Executive Attention

Its Impact on Reading

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NEUROLOGY—REVEALED BY AMRI AND FMRI—UNDERLYING ADHD

- Frontal (and all subdivision!)
- Striatal (emphasis on caudate)
- Cerebellar (most distinctive)
- Underactivated caudate and MPH response of caudate most consistent findings

"Attention-deficit/hyperactivity disorder is characterized by a delay in cortical maturation."

- This is the title of the publication by Shaw P, Eckstrand K, Sharp W, Blumenthal J, Lerch JP, Greenstein D, Clasen L, Evans A, Giedd J, Rapoport JL, 2007 PNAS, 104:19649-19654
- Cortical growth-to-max trajectories measured on aMRIs

Multifactorial Cognitive Etiology Model of ADHD

- "Impulsive cognitive style is attributive to an additive or interactive dysfunciton in multiple (but probably related) cognitive systems and their closely related mediating neural networks" (Sergeant et al., 2003; Willcutt et al., 2005)

EF Popularized As Neuropsychology of ADHD

- Executive Function (EF) is domain of direct interest, implicates "Frontal" circuits
- Barkley's book explains that all EFs flow (linearly, developmentally) from the primary one, INHIBITION
- Others view INHIBITION and RESPONSE PREPARATION as "two sides of the same coin"
- Add "Sustain," "Initiate" and "Shift"

Emphasis Shift: Not Just Inhibition is Deficient with ADHD

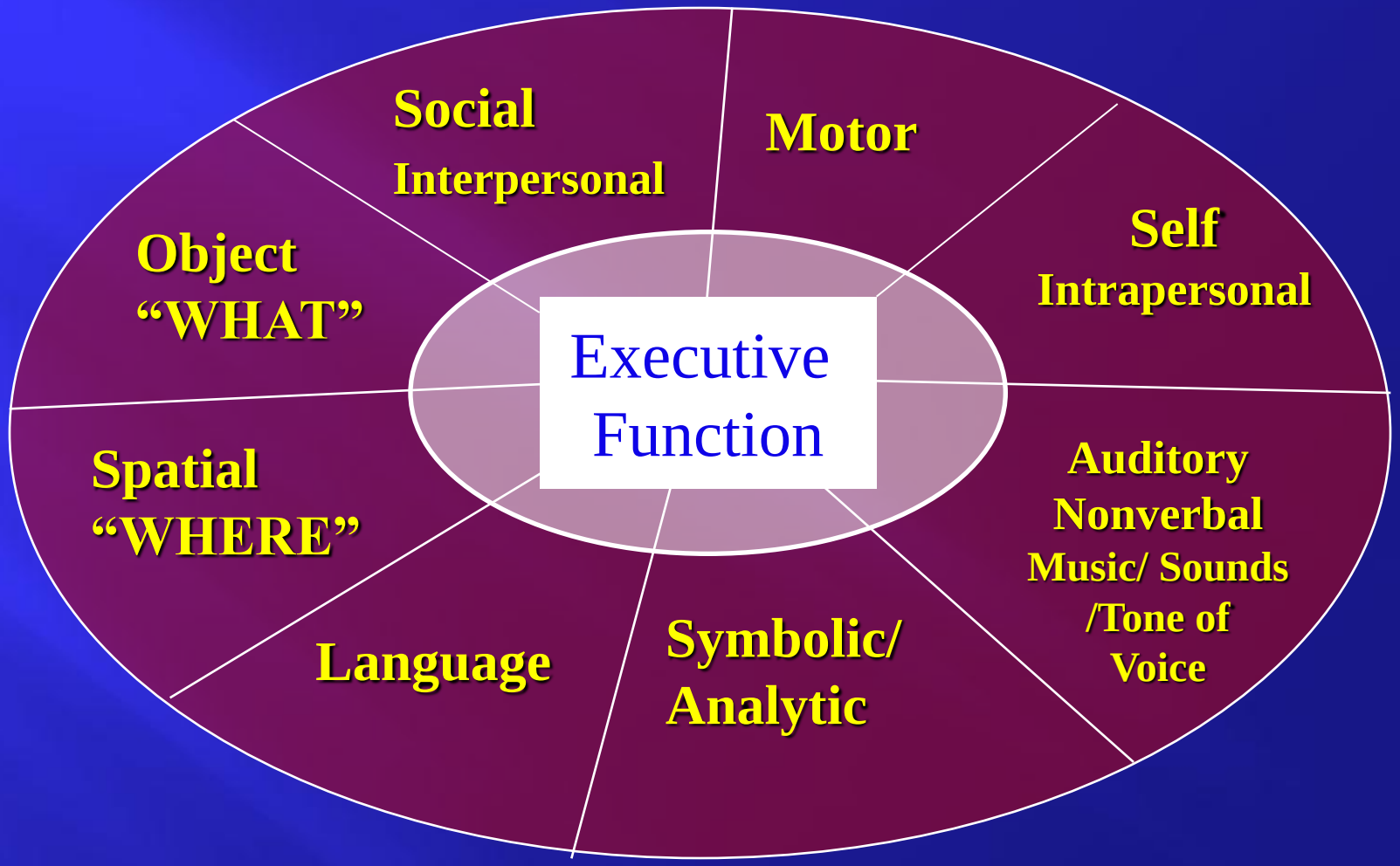
- Speed of Motor Output
- Timing of Motor Output
- VARIABILITY of Motor Output
- These now “Motor Endophenotype”

