DYSLEXIA AND DYSCALCULIA:
a review and programme of research

Brian Butterworth
Institute of Cognitive Neuroscience
& Department of Psychology
University College London

www.mathematicalbrain.com

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

High correlation between literacy and numeracy abilities at school

- Ostad (1998) - correlations of .47 between maths and spelling scores, and in the Maths Disabled groups scored lower on spelling tests.
  - *Sample*
    - 927 children in grades 2, 4, and 6 (ages 8;6, 10;5, 12;6) excluding mentally retarded, deaf and blind
    - Stanford Achievement Test
    - WISC-R

Ostad, S. (1998) *Log. Phon. Vocal., 23, 145-154*

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Prevalence estimates of Maths Disabled

STUDY location	ESTIMATE OF LEARNING DISABILITY	CRITERION	PERCENTAGEL ITERACY DISORDER
OSTAD (1998) Norway *Log. Phon. Vocal., 23, 145-154*	10.9% "Maths disabled"	Registered for special long-term help	51% Spelling disorder
LEWIS et al (1994) England *J. Child Psychol. Psychiat., 35, 283-292*	3.6% "specific arithmetic difficulties"	<85 on arithmetic test, >90 on NVIQ	64% Reading difficulties
GROSS-TUR et al (1996) Israel *Dev. Medicine Child Neurol., 38, 25-33*	6.4% "dyscalculic"	Two grades below Chronological Age	17% Reading disorder

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

High-functioning adult dyslexics (Simmonds, 1995)

	Controls [best]	Dyslexics [best]	
Mental arithmetic (n=58) correct	53 [57]	48* [57]	
Mental arithmetic (n=58) Reaction Time	5.1s [4]	8.4s* [2]	
Written arithmetic (n=12) correct	10.7 [12]	8.8* [12]	
Written arithmetic (n=12) RT	4.0s [2]	6.5s* [2]	
Number reasoning (n=24) correct	23.9 [24]	23.5 [24]	
Number reasoning (n=24) RT	3.6s [3]	6.4s* [4]	
Digit span	5.6 [7]	4.4* [6]	

Unpublished report, UCL

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Role of intelligence 1 (Shalev et al, 1997)

TEST	Dyscalculics with reading & spelling disorders *N*=35	Dyscalculics *Ni=104*
Full-scale IQ	95.1	99.3*
VIQ	91.2	96.1**
PIQ	100.0	103.2
Similarities	9.6	10.6*
Vocabulary	8.9	9.8*
Object assembly	8.6	10.0**

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Role of intelligence 2

- Ostad (1998)
  - Maths Disabled (MD) children somewhat lower than Maths Normal (MN) on WISC, but that includes Arithmetic and Digit Span subtests
  - No difference between MDSpellingD and MDSpellingN

- Lewis et al (1994)

  Groups with minimum IQ. No difference on NVIQ between groups with Specific Arithmetic Difficulties, Arithmetic and Reading Difficulties and Specific Reading Difficulties

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Differences between maths disabled and maths normal

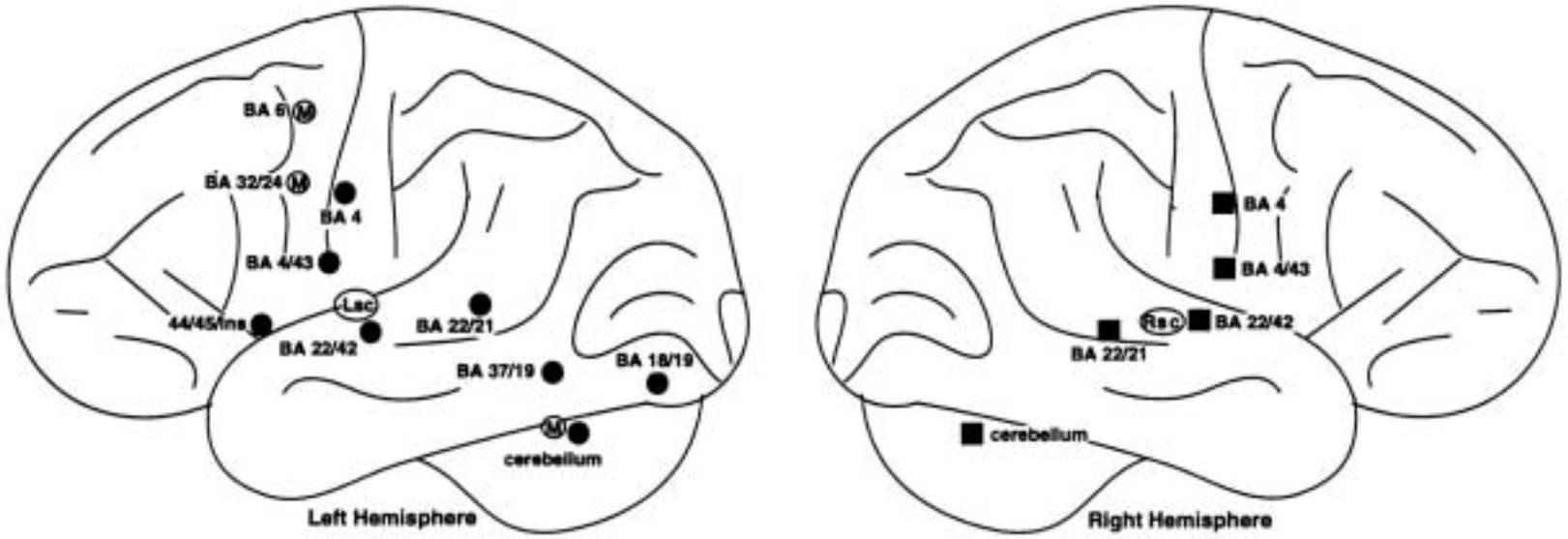
- Generally, poorer span (though not in all studies)
- Worse on arithmetical facts
- Fewer strategies
- Immature strategies

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Why are dyslexics more likely to have maths learning difficulties?

