STANFORD MATH PROJECT

A Developmental Neuroscience Study

Monday, January 29, 2007
San Francisco State University, Developmental Psychology

Outline

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- Mathematical Disabilities
- Stanford Math Project
  - Specific Aims & Hypotheses
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  - Testing and Protocol Development
- Initial Results
- Current Challenges
- Looking Ahead

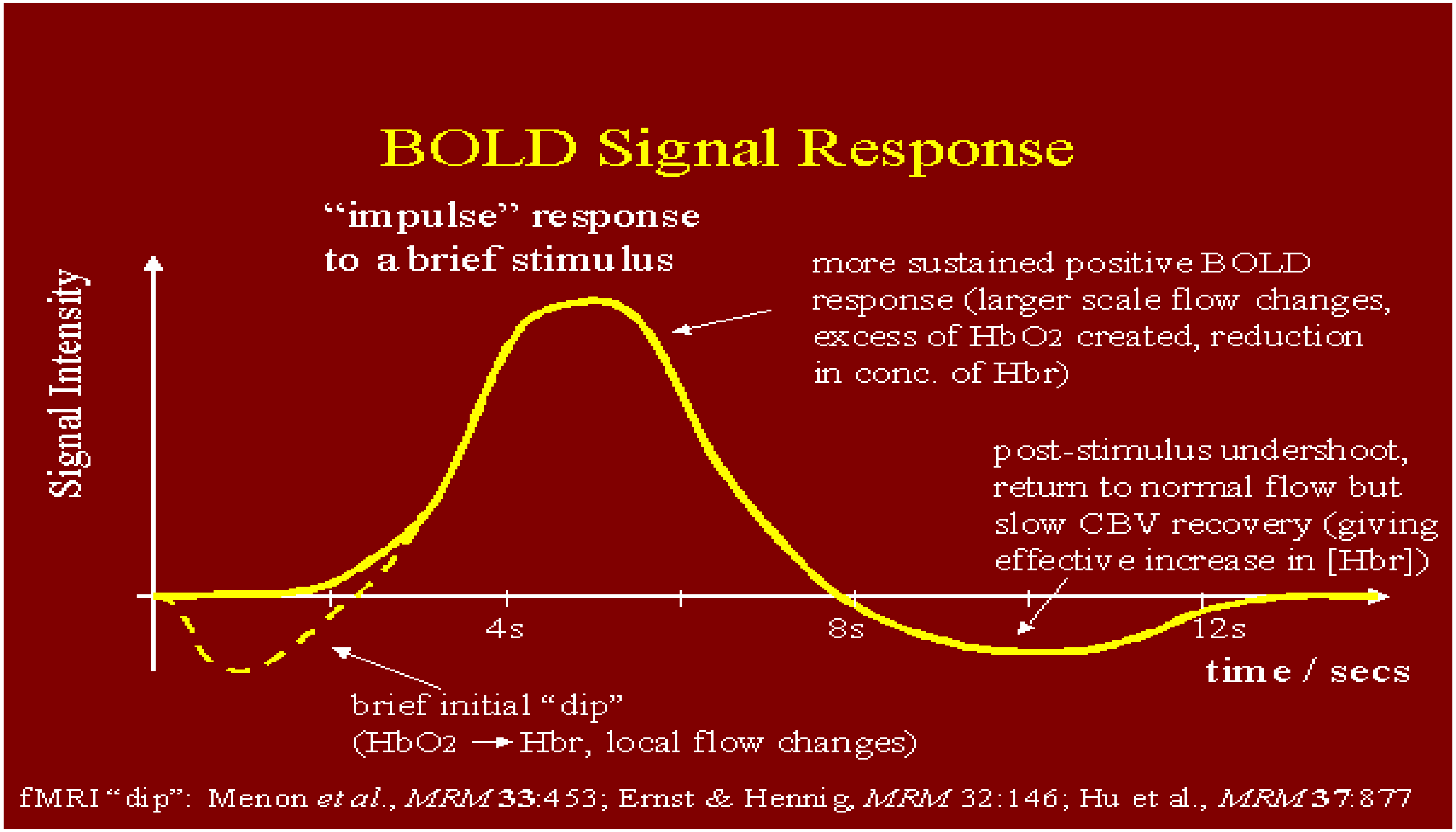
Introduction

- Stanford Cognitive and Systems Neuroscience Laboratory
- Department of Child Psychiatry and Behavioral Sciences, Stanford University School of Medicine
- PI : Dr. Vinod Menon, Ph.D.
- NIH-Funded Study

Developmental Neuroscience

- Developmental Psychology: “the pattern of change that begins at conception and continues through the life span“
  - social, environmental, biological factors
- Neuroscience
  - Study of nervous system
  - Macro- and micro-level

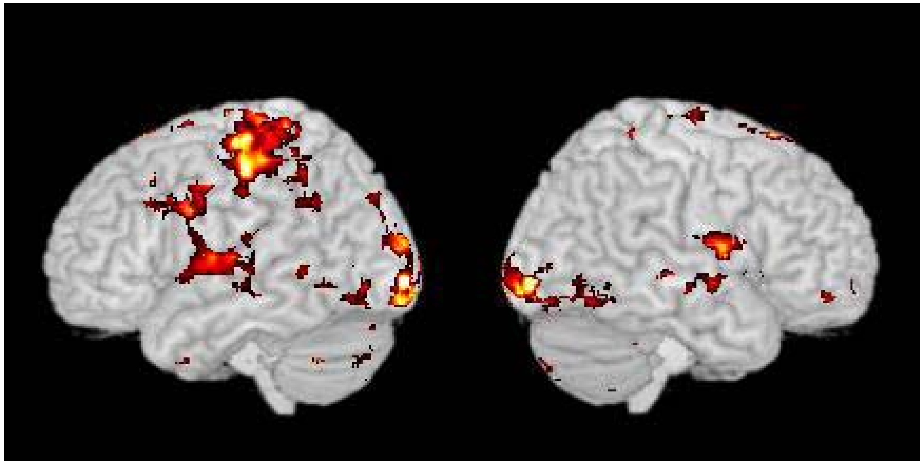
Developmental Neuroscience: MRI



http://www.fmrib.ox.ac.uk/~peterj/

Developmental Neuroscience

- Magnetic field sensitive to deoxygenated blood
- fMRI and structural MRI



Developmental Neuroscience: The Stanford Math Project

- Overarching Goal: To investigate the neural basis of mathematical disability (MD) using a neural systems approach and state-of-the-art functional brain imaging techniques (fMRI).

