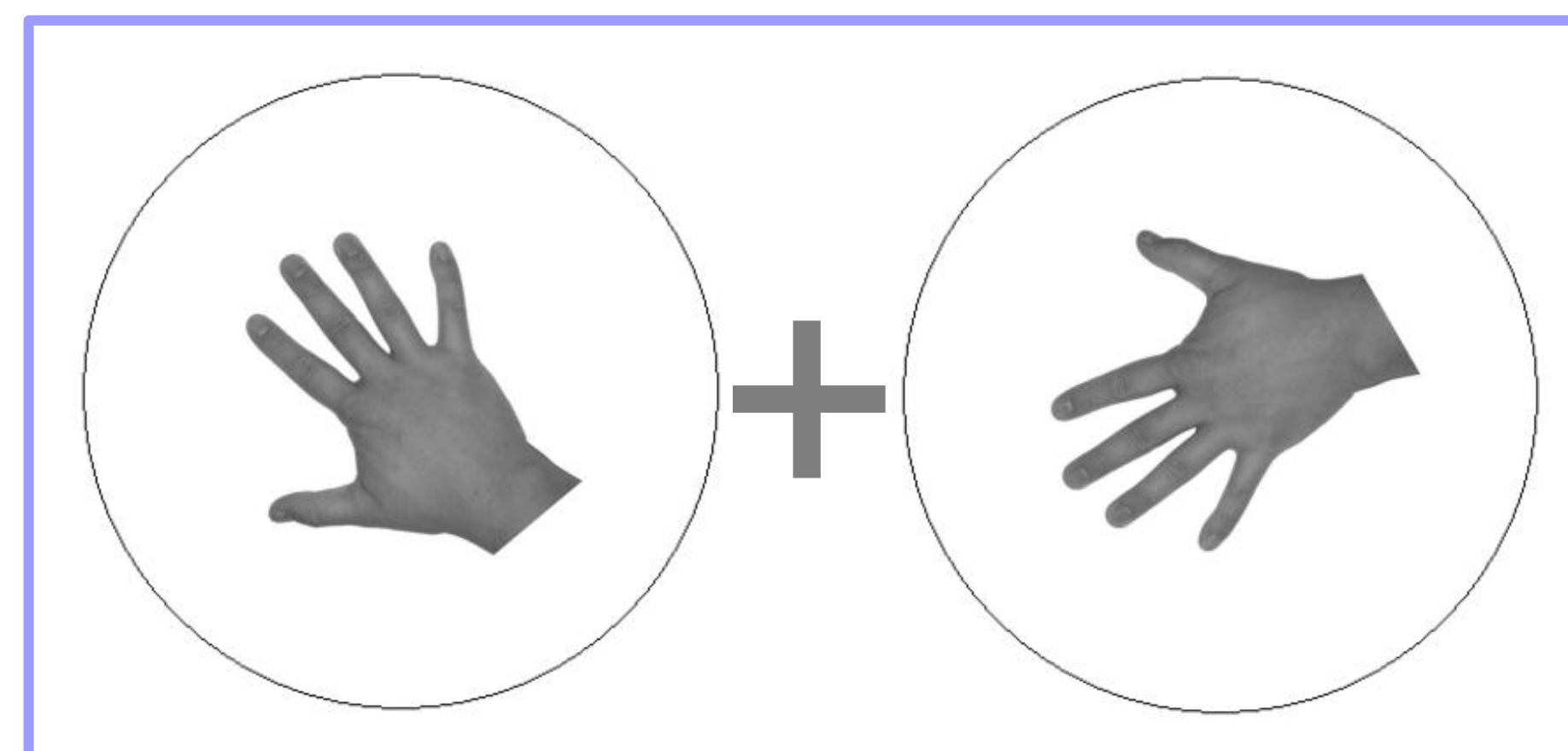
N=75 children born very preterm, in a prospective longitudinal cohort study, attended 8-year follow-up. Excluded: major brain injury (cystic PVL, IVH grade 3/4), visual, hearing, cognitive (IQ<70), motor (non-ambulatory CP) impairments.

