DEVELOPMENTAL DYSCALCULIA

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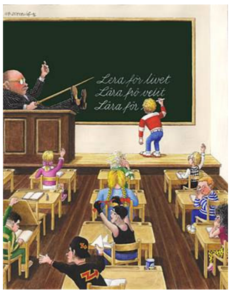
LECTURE TOPICS

- **NORMAL NUMBER ACQUISITION**
- **DEFINITION of DYSCALCULIA**
- **PREVALENCE**
- **DIAGNOSIS**
- **ASSOCIATED DISORDERS**
  - **ADHD**
- **PROGNOSIS**
- **ETIOLOGY**
- **NEUROBIOLOGY**

NORMAL DEVELOPMENT OF ARITHMETIC

- ARITHMETIC IS INHERENT & INBORN
- IT IS APPARENT IN INFANTS
- IT DOES NOT REQUIRE FORMAL SCHOOLING



MILESTONES IN THE NORMAL ACQUISITION OF ARITHMETIC

4-5 months	Recognize, add or subtract small numbers of objects & sounds
3-4 years	Count up to 4 items
4-5 years	Count up to 15 items & comprehend the concept the number represents
8 years	Write 3 digit numbers, recognize symbols, perform addition & subtraction
9-12 years	Proficient in complex addition, subtraction, multiplication & division

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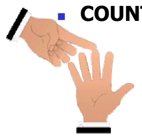
DEVELOPMENTAL DYSCALCULIA
DEFINITION

- **UNEXPECTED DIFFICULTY IN ACQUIRING ARITHMETIC SKILLS**
  - **NORMAL IQ**
  - **WITHOUT SEVERE EMOTIONAL PROBLEMS**
  - **APPROPRIATE SCHOOLING**

MANIFESTATIONS of DYSCALCULIA

- 6-7 years
  - **COUNTING, NUMBER FACTS**

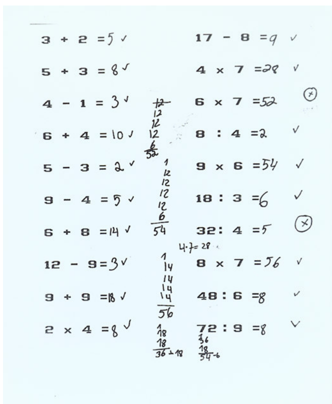


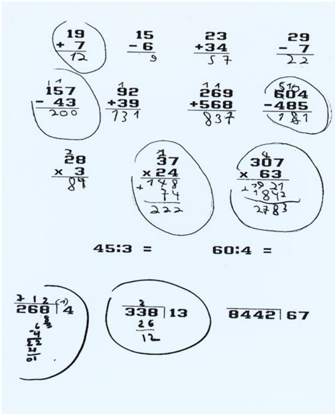
7+8=?

- 9-10 years
  - **NUMBER FACTS**
  - **COMPLEX +, −, ×, /**
  - **CARRYING OVER**
  - **NUMBER ORDER**

CASE REPORT

- 14 year old, 8th grader
- IQ 136, Competent reader
- Reads numbers, addresses, dates correctly
- Unable to solve simple arithmetic exercises, in spite of intensive help
- 9x6=? 12+12+12+12+6
- Family history: Father is a dentist with arithmetic problems





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PREVALENCE

USA (Badian, 1982)	**6.4%**
Israel (Gross-Tsur et al, 1996)	**6.5%**
Germany (Hein et al, 2000)	**6.6%**
India (Ramma et al, 2002)	**5.5%**

DYSCALCULIA.ORG

DYSCALCULIA: REVALENCE & COMORBIDITY

BOYS:GIRLS	**1:1.1**
ADHD	**25%**
DYSLEXIA	**17%**

Gross-Tsur et al, 1996

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- **NORMAL NUMBER ACQUISITION**
- **DEFINITION of DYSCALCULIA**
- **PREVALENCE**
- **DIAGNOSIS: MULTI-STEP PROCESS**
- **ASSOCIATED NEUROLOGIC DISORDERS**
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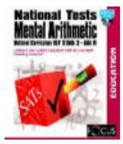
DIAGNOSIS



- STANDARDIZED ARITHMETIC TESTS
  - Wide Range Achievement Test-R (Jastek & Wilkenson, 1984)
  - Woodcock-Johnson Psychoeducation Battery-R (1989)
  - Group Mathematics Test (Young, 1971)
  - Neuropsychological Test Battery for Number Processing and Calculation in Children (von Aster, 2001)

DIAGNOSIS

- Medical History
  - Neurologic
  - Psychiatric
- School History
- Comorbid Conditions
  - Dyslexia
  - Dysgraphia
  - ADHD
- Social Problems
  - SES