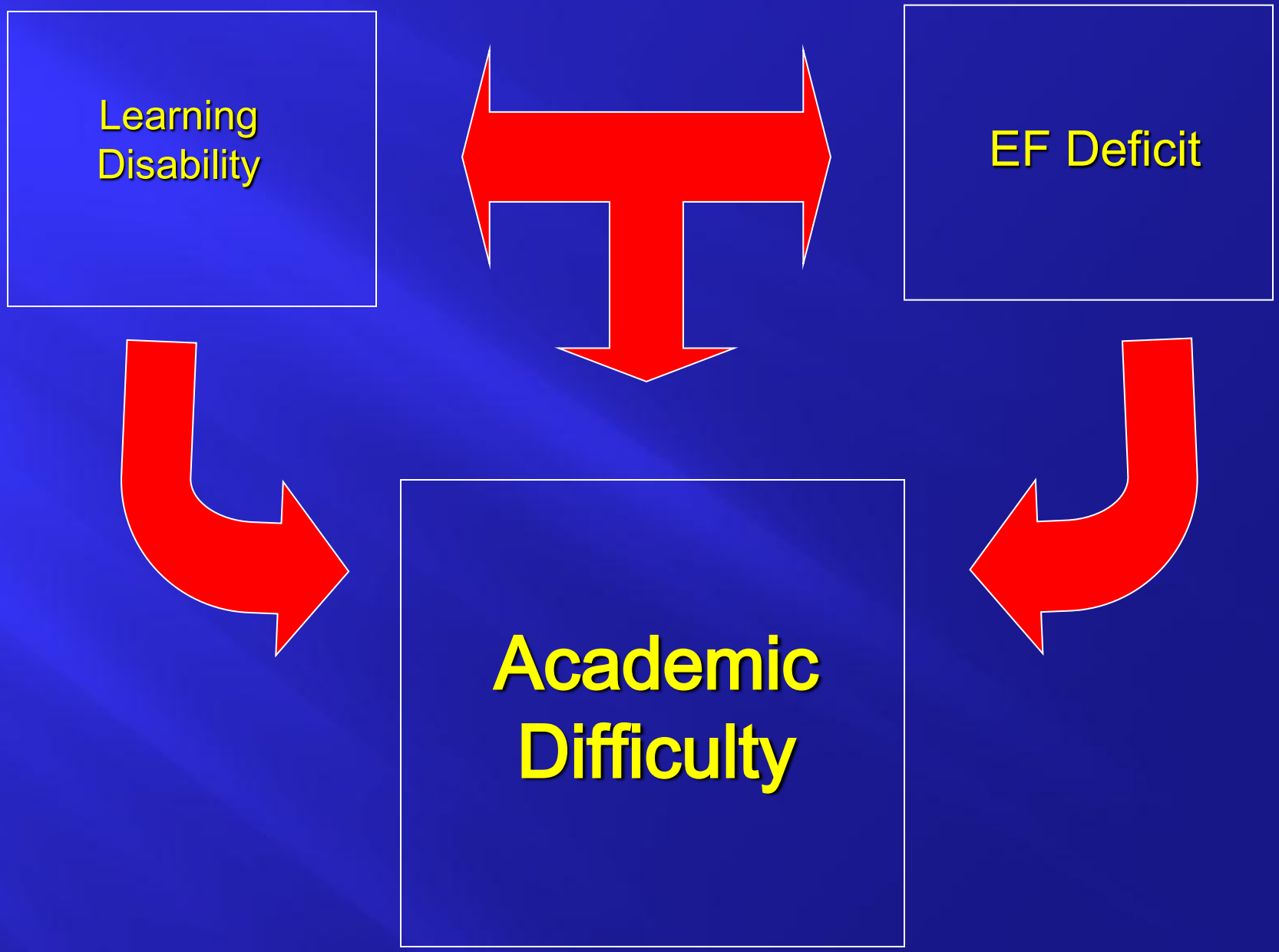
Current Concerns About What Sufficiently Characterizes ADHD

- Does the "traditional triad" cover the syndrome?
- Is "hyperactivity" too superficial or redundant?
- Isn't "inattention" misleading" (better choice "attention mis-allocation")

Is EDF "diagnostic" of ADHD?

- No! Most with ADHD show EDF but reverse is not true!
- EDF is NOT a diagnosis but a "processing problem" (educators' terminology)
- EF has "server loops" from other "posteriorly based" systems (also described as "ingredients")


Social
Interpersonal
Motor
Self
Intrapersonal
Object
"WHAT"
Executive
Function
Spatial
"WHERE"
Auditory
Nonverbal
Music/ Sounds
/Tone of
Voice
Language
Symbolic/
Analytic


Learning Disability
EF Deficit
Academic Difficulty

Identify The Colors You See Below

Read the words listed below

Blue	Yellow	Green
Red	Red	Blue
Yellow	Green	Green
Blue	Yellow	Yellow
Green	Red	Red
Yellow	Green	Yellow
Red	Green	Blue

Say the color in which the word is printed

Blue	Yellow	Green
Red	Red	Blue
Yellow	Green	Green
Blue	Yellow	Yellow
Green	Red	Red
Yellow	Green	Yellow
Red	Green	Blue

PROJECT III: THE EFFECTS OF ADHD (BEYOND DECODING ACCURACY) ON READING FLUENCY AND COMPREHENSION

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Specific Aims

Using ADHD as a model:

1. How does *processing speed* contribute to reading efficiency?
2. How does *working memory* contribute to reading comprehension?
3. How does *repeated exposure* and practice affect reading efficiency and textual fluency?

Participants

- *n* = 100, grades 4-8 (50 control/50 ADHD)
- Exclusion criteria (ADHD/controls)
  - Adequate word recognition/decoding skills
  - No Language Disorder (< 1.5 sd on CELF-4 receptive or expressive language composite OR < 1.0 sd on both)
- Neuropsychological assessment, ERP, fMRI, and DTI

Inclusions and Exclusions

- DSM-IV diagnosis
  - DICA-IV interview
  - Conners' Rating Scales
  - ADHD Rating Scale IV
- Must meet on DICA-IV, 1/2 parent and 1/2 teacher rating scales

- Autism/PDD
- Conduct Disorder
- Anxiety Disorders
  - Except Specific Phobia
- Mood Disorders
- Psychosis
- Language Disorders
- Word Reading < 37th percentile
- IQ < 70 or > 130
- Long acting psychotropics
- Contraindications to MRI

Deconstructing Executive Control

- Functions
  - Response inhibition
  - Working memory
    - Verbal
    - Spatial
  - Response preparation
    - Initiation
    - Planning
    - Processing speed
    - Variability of responding
- Methods
  - Brain
    - aMRI
    - fMRI
    - DTI
    - Electrophysiology
  - Cognitive
  - Motor
  - Oculomotor

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Processing Speed in ADHD

- As a group, children with ADHD are slow on nearly every timed task
  - Motor *(Cole et al., 2008, Neurology)*
  - Oculomotor *(Mahone et al., 2009, JAACAP)*
  - Reaction times on computer tests *(Wodka et al., 2007, JCEN)*
- Reaction times are also more variable
- Implications for all academic work
- Can we separate "processing" speed from responding speed?