Demographics	Mean (SD)
Gestational age at birth (weeks)	28.2 (2.3)
Boys	56%
Infection (Presence)	41%
Surgeries (None, 1, 2+)	72%, 12%, 16%
Illness severity day 1 (SNAP-II)	13.0 (14.5)
Mechanical ventilation (days)*	45 (38)
Morphine (cumulative mg/kg)*	4.5 (11.0)
Number of invasive procedures	120 (86)
Mother's education (years)*	16 (3)

N=75, \*N=74

## Methods

- Participants completed a mental rotation of hands matching task during fMRI at age 8 yrs<sup>3</sup>
  - Stimuli: pairs of hands either rotated or mirror-images



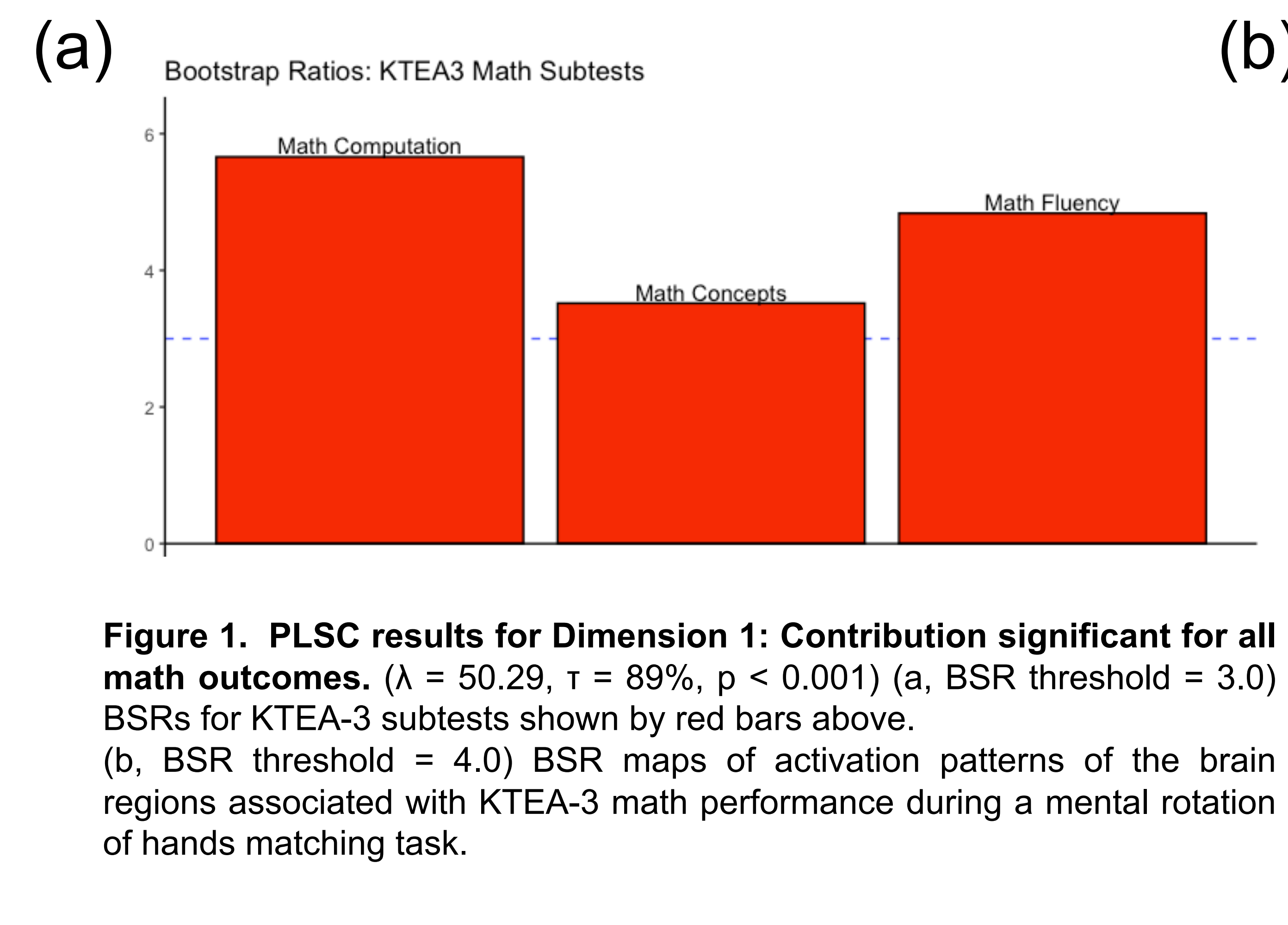
- Kaufman Test of Educational Achievement (KTEA-3)
  - Math Computation
  - Math Fluency
  - Math Concepts & Applications
- Analysis: Partial least squares (PLS) to examine brain activation patterns during visual-spatial processing