DIAGNOSIS

- **NEUROLOGICAL EXAMINATION**

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NEUROLOGICAL DISORDERS ASSOCIATED WITH DYSCALCULIA

- **EPILEPSY**
- **NEUROFIBROMATOSIS**
- **BRAIN MALIGNANCIES**
  - **CRANIAL IRRADIATION, CHEMOTHERAPY**
- **SICKLE CELL ANEMIA**
- **TURNER'S SYNDROME (X0)**
- **METABOLIC DISORDERS**
  - **PHENYLKETONURIA, TREATED**
  - **INSULIN DEPENDENT DIABETES MELLITUS**

NEUROLOGICAL DISORDERS ASSOCIATED WITH DYSCALCULIA

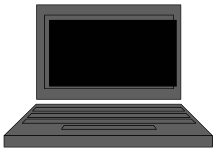
- NEUROBEHAVIORAL DISORDERS
  - DEVELOPMENTAL LANGUAGE DISORDERS
  - DEVELOPMENTAL RIGHT HEMISPHERE SYNDROME
    - NON-VERBAL LEARNING DISABILITIES
  - DEVELOPMENTAL GERSTMANN SYNDROME
  - **ADHD**

1. DYSCALCULIA and ADHD 2. ADHD and ARITHMETIC SKILLS

ATTENTION SKILLS in DYSCALCULIA

- **DYSCALCULICS (n=27)**
  - **IQ>85** **114.7±14.2**
  - **Normal Reading Skills** **101.1±16.7**
  - ***Arithmetic < 1 SD below IQ*** ***92.1±12.4***
- **CONTROLS (n=56)**
  - **IQ>85** **111.6±12.5**
  - **Normal Reading Skills** **112.0 ±13.5**
  - ***Normal Arithmetic Skills*** ***110.8 ±13.0***
    - **Lindsay et al, Dev Behav Pediatr 22:287, 2002**

CONTINUOUS PERFORMANCE TASK (CPT)



Tap immediately on the spacebar for any letter appearing on the computer screen except for the letter X.

DYSCALCULIA and ADHD

Results

- % Omission errors p<0.05
- Inconsistent response times p=0.05
- CPT index: p=NS

Conclusion

- Children with dyscalculia have significantly more parameters of inattention than controls.
  - **Lindsay et al, Dev Behav Pediatr 22:287, 2002**

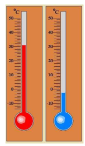
DYSCALCULIA & ADHD

- DYSCALCULIA: 25% have ADHD as a comorbid entity
  - Among children with dyscalculia, the presence of ADHD did not have an additional impact on already impaired arithmetic skills.
    - **Shalev et al, Math Cogn 3:105, 1997**

ADHD and ARITHMETIC

- **Among 140 boys with ADHD, 21% had a learning disability in arithmetic.**
  - **Faraone et al, Am J Psychiatry 150, 891, 1993**
- **Do children with ADHD without dyscalculia have more problems with arithmetic than expected?**

Number Processing & Calculations



- Nonverbal Magnitude Representations
  - Thermometer Task: position number on scale
  - Number Comparison: which number is larger: 4 or 7
- Verbal Numerical Representations
  - Counting sequences (15 to 1)
  - Transcoding (read and write 2-3 digit numbers)
  - Count dot arrays (1-10 dots)
- Calculation Tasks
  - Simple (single digit) mental
  - Complex (2 digit) mental
  - Written (2 digit)

(Kaufmann et al, Unpublished Data)

Working Memory

- **Digit span forwards and backwards**
- **Listening span**
- **Serial (word order) recognition test**
- **Memory for phonologically dis/similar short and long words**
- **Corsi block test**
- **Mazes**
- **Semantic verbal fluency (category)**

ADHD and ARITHMETIC

RESULTS:

- Normal performance on working memory tasks.
- Normal performance on arithmetic tasks related to verbal representations and calculations.
- Lower scores on non-verbal magnitude representations.
  - **Thermometer Task: Position number on scale**
  - **Number Comparison:**
    Which number is larger: 4 or 7

ADHD and Arithmetic Word Problems

- Children with ADHD without dyscalculia have difficulty inhibiting irrelevant data:
  - Verbal, semantic information
  - Numerical, arithmetic information

    - **Marzocchi GM et al, Dev Neuropsychol, 2002**

ADHD, Arithmetic & Dyscalculia

- Among children with **ADHD**, 20% have **dyscalculia**
- **ADHD** impacts on arithmetic processes in children who are not dyscalculic
  - **Magnitude processing**
  - **Inhibition of irrelevant information**
- Children with **dyscalculia**
  - **Large percentage (25%) have ADHD**
  - **Arithmetic problems severe; the additional presence of ADHD does not change arithmetic profile.**