Processing Speed and Fluency

- Poor fluency increases demands on other processes (e.g., working memory) can affect comprehension

- Higher level processes compete with decoding for time limited resources and create a bottleneck

Rapid Naming is Slower

- Children with ADHD show deficits in rapid color naming *(Wodka et al., 2008; Tannock et al., 2000)*
- Treatment with stimulants improves naming speed *(Bedard et al., 2002)*
- Elements of naming appear separable
  - Articulation time, pause time, variability *(Neuhaus et al., 2001)*

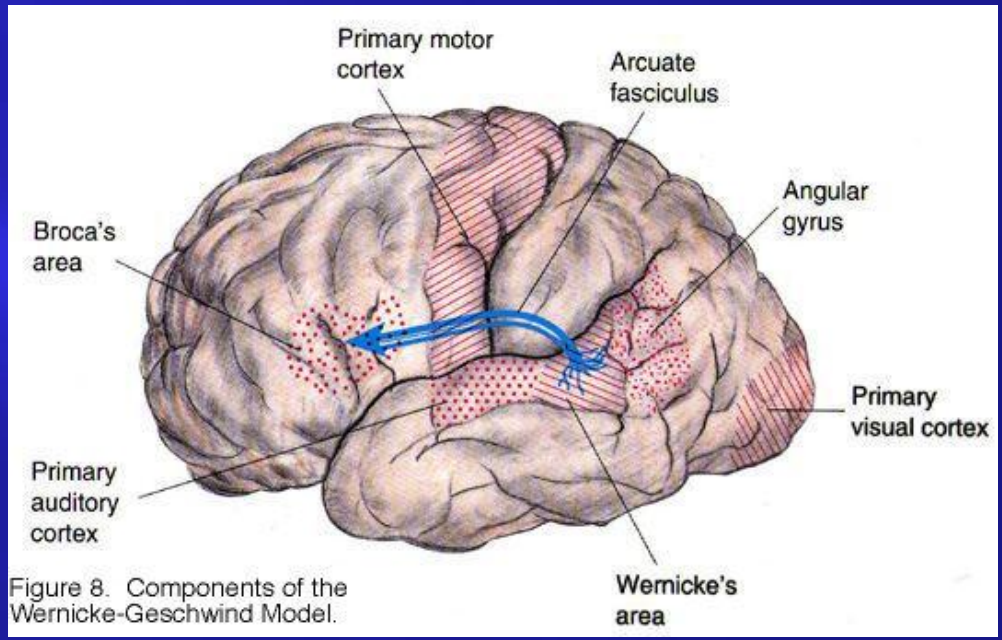
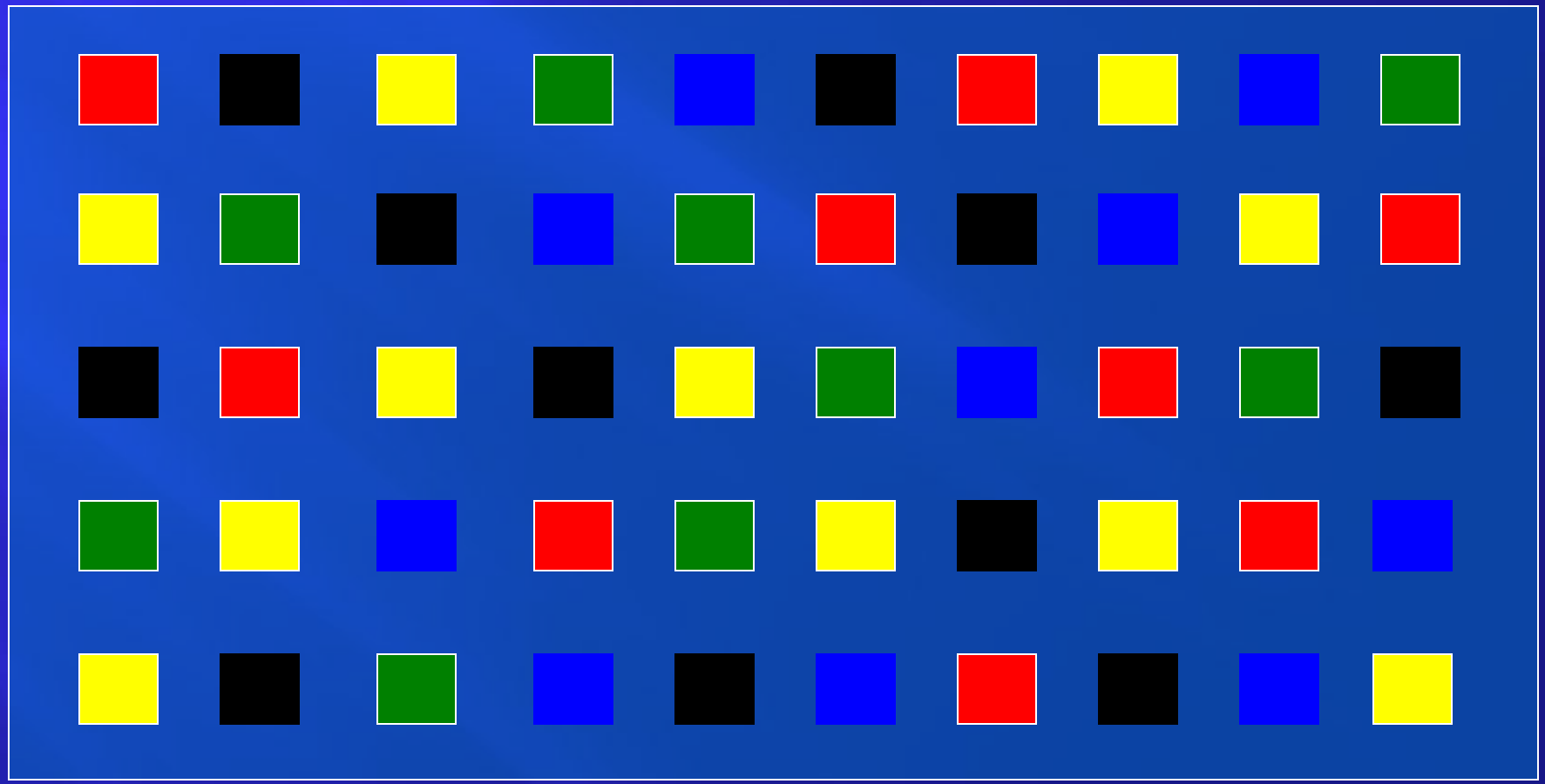