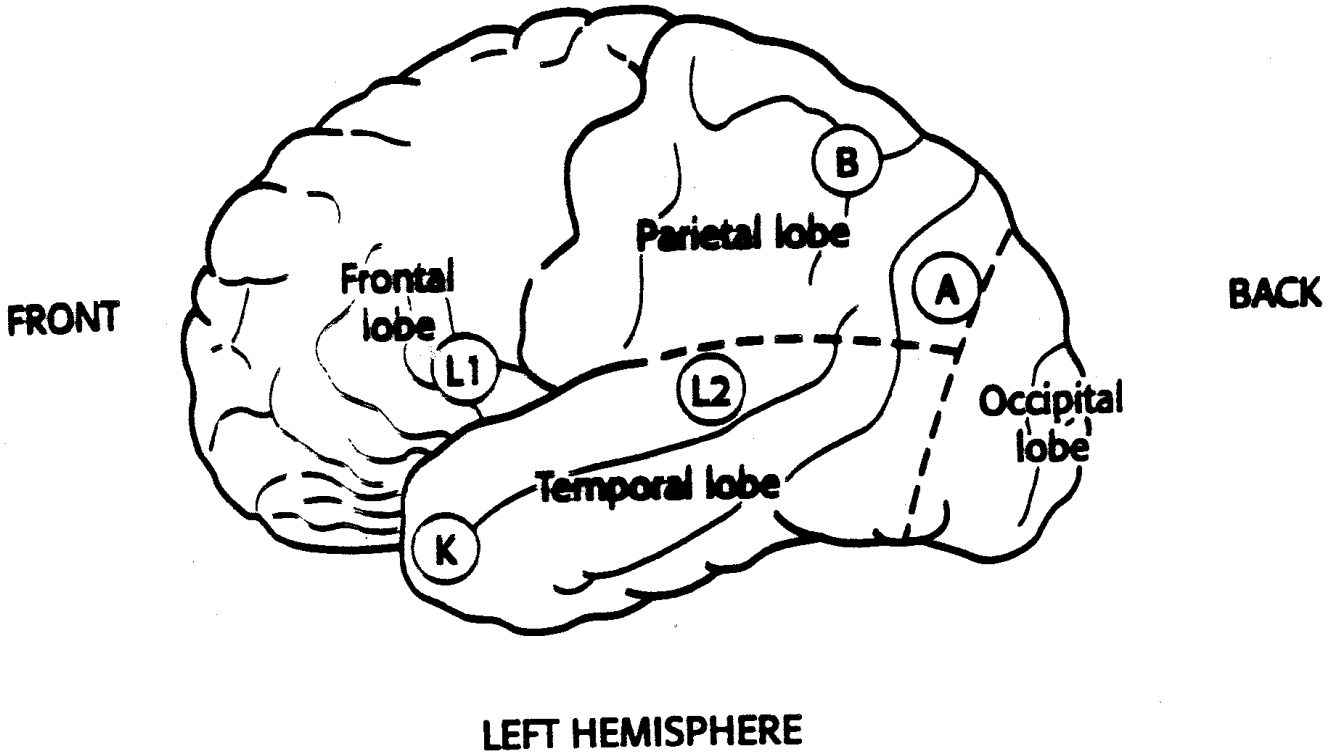
- Problem: Literacy and numeracy two very different neuro-cognitive systems
  - Different brain systems
  - Literacy parasitic on language. No innate system for specialised for reading and spelling
  - Some “biologically basic” (Geary) numerical capacities appear to be innate.
    - Infant numerical capacities
    - Ancestral non-human capacities?
  - Different genetic basis?

© Brian Butterworth, 2002 & 2005. All Rights Reserved.



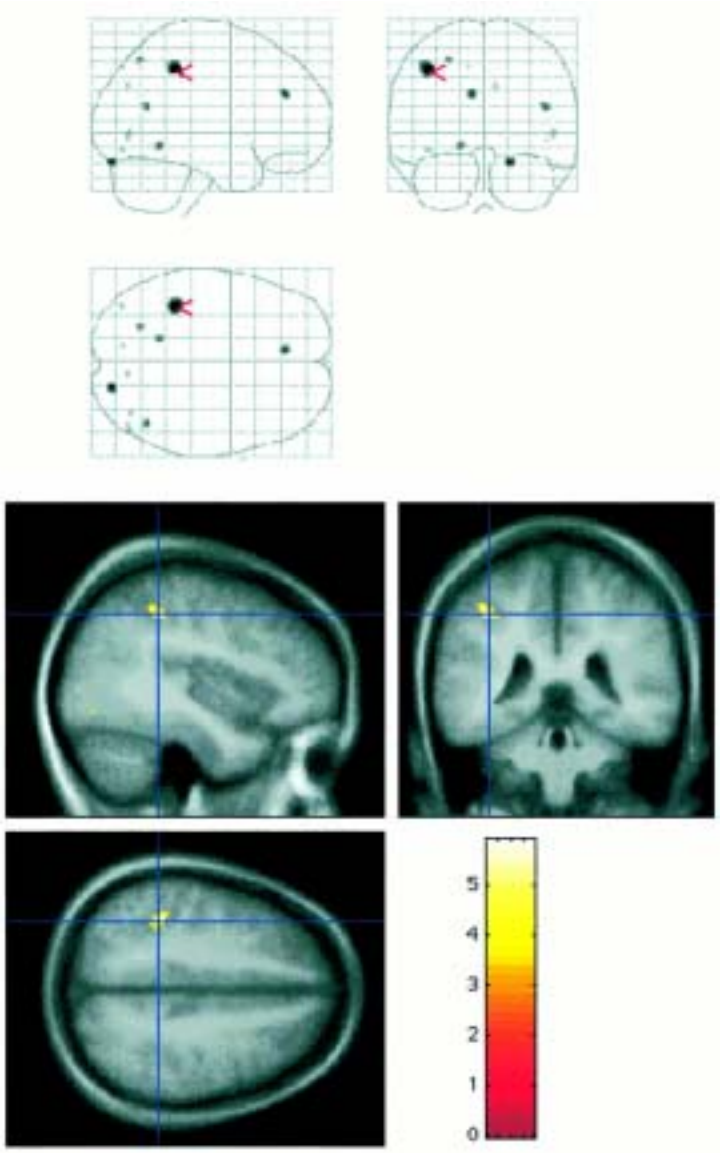
© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Language and numbers in the brain



© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Reduced grey matter in adoloscents poor on simpelnumber tests