Mathematical Disabilities (MD)

- Why do we care about MD?
- Much behavioral work has explored children’s developing “number sense” and mathematical strategy use (Geary et al.)
  - counting, retrieval, decomposition
  - http://web.missouri.edu/~psycorie/articles_math.htm

Mathematical Disabilities (MD)

- < Grade level performance, but normal IQ and reading ability
- Inability to accurately and efficiently retrieve basic arithmetic facts.
- Investigating the neural basis of deficits in basic mental arithmetic (MA) -> cognitive mechanisms used -> theoretical models of math development.

Stanford Math Project

- Compare typically developing (TD) and MD performance on:
  - behavioral measures
  - strategy use
  - mental arithmetic (basic addition and subtraction) tasks as assessed with fMRI.
    - performance
    - brain activation

Participants

- Ages 7 to 9 (Grades 2 & 3)
- Target: 40 TD children, 40 MD children
- Longitudinal design to assess shift in strategy use over the course of development
  - Time 1 = Grade 2
  - Time 2 = Grade 3

Specific Hypotheses

- Relative to the TD group, the MD group will show
  - Significant performance deficits in addition and subtraction, subtraction more than addition
  - Use less efficient strategies
  - Rely heavily on areas related to computation (PFC), less on retrieval (PPC)

Specific Hypotheses

- Relative to the TD group, between Time 1 and Time 2 the MD group will show
  - Smaller improvements in performance
  - Sustained reliance on PFC, less development of PPC
  - Smaller increases in functional connectivity between brain areas associated with math performance (PPC, PFC, medial temporal lobe, early visual processing areas)

Study Design

Time 1:

1. Neuropsychological Assessments
2. Brain Scan
   - Addition and subtraction, block- and event-related tasks
3. Strategy Assessment

Time 2:

- Sessions 1-3 repeated to assess longitudinal changes in MA development

Neuropsychological Assessments

- WIAT–II
- WASI
- WMTBC (Pickering & Gathercole, 2001)
  - Central executive, phonological loop, VSS,
- CPT (Conners’ Continuous Performance Test)

Additional Measures

- Child
  - Edinburgh Handedness Test
  - Math Anxiety (Suinn, 1972)
  - Attitudes Toward Math Questionnaire
- Parent
  - Family Demographic Questionnaire
  - Child Behavior Checklist
  - Math Intervention Questionnaire
    - e.g. “Is your child currently attending a math tutoring or math schooling program?”

Exclusion Criteria

- MRI compatibility (metal in body)
- Serious medical illness, head injury, sensory impairments (visual or auditory)
- Psychopathology/behavioral problems (assessed with CBCL)
- IQ below 80
- Reading score below 25th percentile

Testing and Protocol Development Scanner Tasks

- Format a + b = c (based on Geary, 1999)
- Which numbers to use?
  - Capture range of skills
  - Variety to prevent exposure
- What is an appropriate control to use?
  - a +1 = b
  - Number Identification: 1)4@5o2