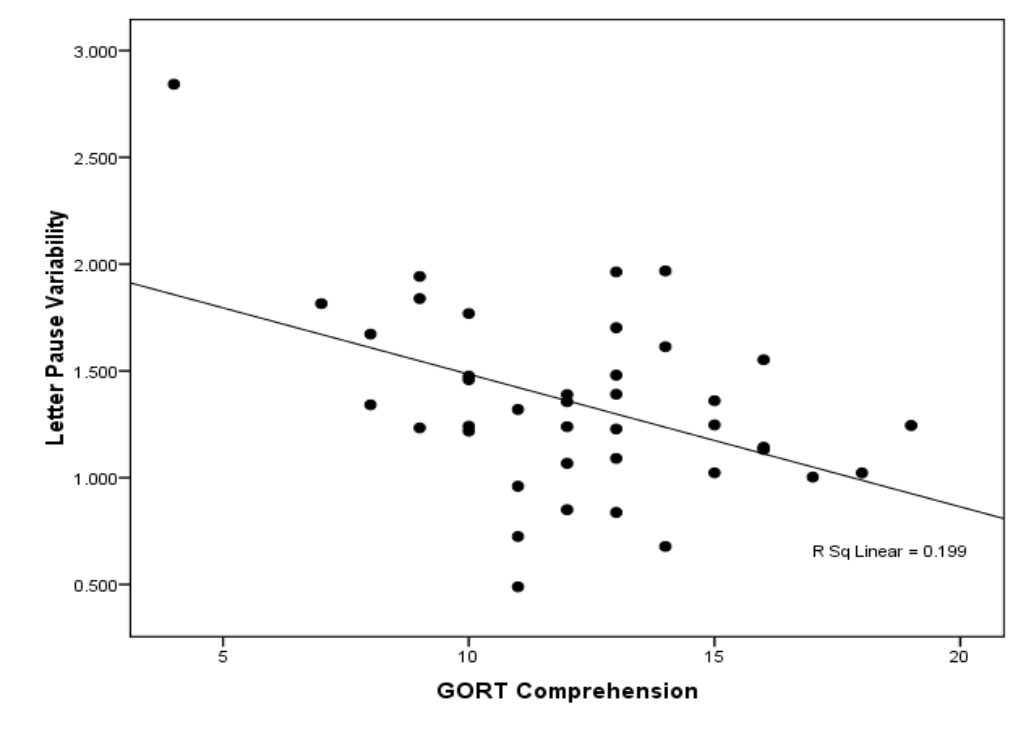
Figure 8. Components of the Wernicke-Geschwind Model.

Visual-Verbal Connection ("see-it/say-it") involving arcuate and/or inferior longitudinal fasciculus

Rapid Automatized Naming (RAN)



Variability Predicts Reading Comprehension



Predictor	β	ΔR^2	*p*
Age	-.275	.075	.100
Group	.078	.006	.638
Articulation Time	.071	.004	.722
Pause Time	-.242	.039	.240
Articulation Variability#	-.203	.035	.266
Pause Variability	-.447	.136	**.022**

Naming variability is a stronger predictor of comprehension than pause time

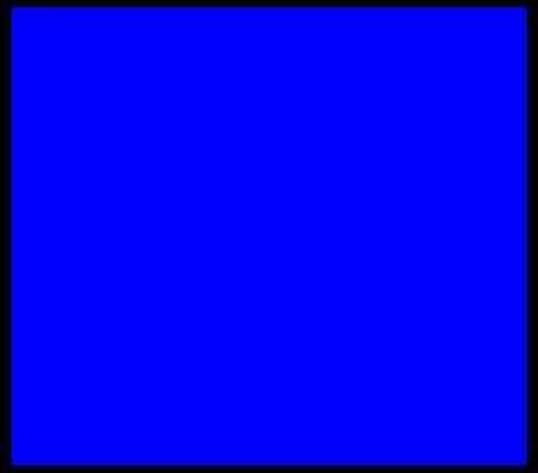
Li, Cutting, Ryan, Zilioli, Denckla, & Mahone (2009). JCEN

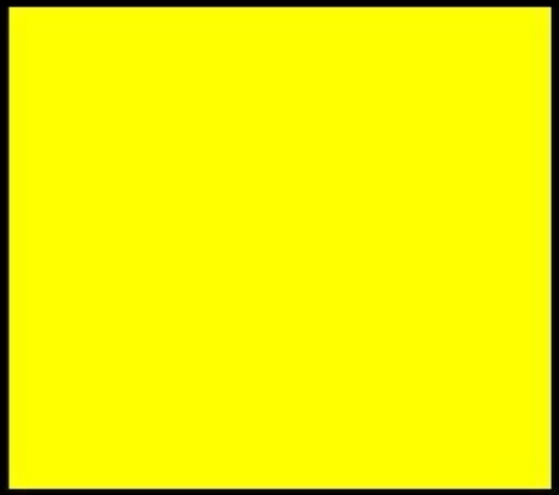
Why Slower?

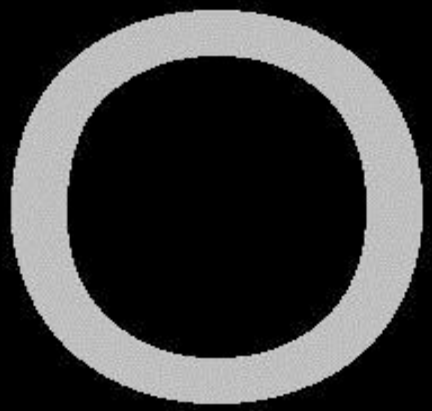
- We measure response times
- Response times are composed of a chain of processes
  (Pashler & Johnson, 1989)
  - Perceptual analysis
  - Decision / response preparation
  - Response execution