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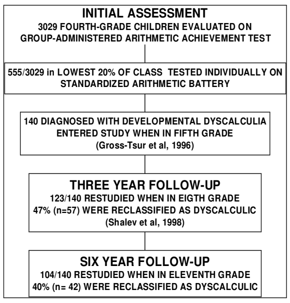
DYSCALCULIA: PROGNOSIS

- **THE NATURAL HISTORY OF DEVELOPMENTAL DYSCALCULIA IS SIMILAR TO THAT OF OTHER LEARNING DISABILITIES.**
- **DYSCALCULIA PERSISTS.**

DYSCALCULIA: PROGNOSIS



DYSCALCULIA: 6 YEAR FOLLOW-UP

DYSCALCULIA IS A PERSISTING LEARNING DISABILITY

- 40% (42/104) WERE RECATEGORIZED AS DYSCALCULIC
- 95% (99/104) IN LOWEST QUARTILE OF CLASS

DYSCALCULIA SIX YEAR FOLLOW-UP

	PDC n=42	NPDC n=62	p
IQ	94±10.5	101.1±9.5	.004
Attn: (P)	10.8±7.2	5.7±5.3	.001
Attn: (T)	13.9±7.8	8.7±7.4	.006
8th grade arithmetic score	23.0±4.5	29.5±5.3	.001

- NON SIGNIFICANT FACTORS:
  - SES, READING, GENDER

DYSCALCULIA: PERSISTING LEARNING DISABILITY

6 YEAR FOLLOW-UP

- RISK FACTORS FOR PERSISTENCE:
  - LOWER IQ
  - INATTENTION (ADHD)
  - SEVERITY OF DYSCALCULIA IN 8TH GRADE
- NON SIGNIFICANT FACTORS
  - GENDER
  - READING SKILLS
  - SES

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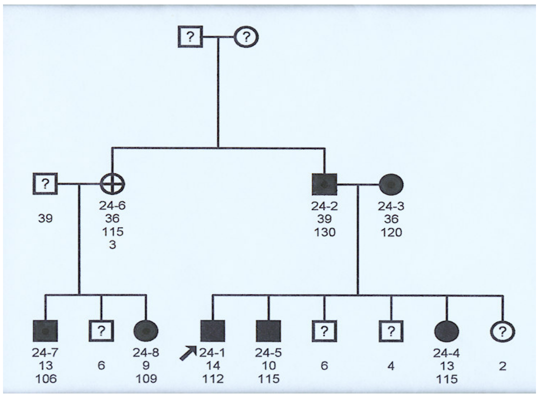
FAMILAL-GENETICS of DYSCALCULIA

ETIOLOGY:
TWIN STUDY PARADIGM

- THERE IS A SIGNIFICANT GENETIC CONTRIBUTION FOR DYSCALCULIA AS A LEARNING DISABILITY.
  - ALARCON ET AL, 1997



FAMILAL-GENETICS of DYSCALCULIA

	DYSCALCULIA n	%
33 Families		
90 SIBLINGS	47	52
38 BROTHERS	*38*	*53*
52 SISTERS	*27*	*52*
43 PARENTS	23	53

GENETICS OF DYSCALCULIA

- THE RISK FOR SIBLINGS AND PARENTS OF CHILDREN WITH DYSCALCULIA TO ALSO HAVE DYSCALCULIA IS GREATER THAN EXPECTED FOR THE NORMAL POPULATION.

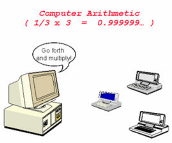
FACTORS CONTRIBUTING TO DEVELOPMENTAL DYSCALCULIA

- **INADEQUATE TEACHING METHODS**
- **UNTESTED ARITHMETIC CURRICULA**
- **OVERCROWDED CLASSROOMS**
- **DIVERSITY OF STUDENT BODY**
- **MATHEMATICS ANXIETY**
- **ENVIRONMENTAL DEPRIVATION**

FAMILAL-GENETICS of DYSCALCULIA

CONCLUSIONS

- THESE RESULTS IN COMBINATIONS WITH THE TWIN STUDIES BOLSTER THE HYPOTHESIS THAT THERE IS A GENETIC-FAMILIAL BASIS
- POOR TEACHING AND LOW MOTIVATION ALSO PLAY A ROLE



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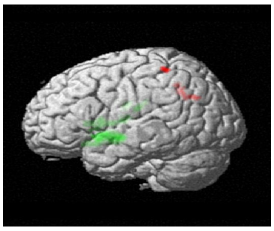
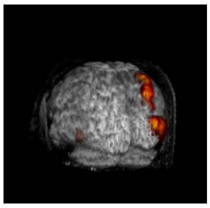
NEUROBIOLOGY