Testing and Protocol Development Scanner Tasks

- Duration of Trial
  - Once again range of skill issue
- Target accuracy

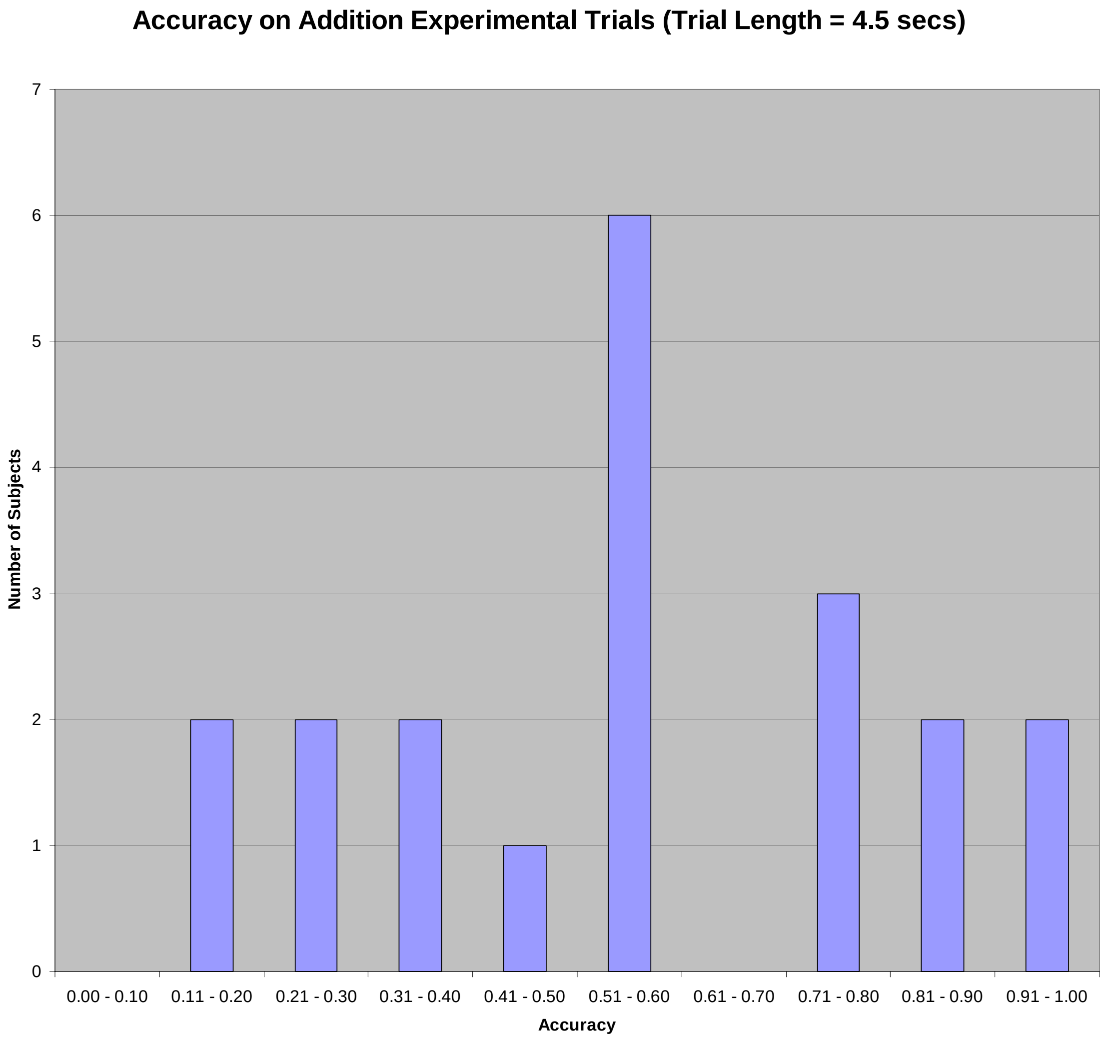
Testing and Protocol Development: Scanner Tasks

1. Event-Related Design vs. Block Design: Addition, Subtraction
   - Event-related design corrects for predictive responses
   - Block design provides stronger signal for analysis of brain activation

Testing & Protocol Development

- Pilot Testing – 2nd Graders
  - Trial length = 3.5 secs
    - Accuracy on experimental trials below 40%
  - Trial length = 4.5 secs
    - Subjects perform well on control trials, but experimental accuracy remains below the 70% target
    - Accuracy decreases as smaller addend increases