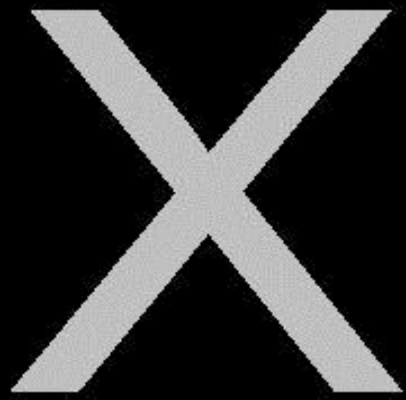
Psychological Refractory Period

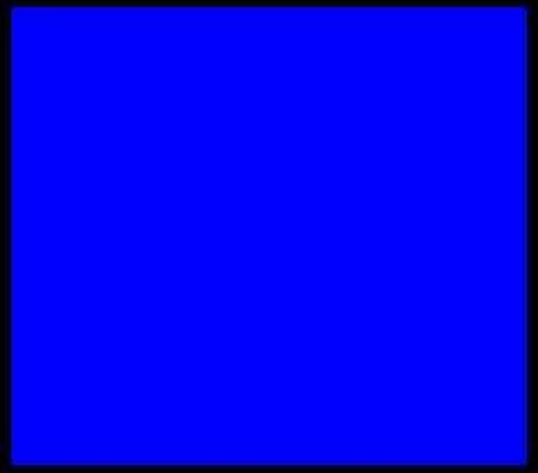
- Useful for studying dual-task interference (i.e., the bottleneck problem)
- Two targets (T1 & T2) are presented—each in choice reaction time format
- When *stimulus onset asynchrony* (SOA) between T1 and T2 is short, the response time for T2 (RT2) *increases* sharply
  - Bottleneck at *response selection/preparation* stage
  - Selection of T2 response postponed till after the T1 response has been selected

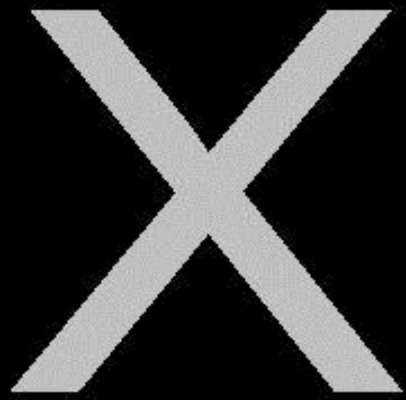




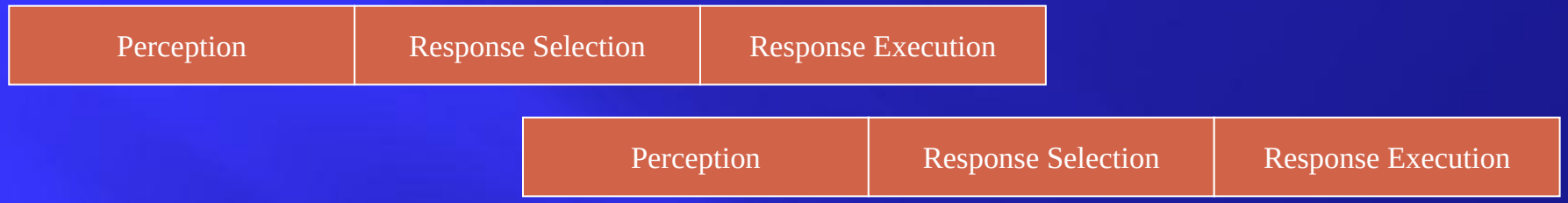




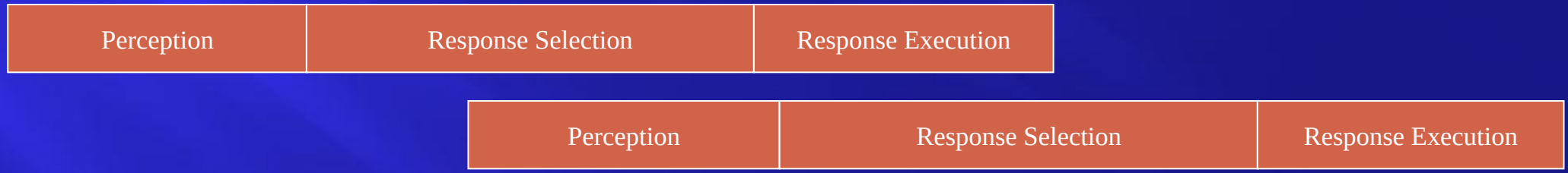




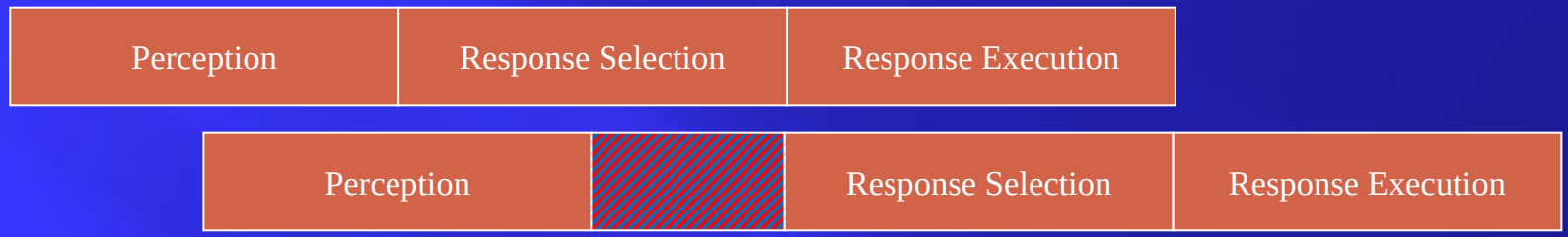
Long SOA, Control



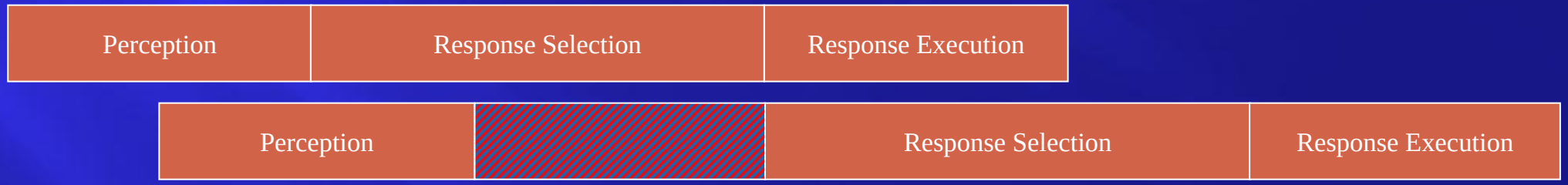
Long SOA, ADHD *(ADHD hypothesized to have longer Response Selection time but same Perception and Execution)*