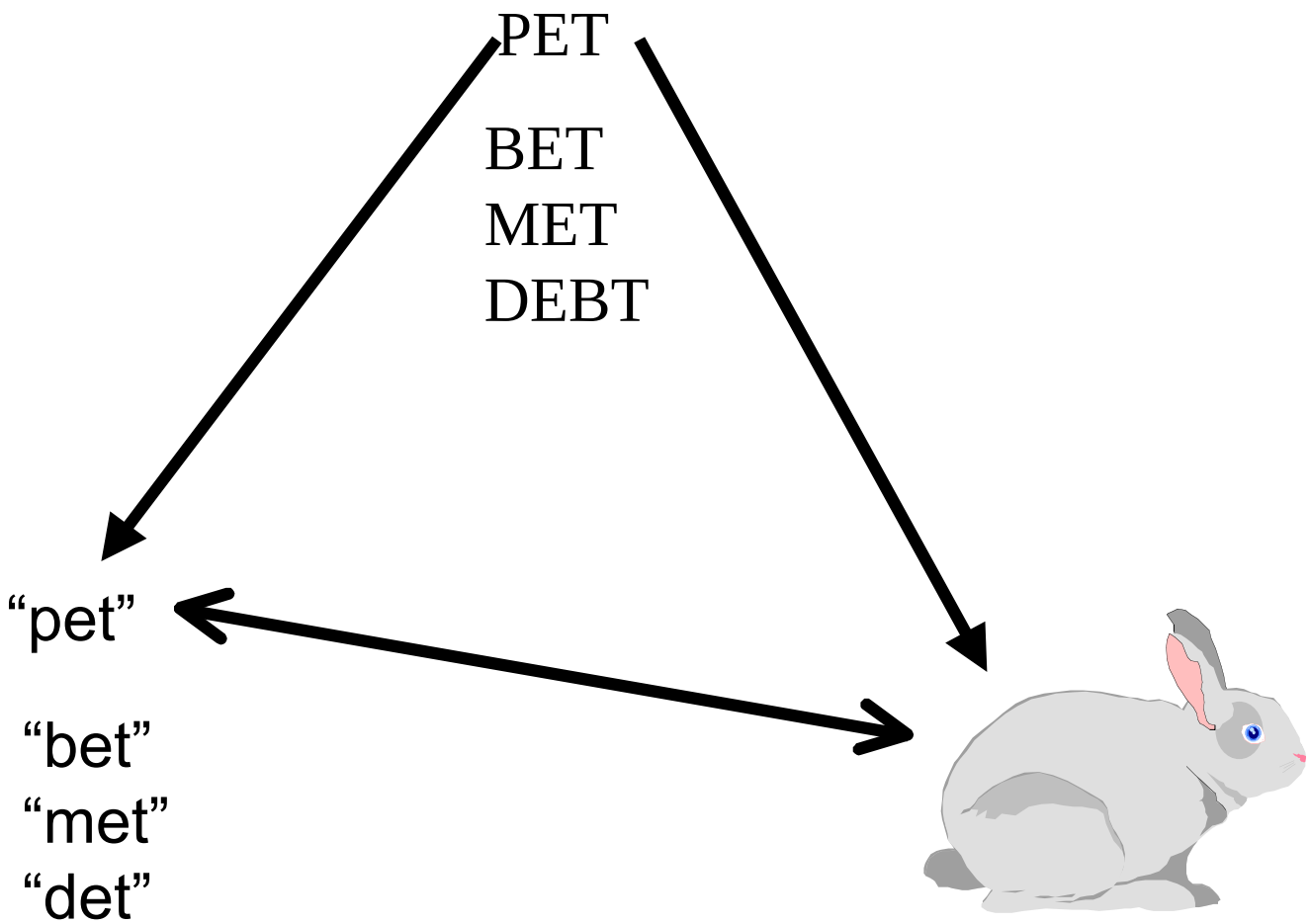


From Isaacs et al,
Brain, 2001

Why are dyslexics more likely to have maths learning difficulties?

- Problem: Literacy and numeracy two very different neuro-cognitive systems
  - Different brain systems
  - Literacy parasitic on language. No innate system for specialised for reading and spelling
  - Some “biologically basic” (Geary) numerical capacities appear to be innate.
    - Infant numerical capacities
    - Ancestral non-human capacities?
  - Different genetic basis?

© Brian Butterworth, 2002 & 2005. All Rights Reserved.



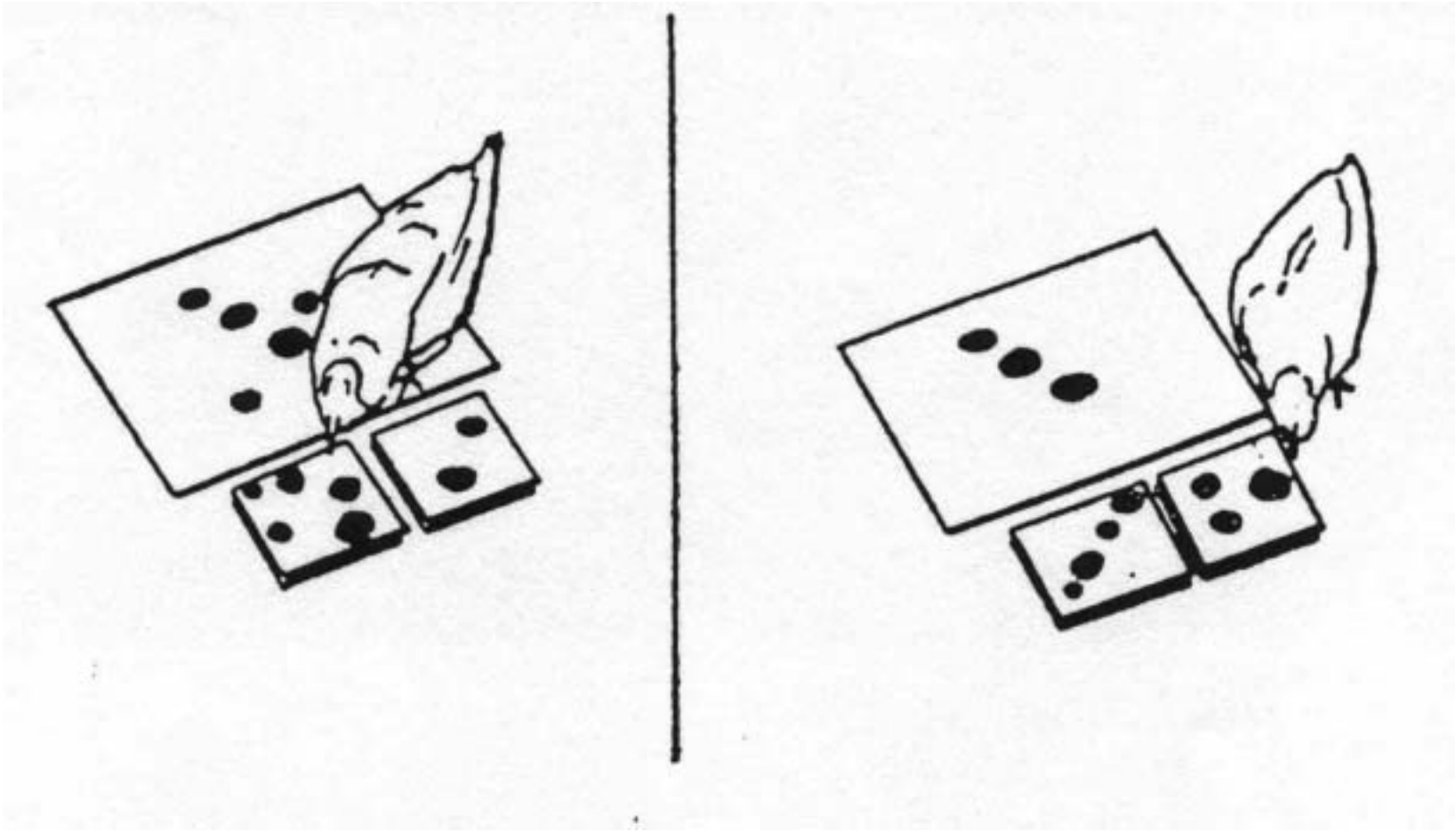
© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Why are dyslexics more likely to have maths learning difficulties?