Testing & Protocol Development



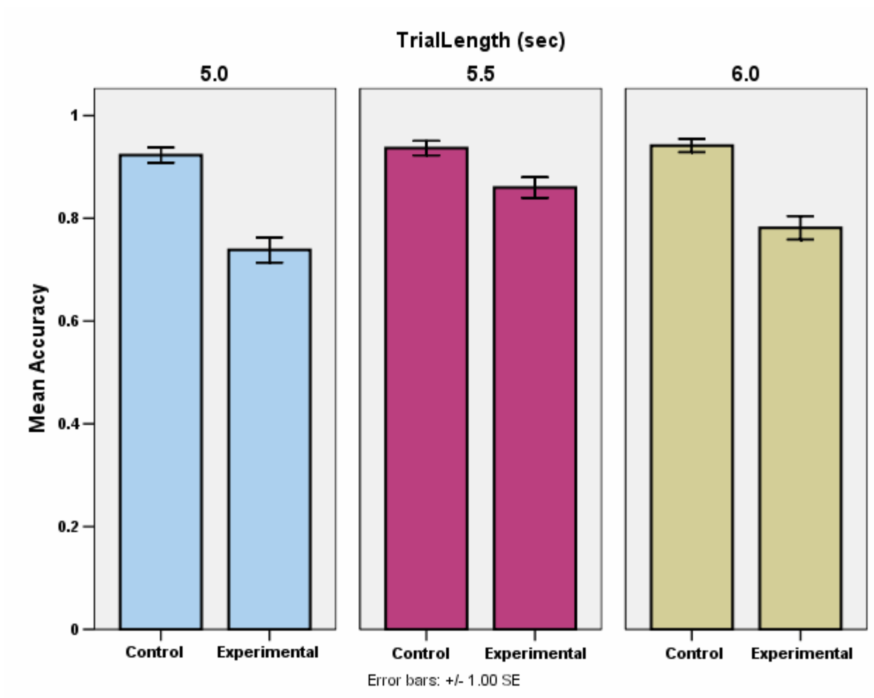
Testing & Protocol Development

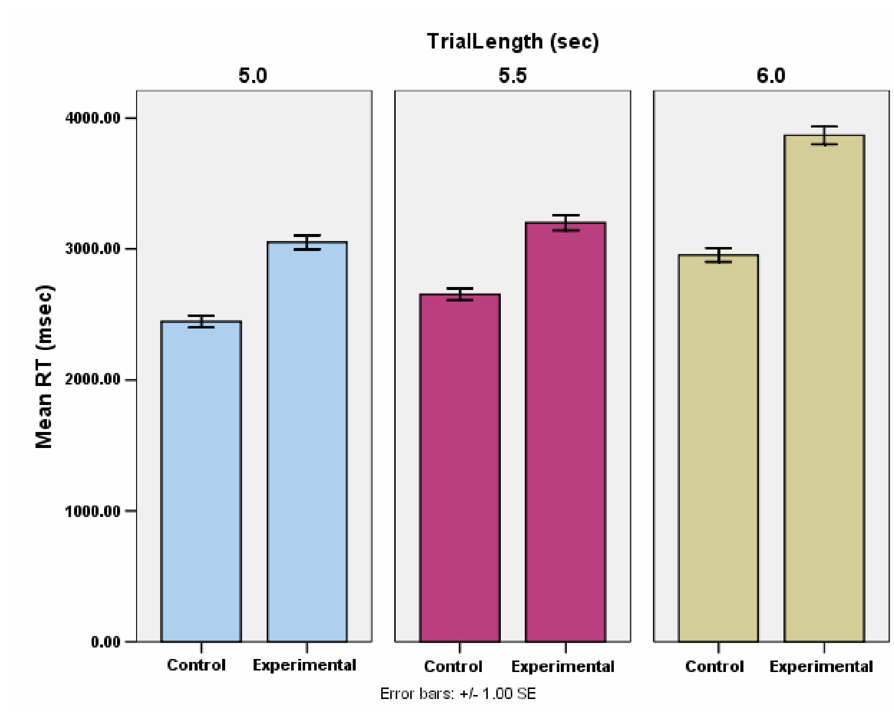
- Pilot Testing – 2nd Graders
  - Testing at 4.5 secs revealed that this trial length was still too short to achieve 70% accuracy on experimental trials
  - We decided to conduct further pilot testing, randomly assigning children to trial lengths of 5.0, 5.5, or 6.0 secs, to determine the shortest trial length necessary to obtain an adequate level of performance