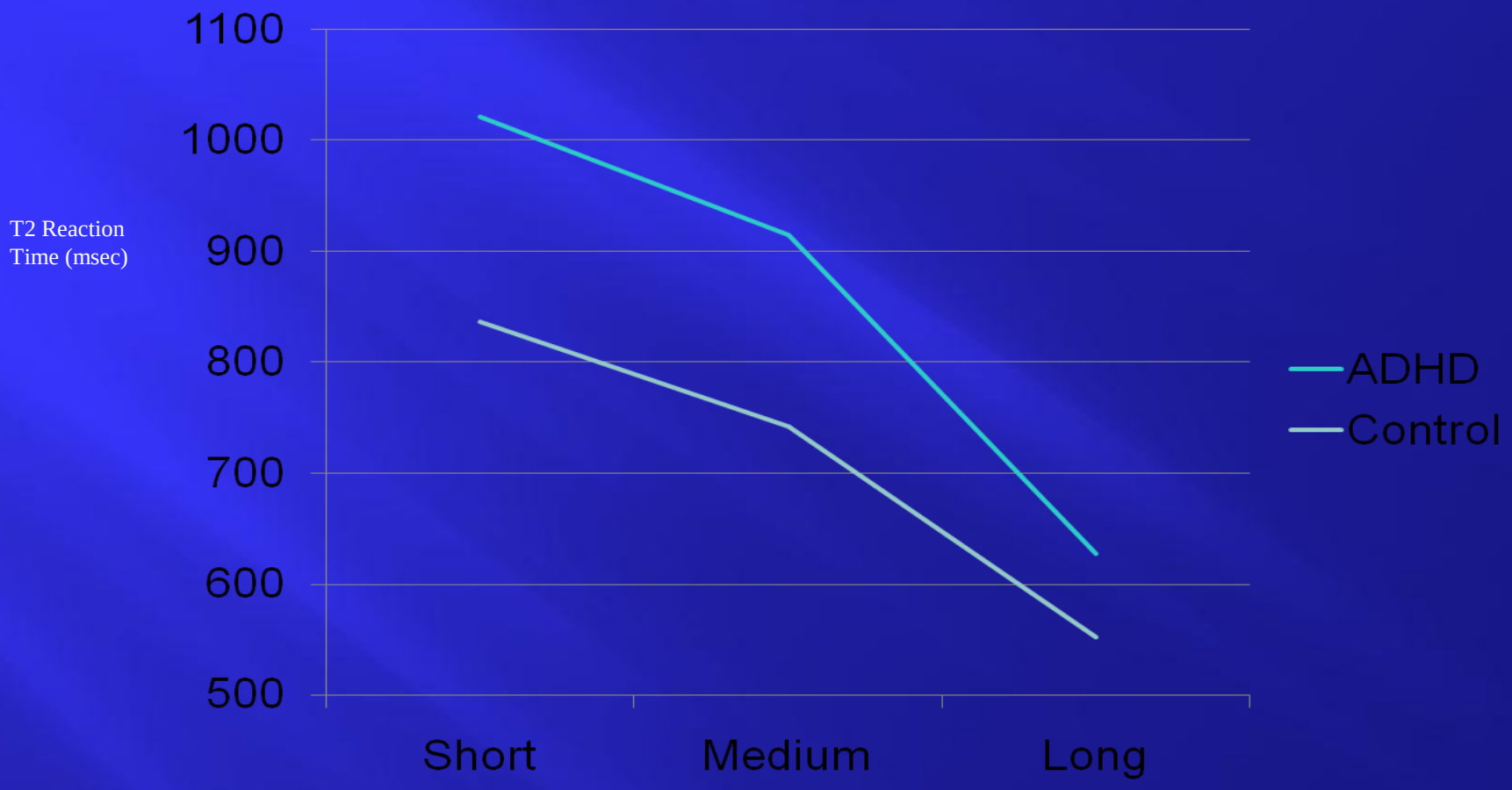
Short SOA, Control



Short SOA, ADHD



The PRP Effect in ADHD



N = 17 (8 ADHD)
SOA: $p = .000$; , $\eta^2 = .92$
SOA x Group: $p = .08$, $\eta^2 = .30$

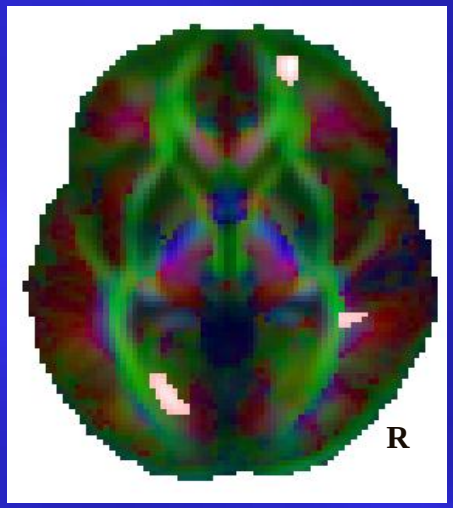
Ewen et al. (2009). Cognitive Neuroscience Society

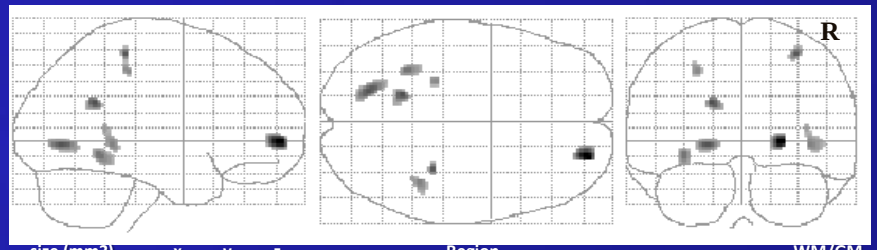
Do White Matter Anomalies Contribute to "slowing" in ADHD?