- Problem: Literacy and numeracy two very different neuro-cognitive systems
  - Different brain systems
  - Literacy parasitic on language. No innate system for specialised for reading and spelling
  - Some “biologically basic” (Geary) numerical capacities appear to be innate.
    - Infant numerical capacities
    - Ancestral non-human capacities?
  - Different genetic basis?

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

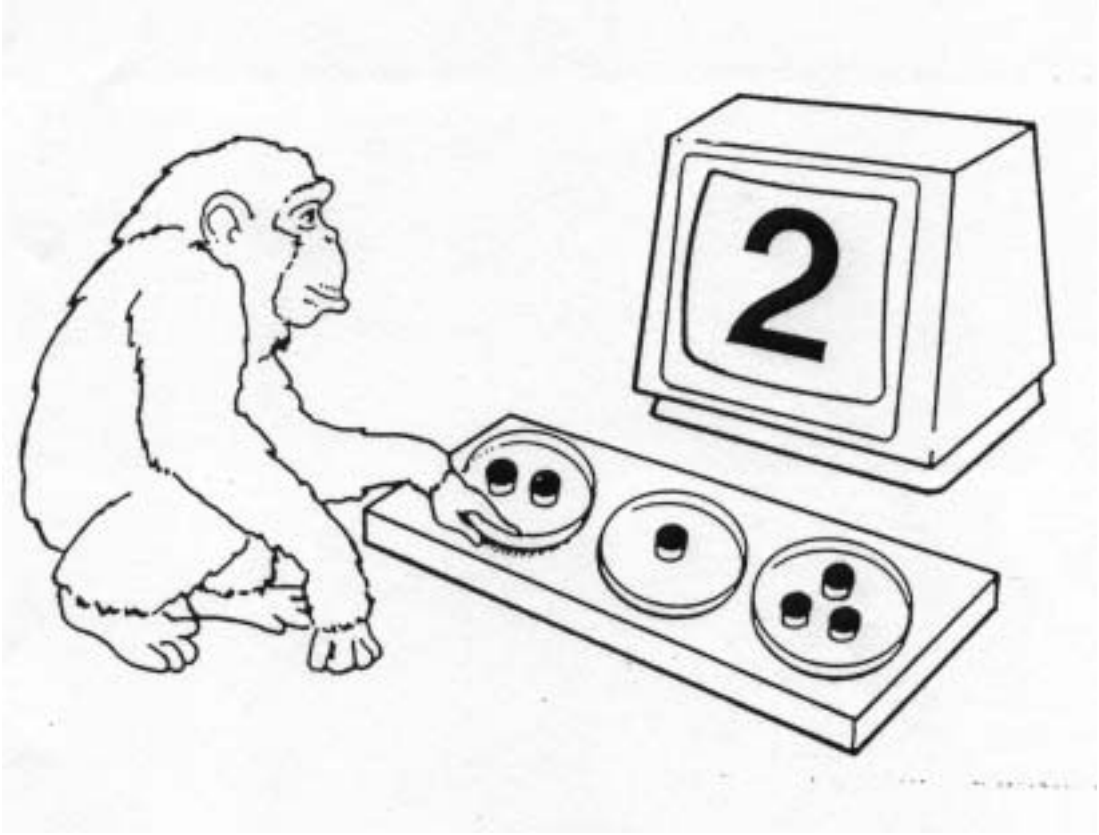
Raven matching numerosities to sample



From Otto Koehler

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Chimp training to use numerals



From Boysen

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Why are dyslexics more likely to have maths learning difficulties?

- Impaired common function (e.g. short-term memory, long-term memory, verbal memory, language)?
  - Problems: neuroanatomy, exceptions,
- Reading difficulties lead to the slowed learning of everything, including mathematics?
  - Problem: 60% of dyslexics are unaffected
- Unexplained cause of comorbidity of two distinct cognitive functions (e.g. genetic anomaly)?
  - Problem: maybe two sorts of dyslexic maths difficulty: comorbid and consequential

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Why are dyslexics more likely to have maths learning difficulties?

- Problem: Literacy and numeracy two very different neuro-cognitive systems
  - Different brain systems
  - Literacy parasitic on language. No innate system for specialised for reading and spelling
  - Some “biologically basic” (Geary) numerical capacities appear to be innate.
    - Infant numerical capacities
    - Ancestral non-human capacities?
  - Different genetic basis?

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

Problems with the existing studies

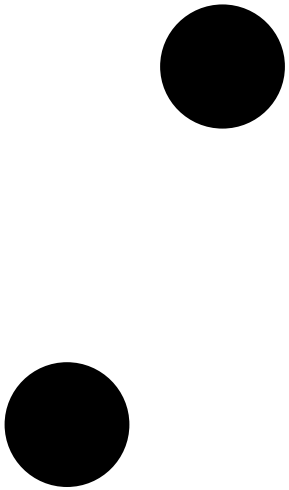
- Many reasons for being bad at maths and the standard tests confound them
- If there is such a thing a specific maths learning disorder - dyscalculia, it needs to be properly characterised.
- If it has a genetic cause (and there is evidence for it being there at birth), then it is likely to affect very basic numerical capacities, and tests should focus on these.

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

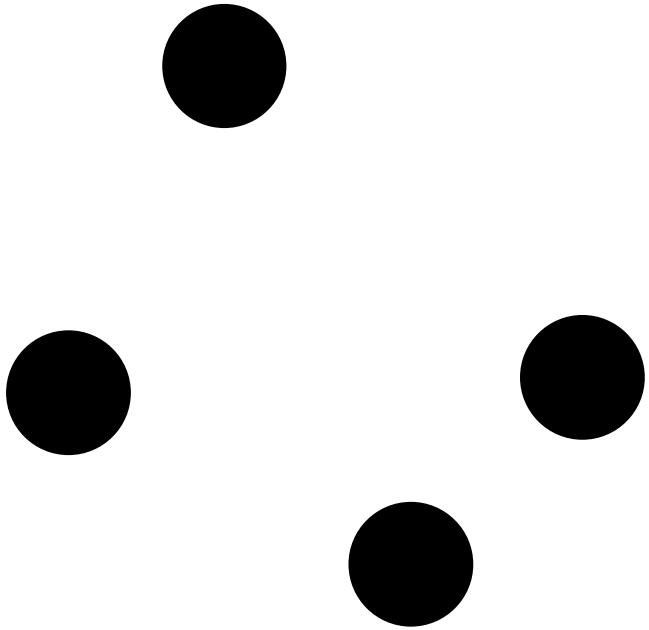
Tests of basic numerical capacities

Capacity	Tests
Numerosity as a property of sets	Enumeration, conservation, matching
Estimated numerosities	Estimation
Sense of ordered numerosities (magnitudes)	Number comparison
Acquiring cultural tools for numbers	Counting