Testing & Protocol Development

Accuracy

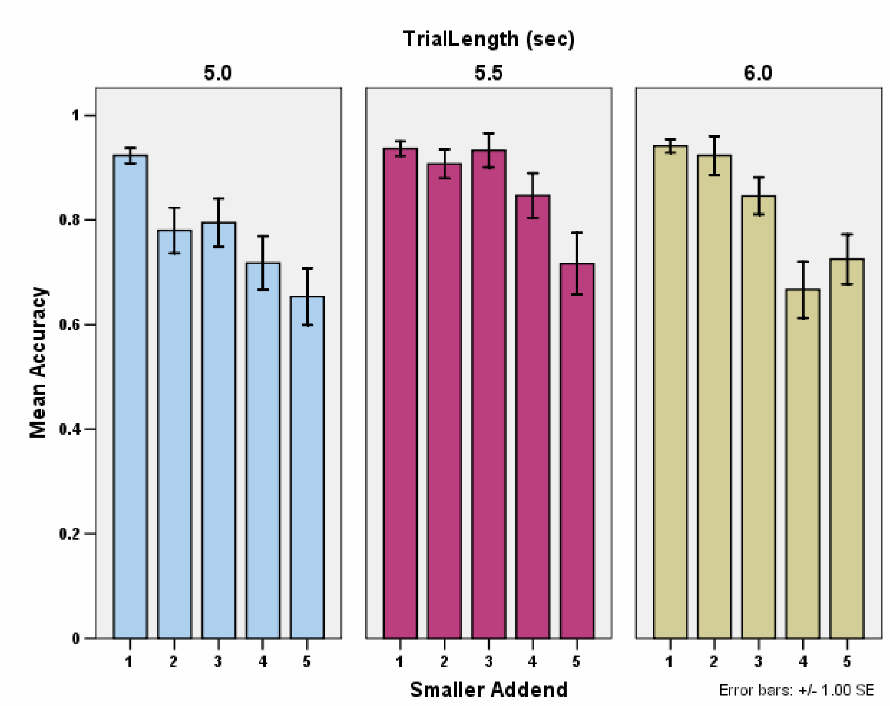
RT





Testing & Protocol Development

Accuracy



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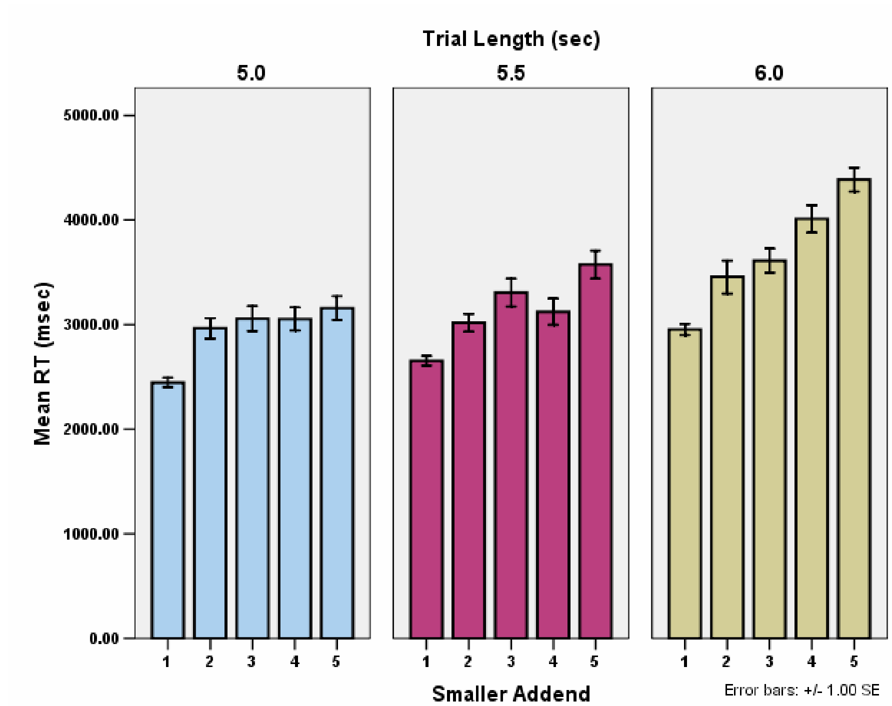
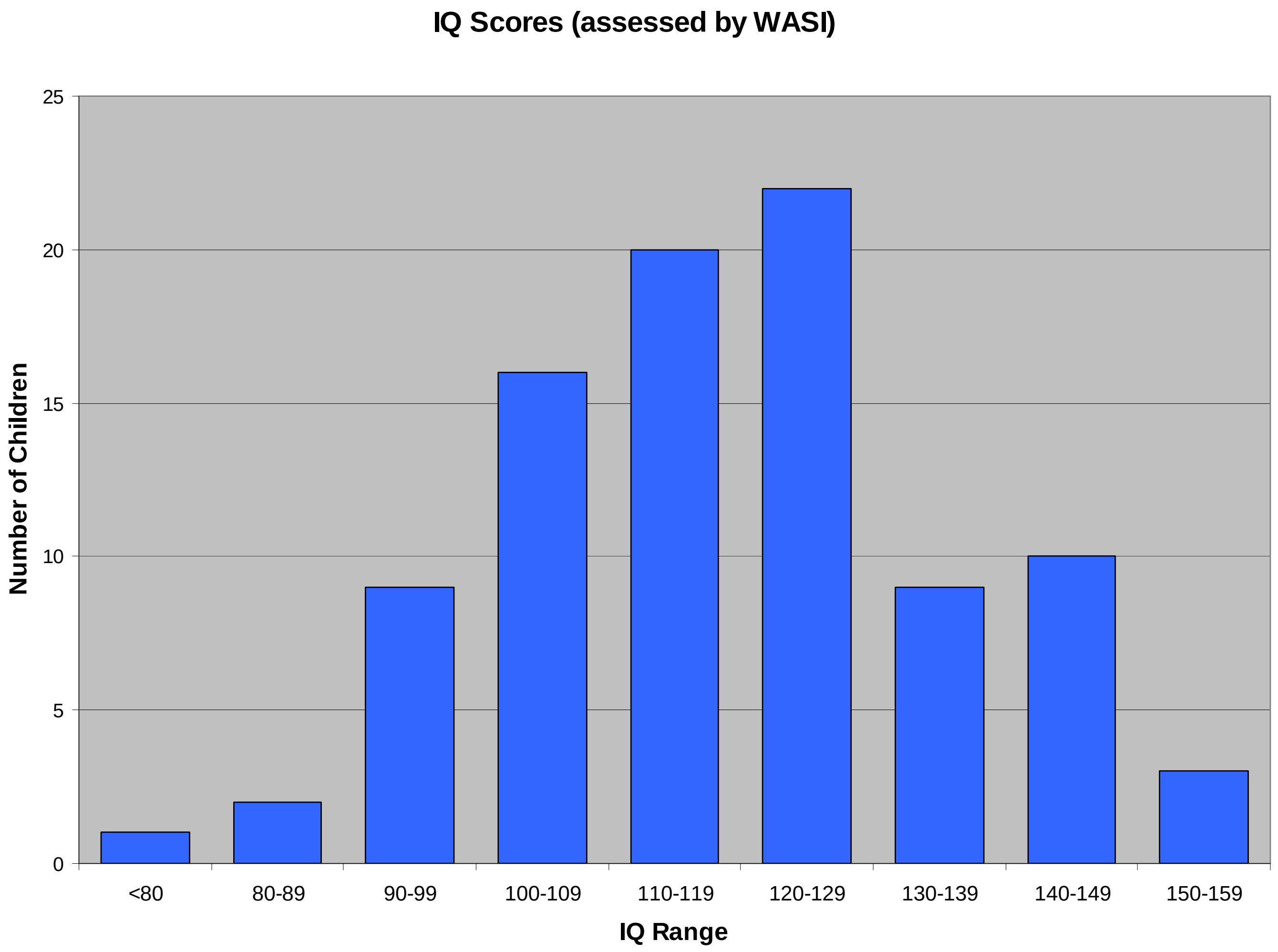