- Fiber track disturbances addressed with diffusion tensor imaging (DTI)
- *Fractional anisotropy* (FA) reflects directionality of water diffusion through tissue
  - FA higher in more organized white matter fibers
  - Myelinated tracts restrict diffusion
- Higher FA is associated with greater fiber integrity

- Several regions of *increased* FA in ADHD
- No regions of decreased FA
- Increased FA correlates with decreased reading fluency

	ADHD		Control	
	N	Mean Age (SD)	N	Mean Age (SD)
Male	12	11.30 (1.33)	12	11.14 (2.30)
Female	4	11.21 (2.34)	4	11.21 (1.88)

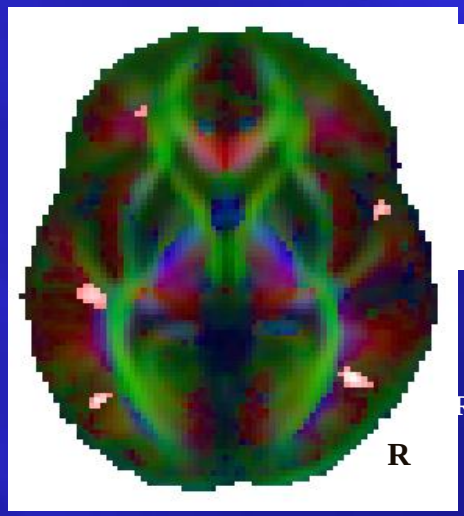


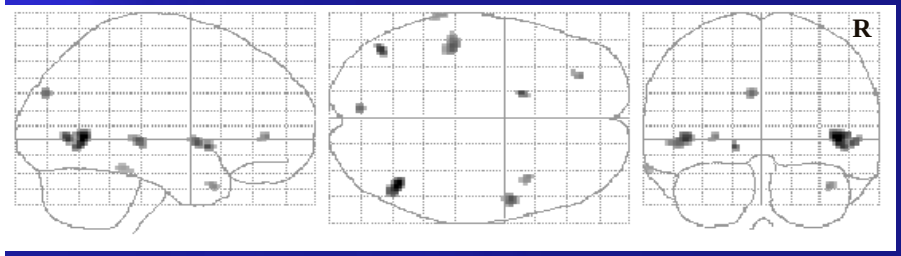


R

size (mm3)	x	y	z	Region	WM/GM
688	44	-60	5	Right Middle Temporal Gyrus	WM
208	-44	-68	3	Left Middle Occipital Gyrus	GM
96	-16	10	-4	Left Putamen: Lentiform Nucleus	GM
176	51	4	-2	Right Superior Temporal Gyrus	GM
408	-46	-37	2	Left Superior Temporal Gyrus	WM
128	-6	-78	32	Left Cuneus	GM
80	-26	43	0	Left Frontal White Matter	GM
104	38	12	-26	Right Superior Temporal Gyrus	WM
96	-65	-38	-13	Left Middle Temporal Gyrus	WM

Figure 1. *Regions of increased FA in ADHD compared to controls*





R

size (mm3)	x	y	z	Region	WM/GM
624	24	56	-3	Right Superior Frontal Gyrus	WM
360	-18	-49	26	Left Cingulate Gyrus	WM
616	-20	-70	2	Left Lingual Gyrus	GM
112	32	-30	55	Right Precentral Gyrus	GM
408	-34	-49	-4	Left Parahippocampal Gyrus	WM
360	38	-44	10	Right Posterior Thalamic Radiation	WM
120	-26	-29	44	Left Postcentral Gyrus	WM

Figure 2. *Regions in which FA was inversely correlated with GORT-IV Fluency*

Statistical parametric maps are at a threshold of $p<0.001$, with a cluster extent of $80mm^3$

Peterson , Ryan, Richardson, Rimdodt, Cutting, & Mahone (2009). International Neuropsychological Society

FA Increase and Dysfunction?

- Recent studies reported pathological increases of FA (e.g., Williams syndrome *(Hoeft et al. 2007)*
- Given reports of decreased white matter volume in ADHD *(Mostofsky, 2002; Castellanos, 2002; Hill, 2003)* the finding of increased FA in ADHD suggests that:
  - Decreased branching of white matter tracts;
  - Reduced number of crossing association or commissural fibers;
    - *May* result in increased directionality of water diffusion within the white matter

Working Memory

- Temporary retention of information that was just experienced but no longer exists
  - Can be stored for short periods of time
  - Manipulation or rehearsal
  - Central to *dual-tasking*
  - May be necessary to guide controlled behavior
  - Increased working memory load may negatively affect performance *(Rubia, 2001)*

Brain Activation in Working Memory

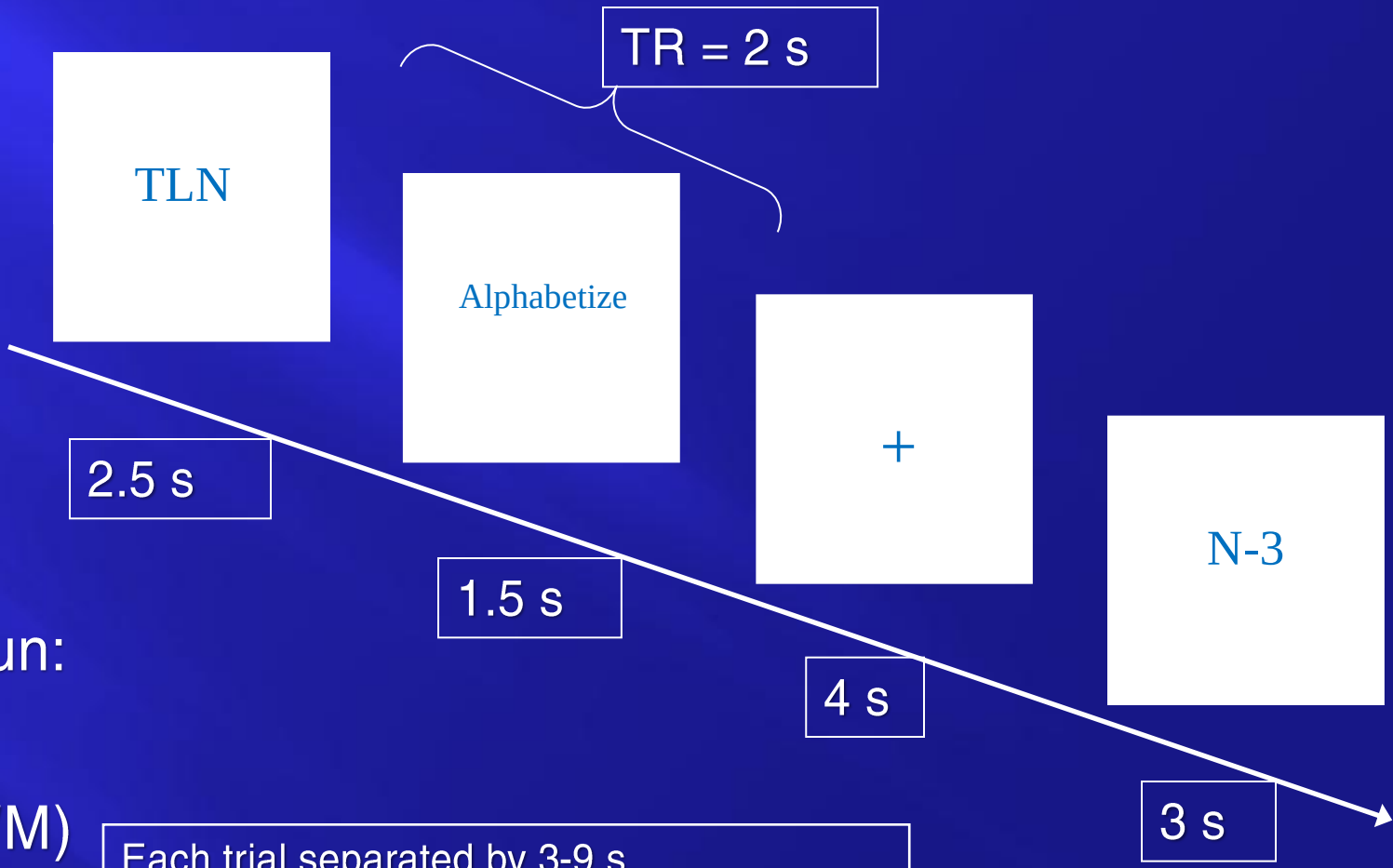
- Working memory is thought to be dependent on dorsolateral prefrontal brain circuit
- Hypothesize that children with ADHD less efficient brain activation on WM tasks
- This inefficiency affects WM and will ultimately impede reading comprehension