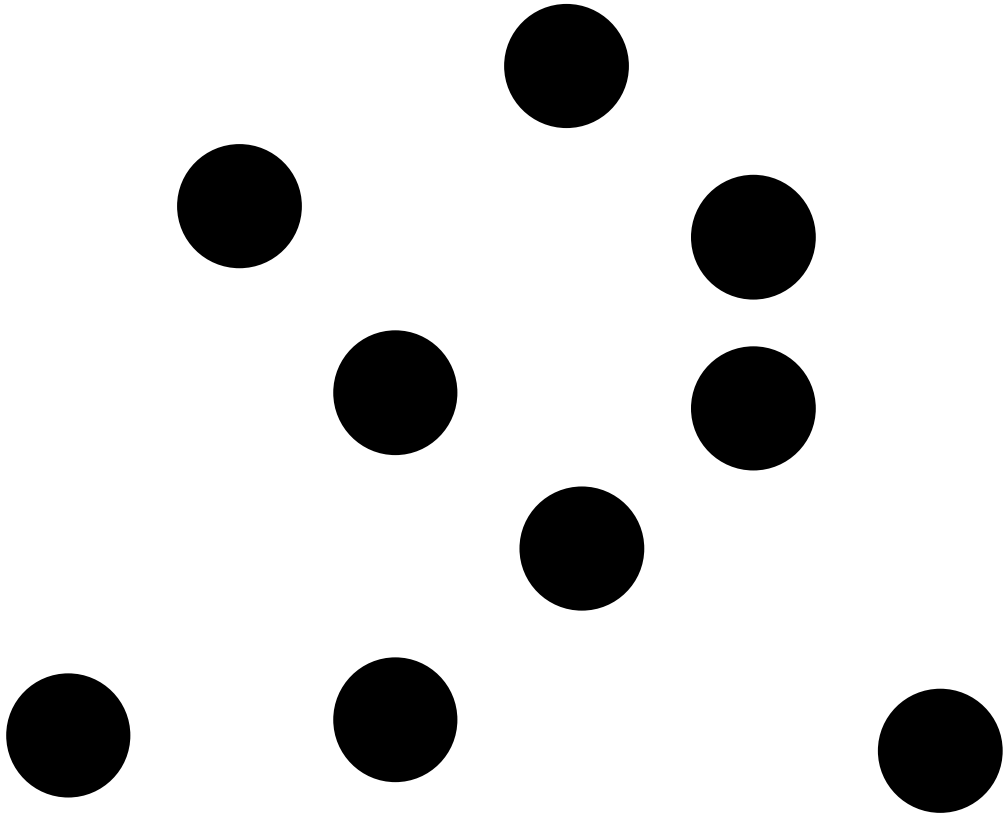
© Brian Butterworth, 2002 & 2005. All Rights Reserved.



© Brian Butterworth, 2002 & 2005. All Rights Reserved.



© Brian Butterworth, 2002 & 2005. All Rights Reserved.

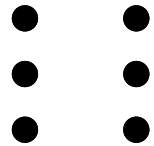


© Brian Butterworth, 2002 & 2005. All Rights Reserved.

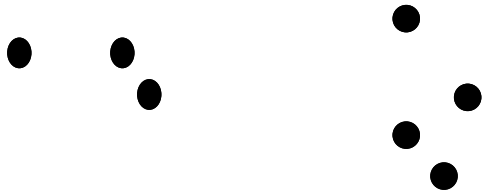
Subitizing (1-4)

Counting (6-9)

CANONICAL



RANDOM



6 5

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

2 9

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

8 7

Stroop conditions

Task	*Neutral*	*Congruent*	*Incongruent*
Numerical	*3 6*	*3 6*	*3 6*
Physical	*3 3*	*3 6*	*3 6*

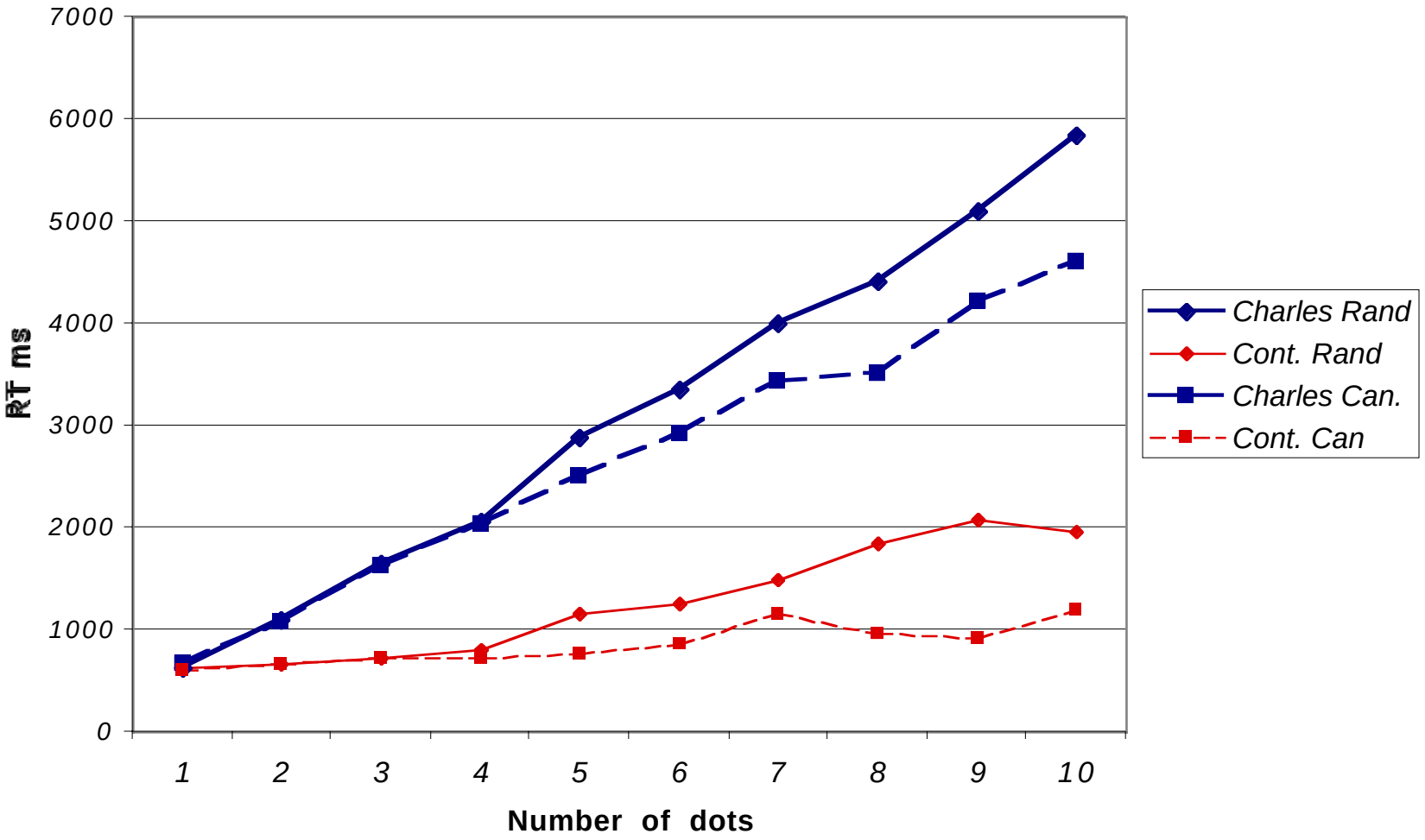
Dyscalculics may fail on some of these basic tests