NORMAL ARITHMETIC PROCESSES

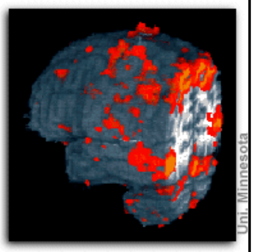


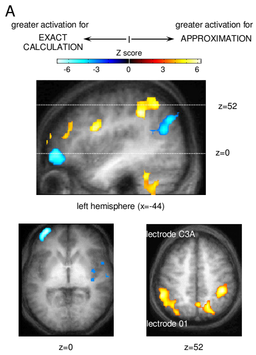
Functional MRI

- Premise: Undertaking a cognitive task results in activation of specific areas of the brain.
- This activation increases blood flow.
- The change in blood flow can be quantified
- Safe technique



fMRI





Dehaene et al., *Science* May 7th 1999
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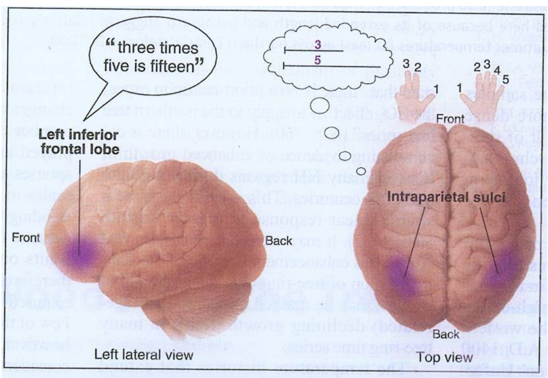
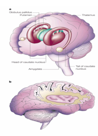
Service Hospitalier Fr·d·ric Joliot, CEA/DSV, Orsay, France



NEUROBIOLOGY OF DYSCALCULIA

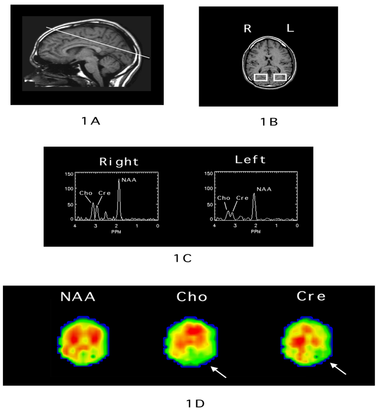


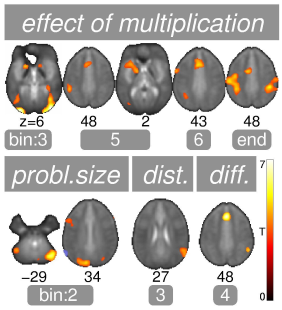
- RIGHT HEMISPHERE
- LEFT HEMISPHERE — Grafman et al, 1982
- BASAL GANGLIA — Hittmair-Delazer et al, 1994
- THALAMUS — Ojemann, 1974

H-Magnetic Resonance Spectroscopy

Abnormalities in density and energetics of cells in left posterior temporo-parietal areas

Levy et al, Neurology, 1999



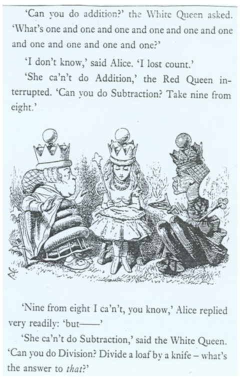


- **Activation of visual cortex**
- **Precise calculations**
  - **Basal gg**
  - **Language area**
- **Magnitude processing**
  - **Biparietal areas**

  - **Morocz et al, 2004**

DYSCALCULIA

- FREQUENCY: 6%
- PERSISTING DISORDER
  - RISK FACTORS:
    - IQ
    - INATTENTION
- ETIOLOGY:
  - FAMILIAL-GENETIC
  - EDUCATION*
- NEUROBIOLOGY:
  - Bi-HEMISPHERE



'Can you do addition?' the White Queen asked. 'What's one and one and one and one and one and one and one and one and one and one?'

'I don't know,' said Alice. 'I lost count.'

'She ca'n't do Addition,' the Red Queen interrupted. 'Can you do Subtraction? Take nine from eight.'

'Nine from eight I ca'n't, you know,' Alice replied very readily: 'but——'

'She ca'n't do Subtraction,' said the White Queen. 'Can you do Division? Divide a loaf by a knife – what's the answer to *that*?'

FAMILAL-GENETICS of DYSCALCULIA

RESULTS

	WRAT-R	IQ
SIBLINGS		
DYSCALCULIC+	80.7±22.5	108.2±12.4
DYSCALCULIC-	91.4±13.0	112.7±14.8
	p<.008	**p=NS**
PARENTS		
DYSCALCULIC+	74.1 ±8.0	108.4 ±12.3
DYSCALCULIC-	95.2 ±12.5	116.0 ±14.8
	p<.001	**p=NS**