Working Memory and Reading Comprehension

Delayed Response Task
(D'Esposito et al., 1999)

½ "maintenance" trials
("Forward")

½ "manipulation" trials
("Alphabetize")



4 Runs
16 trials in each run:
8 maintenance
8 manipulation (WM)
pseudorandom order

Each trial separated by 3-9 s,
with central crosshair on the screen

U H Z

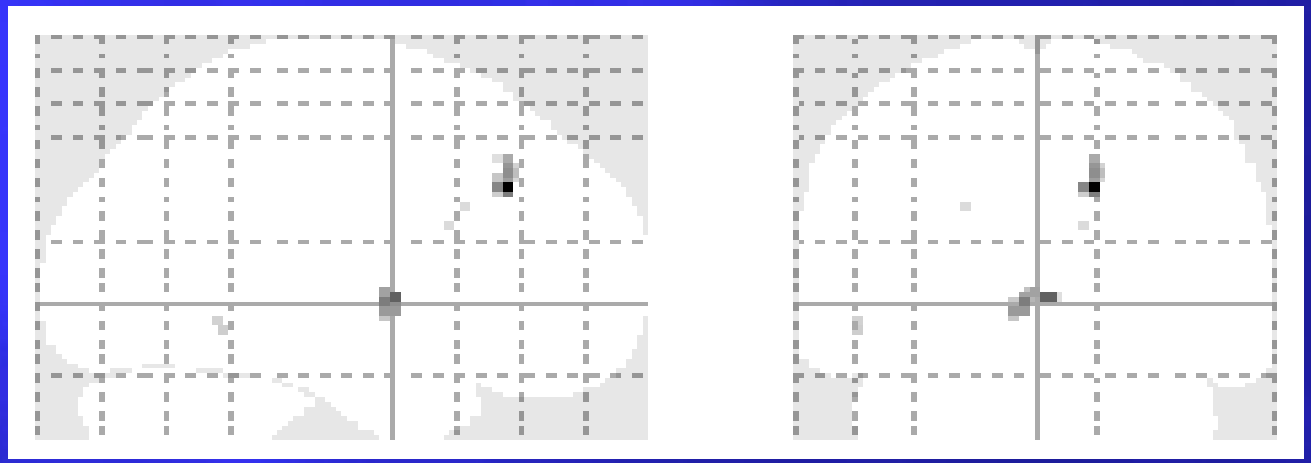
alphabetize

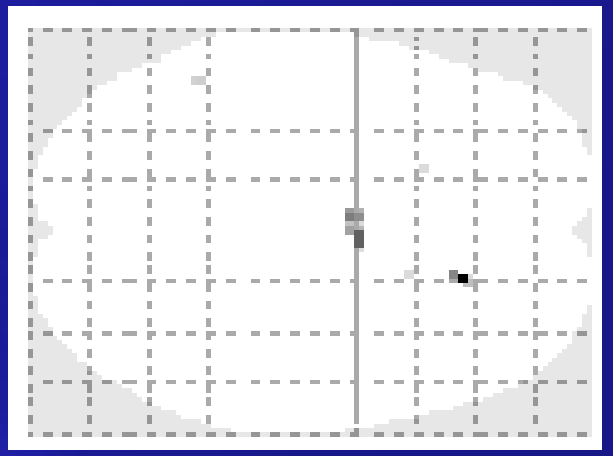
H - 1

Not Correct

Correct

Correlation between "Alphabetize vs. Same" Contrast and DAB-2 Comprehension





n = 12 (6 ADHD, 6 controls); p < .001 (uncorrected)

Performance on the **DAB-2** was associated with activation in the right prefrontal cortex in a region comprising both dorsolateral prefrontal cortex (DLPFC) and dorsomedial prefrontal cortex (DMPFC). Performance on the **GORT-IV** was not associated with any activation in the prefrontal cortex.

Mostofsky, Tsen, Ryan, Denckla, & Mahone (2009). Organization of Human Brain Mapping

fMRI of WM and Comprehension

- Regions important for working memory (DLPFC) and self-monitoring necessary for complex-knowledge based decision-making (DMPFC) showed a strong association with DAB-2, but not GORT-IV
  - Unsupported listening format of the DAB-2 may place demands on working memory more than the GORT-IV
  - Format of hearing the passage and comprehension questions (in addition to reading them) on the GORT-IV may minimize working memory demands, c/w DAB-2