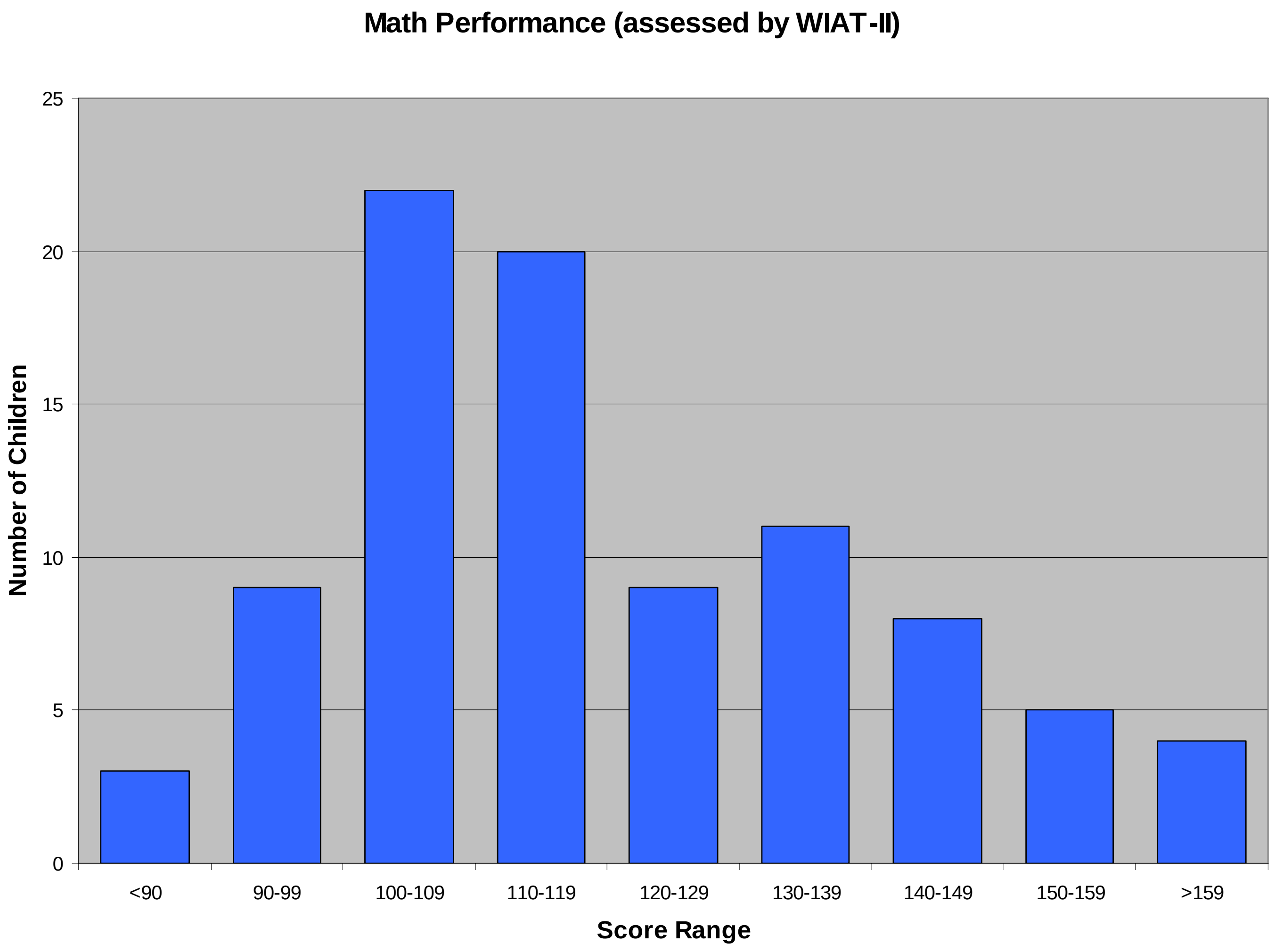
Initial Results

- Participant Pool: 86 children
  - 47 second-graders, 39 third-graders
  - 53% male, 47% female
  - 43 TD, 7 MD, 36 “Gifted” (IQ over 120)
  - WASI IQ scores
    - Range: 79-158
    - Mean: 119
    - St Dev: 17
  - WIAT-II Math Composite scores
    - Range: 65-160 (maximum score: 160)
    - Mean: 119
    - St Dev: 20