- CW
  - Degree in psychology; postgraduate qualifications; always very bad at maths at school; finds shopping extraordinarily difficult. Takes 4-5 times as long as normals adding single digits; cannot subtract two digit numbers. Always calculates on his fingers (which makes multiplication hard).
  - Compensated dyslexic

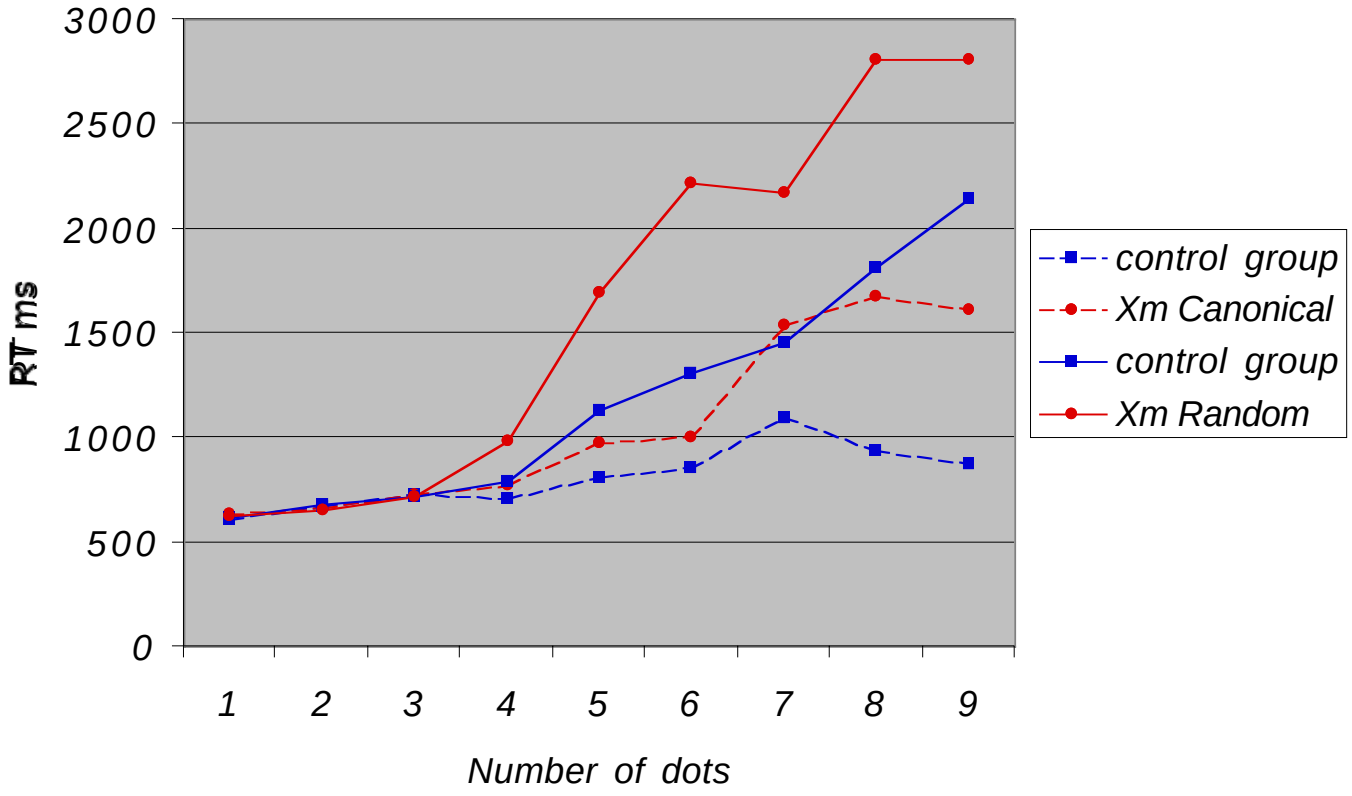
- Turner Syndrome (45X,m)
  - Very slow simple arithmetic, may fail GCSE
  - High-functioning, good language and reading, A-level maths in some cases

© Brian Butterworth, 2002 & 2005. All Rights Reserved.