## Results: Outcomes at 8-year follow-up (mean, SD) N=75

Age at 8-year follow-up	8.4 (0.4) years
IQ (WASI-II FSIQ)	103 (14)
KTEA-3 Math Computation	92 (11)
KTEA-3 Math Fluency	89 (15)
KTEA-3 Math Concepts & Application	94 (13)

WASI-II & KTEA-3: mean=100, SD=15

## Results: Partial Least Squares Analysis



**Figure 1. PLS results for Dimension 1: Contribution significant for all math outcomes.** ( $\lambda = 50.29$ ,  $\tau = 89\%$ ,  $p < 0.001$ ) (a, BSR threshold = 3.0) BSRs for KTEA-3 subtests shown by red bars above. (b, BSR threshold = 4.0) BSR maps of activation patterns of the brain regions associated with KTEA-3 math performance during a mental rotation of hands matching task.

**Table 1. PLS results for Dimension 1: Largest contribution in right superior temporal-parietal regions.** ( $\lambda = 50.29$ ,  $\tau = 89\%$ ,  $p < 0.001$ , BSR threshold = 4.0). Activation clusters showing maximal covariance with KTEA-3 math subtests on a mental rotation of hands matching task.

Region (L Hemisphere)	Cluster Size (Voxels)	Peak Voxel Co-ord (X, Y, Z)	Region (R Hemisphere)	Cluster Size (Voxels)	Peak Voxel Co-ord (X, Y, Z)
superior temporal sulcus	2264	28, 57, 73	superior temporal sulcus	2264	28, 57, 73
inferior parietal gyrus	503	119, 44, 98	precuneus	684	59, 58, 96
caudal middle frontal	257	111, 122, 99	caudal middle frontal	430	38, 127, 100
middle temporal	137	133, 85, 51	pars triangularis	281	23, 120, 56
inferior temporal	131	124, 79, 46	caudal middle frontal	240	26, 104, 103
rostral middle frontal	83	97, 136, 95	Inferior temporal	217	18, 75, 48
precuneus	67	83, 55, 95	rostral middle frontal	172	46, 146, 81
			posterior cingulate	155	68, 86, 92
			superior frontal	143	68, 128, 87
			caudal middle frontal	118	109, 106, 96
			pars opercularis	111	41, 121, 72
			middle temporal	84	19, 75, 55

## Conclusions

### Brain activation during mental rotation is related to math skills at age 8 years in children born very preterm

- This relationship was primarily seen in the right superior temporal-parietal regions with some bilateral frontal contributions
- Math computation, concepts & applications, and fluency all were related to brain activation during visual-spatial processing (mental rotation), with computation playing the largest role

## Future Work

- Neonatal factors such as pain-stress exposure from daily invasive procedures may be related to altered networks during visual-spatial processing in children born preterm

## References

- 1 Grunau RE et al (2002) *Archives of Pediatrics & Adolescent Med*; 156(6)
- 2 Grunau RE et al (2004) *Pediatrics*; 114(6)
- 3 Kosslyn SM et al (1998) *Psychophysiology*; 35(2)
- 4 Richards JE et al (2016) *NeuroImage*; 124(January)