Initial Results: Behavioral

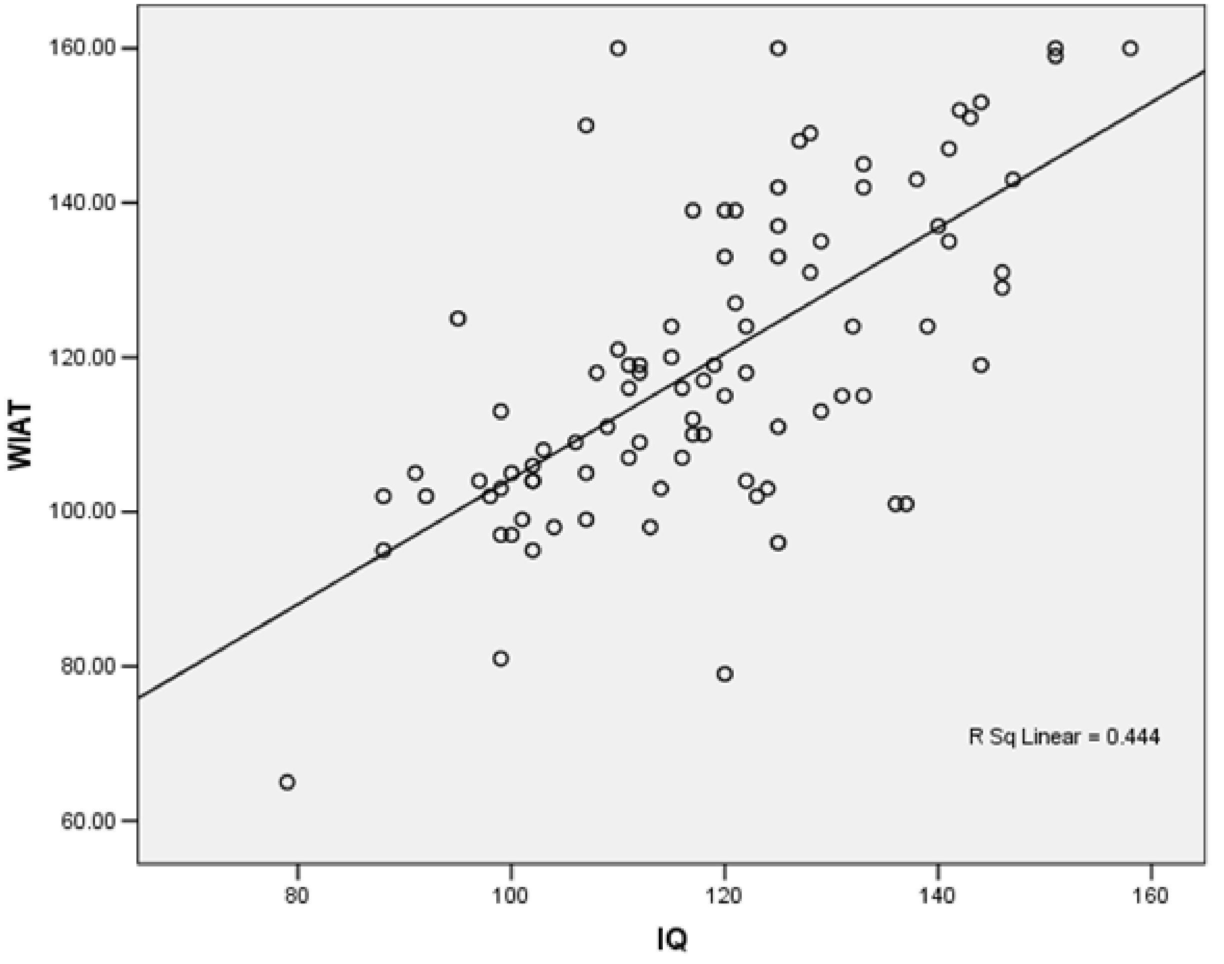


Initial Results: Behavioral



Initial Results: Behavioral

Correlation Between Math Scores & IQ



Initial Results: Behavioral

Correlation Between Math Scores & Working Memory Performance

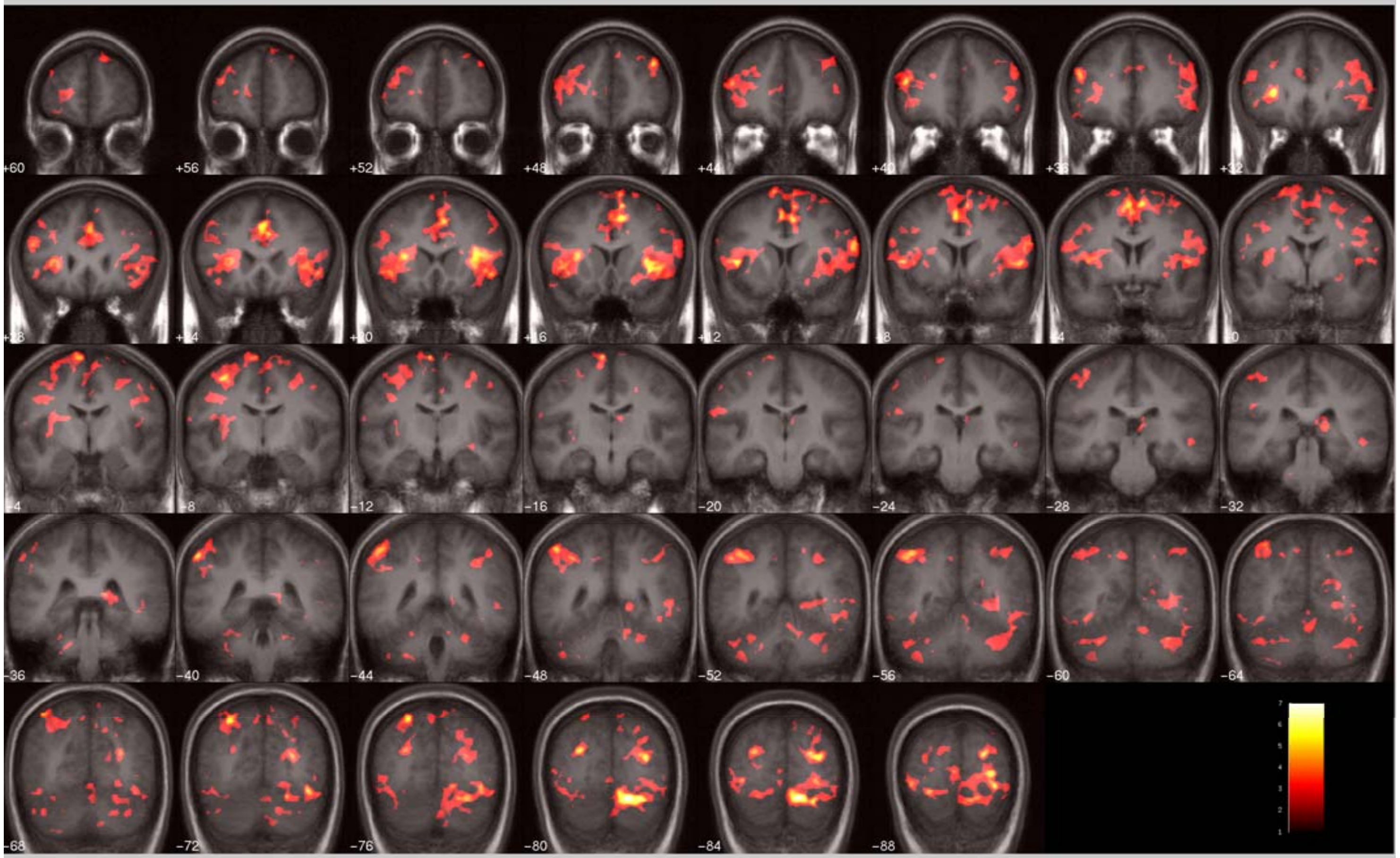
		WIAT	DR	BR	CR	BDR
WIAT	Pearson Correlation	1	.328(**)	.453(**)	.540(**)	.367(**)
	Sig. (2-tailed)		.002	.000	.000	.000
	N	88	88	88	88	88
DR	Pearson Correlation	.328(**)	1	.190	.331(**)	.377(**)
	Sig. (2-tailed)	.002		.076	.002	.000
	N	88	88	88	88	88
BR	Pearson Correlation	.453(**)	.190	1	.415(**)	.394(**)
	Sig. (2-tailed)	.000	.076		.000	.000
	N	88	88	88	88	88
CR	Pearson Correlation	.540(**)	.331(**)	.415(**)	1	.542(**)
	Sig. (2-tailed)	.000	.002	.000		.000
	N	88	88	88	88	88
BDR	Pearson Correlation	.367(**)	.377(**)	.394(**)	.542(**)	1
	Sig. (2-tailed)	.000	.000	.000	.000	
	N	88	88	88	88	88