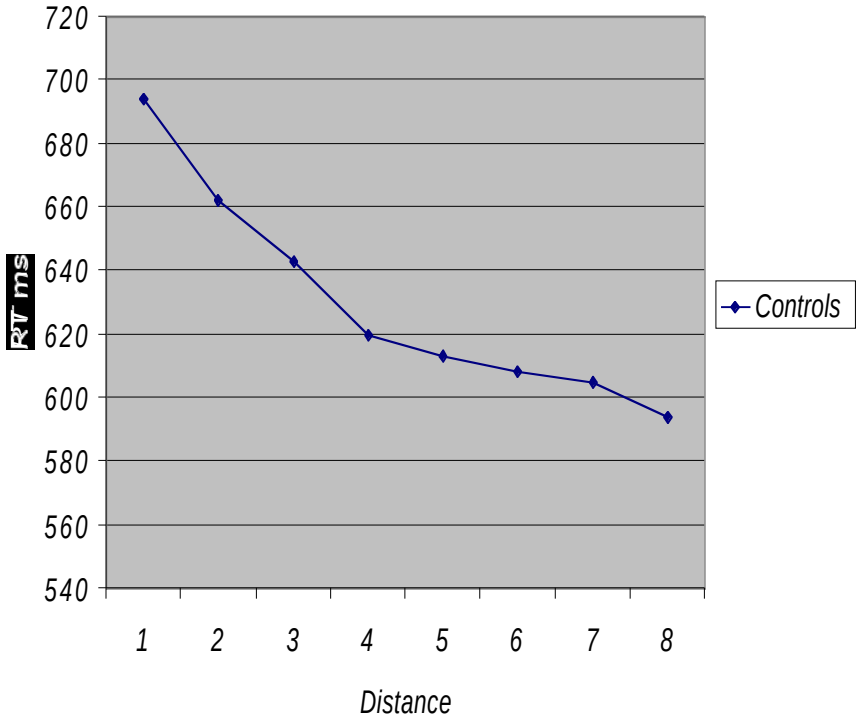
Charles vs controls: dot enumeration

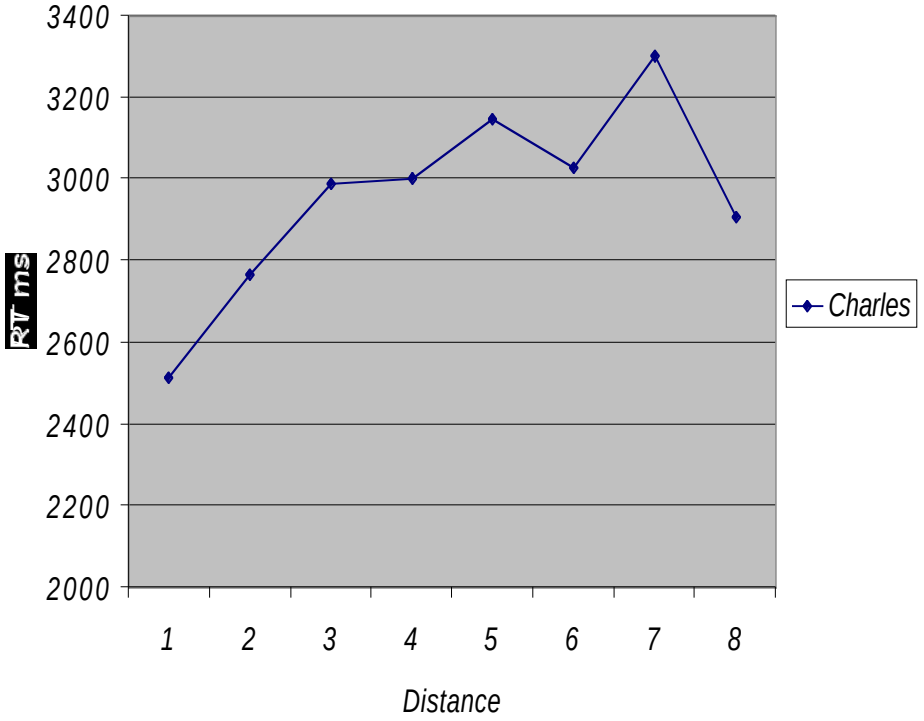


Dots: 45,Xm v. control

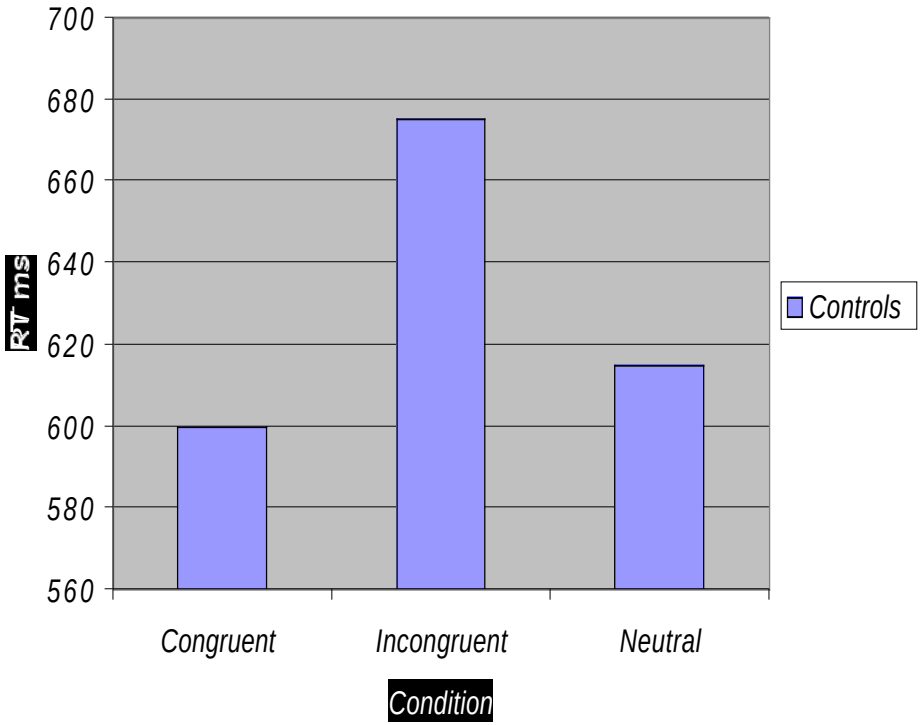


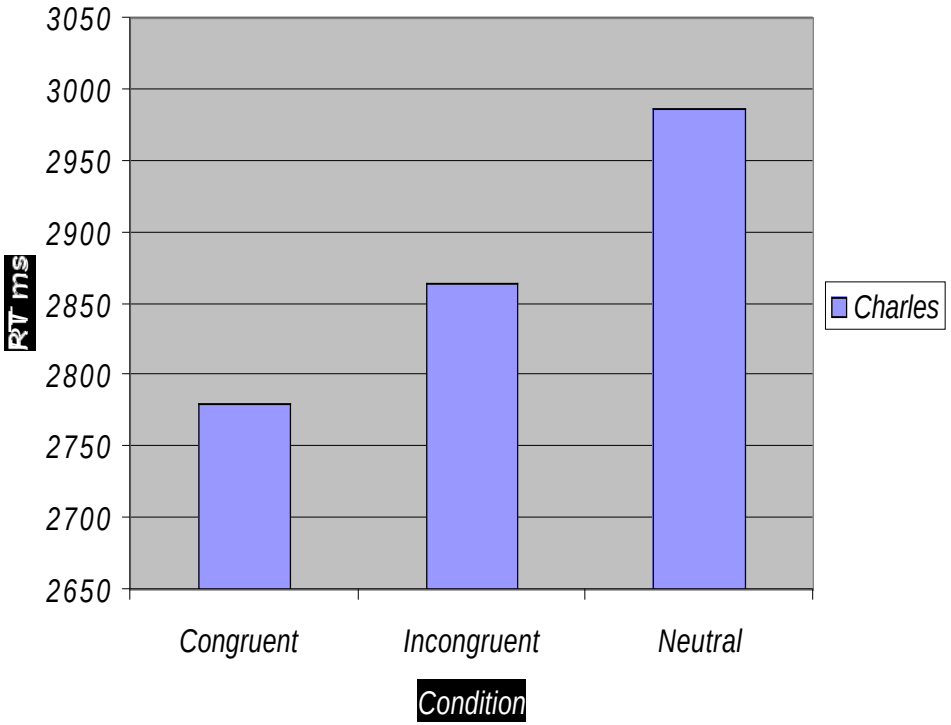
Charles vs controls: number comparison



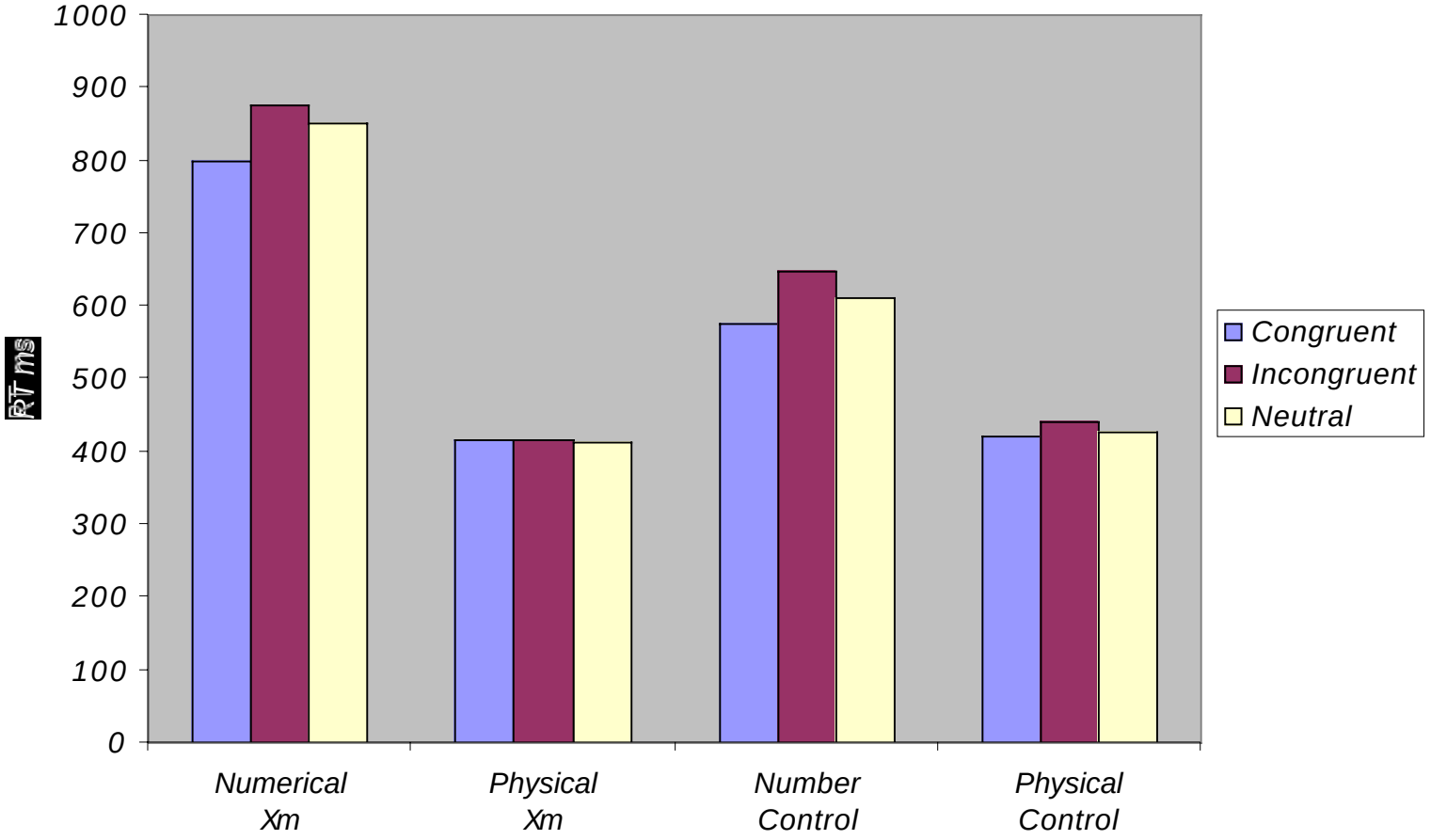


Number stroop. Charles vs controls





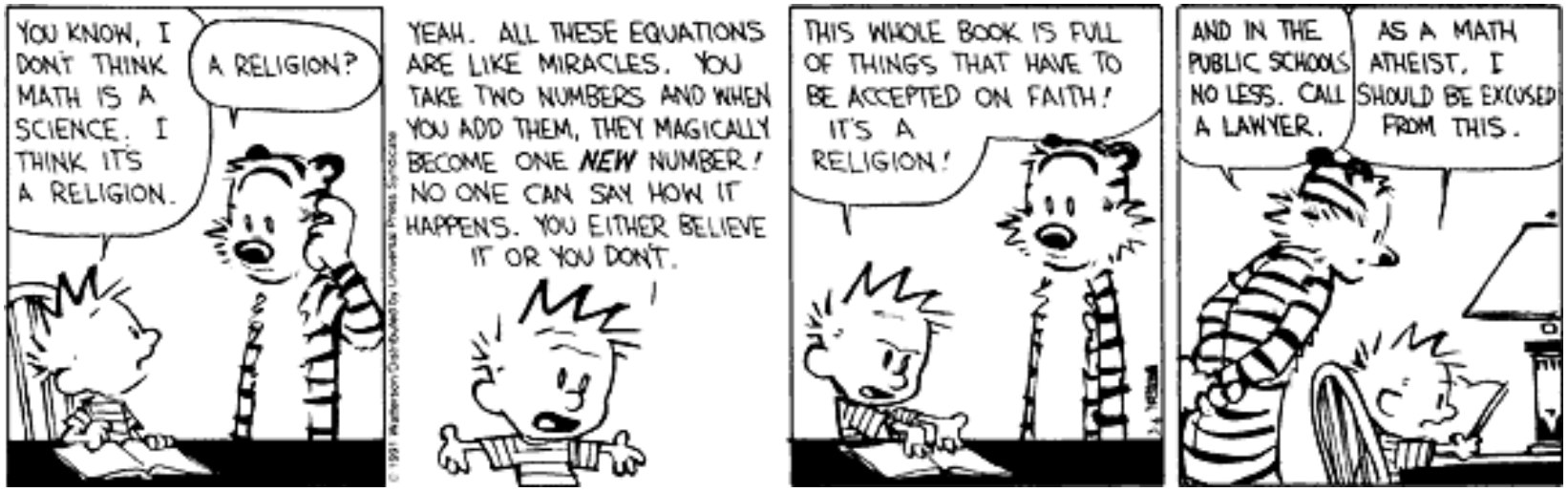
Stroop tasks: 45Xm vs control



Programme of research

- Tests of basic numerical capacities, reading and spelling, and other cognitive abilities in children to characterise the phenotypes
- Longitudinal studies of how these affect acquisition of cultural tools for mathematics in a realistic (school) setting
- Genetic investigations of basic numerical difficulties
  - Anomalous populations
  - Family studies
- Imaging brains of dyscalculics and dyslexics
- Cross-language and cross-cultural studies

© Brian Butterworth, 2002 & 2005. All Rights Reserved.



© Brian Butterworth, 2002 & 2005. All Rights Reserved.