** Correlation is significant at the 0.01 level (2-tailed).

DR = Digit Recall; BR = Block Recall;
CR = Counting Recall; BDR = Backward Digit Recall

Initial Results: Imaging

Children : Experimental vs. Rest



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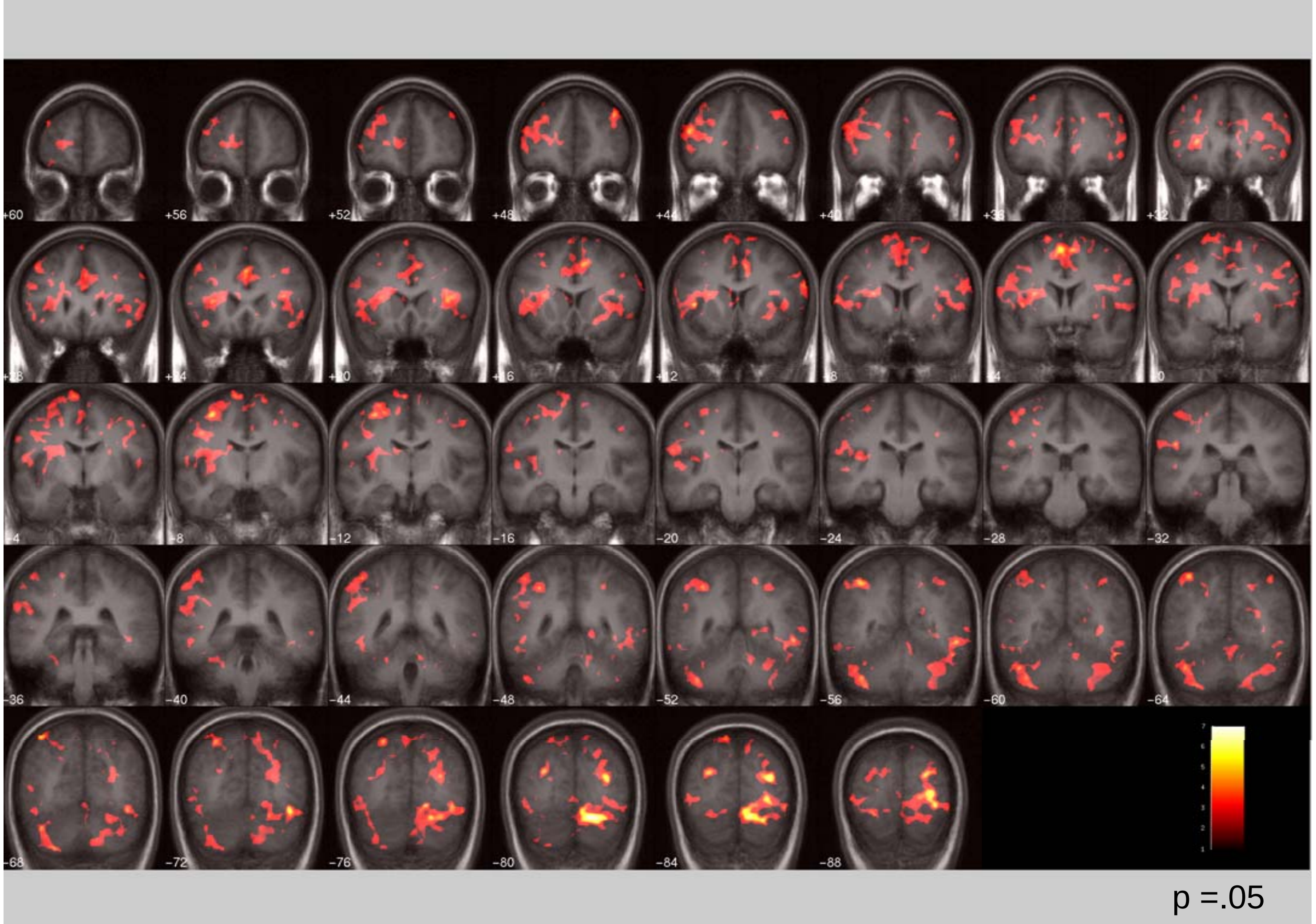
Initial Results: Imaging

Children : Control vs. Rest



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Initial Results: Strategy

- 39 scanned
- 14 counters, 15 retrievers, 10 unusable
  - Comparative analyses
    - WASI and WIAT?
    - Task performance
    - Neural activation patterns?
  - Correlative analyses
    - Percentage retrieved correlated with brain activity?

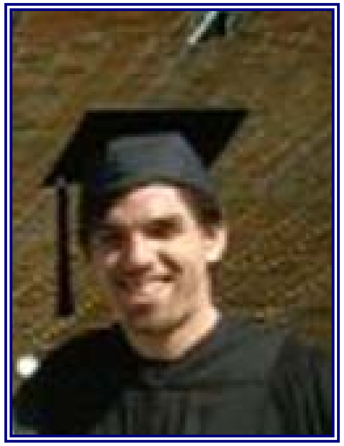
Current Challenges

- MD Recruitment
- Numbers, numbers, numbers
- Retaining longitudinal participants

Looking ahead

- Started 2nd year of study
- 20 MD, 15 TD
- Analyses:
  - Strategy assessment
  - DTI
  - Analyses with Math Anxiety, Math Intervention, Behavioral Measures

Cast of Characters



- Katherine Keller
  - Scripps College
    B.A., Cognitive Neuroscience
- Jose Anguiano
  - Stanford University
    B.S., Psychology
- Meghan Meyer
  - Emory University, B.A. Psychology
  - Ecole Superieur, Paris, M.A. Psychology